Abstract. Eight equivocal two-dimensional echocardiograms with concurrent CT scans were evaluated to identify potential pitfalls in pericardial effusion detection. By echocardiography, two pleural effusions were felt to be pericardial, two hemopericardiums were interpreted as normal myocardium, three loculated pericardial effusions were not seen or were misinterpreted as other mediastinal collections, and one epicardial lipoma was called a pericardial effusion. When the clinical suspicion for pericardial effusion does not correlate with echocardiographic findings, CT scanning may be the definitive arbiter of pericardial disease.

Key words: Pericardial effusion—Echocardiography—Computed tomography—Pericardium

Although it is clinically considered the diagnostic procedure of choice for the detection of pericardial effusion, echocardiography has several limitations in its evaluation of pericardial disease. Computed tomography (CT), on the other hand, has been infrequently used to assess pericardial disease specifically, but is very precise in defining mediastinal pathology. This paper describes 8 cases representing possible errors in echocardiographic interpretation and illustrates how the correct diagnoses were more clearly elucidated by CT.

Method

Eight representative cases (Table 1) of pericardial pathology requiring CT evaluation because of nondiagnostic echocardiography were selected because of potential problems in diagnosis. Four of the patients had plain films suggesting pericardial effusions and also had equivocal echocardiograms. Three had echocardiographic diagnoses of localized pericardial effusions proved by CT not to be pericardial fluid. One case of a large pericardial effusion demonstrated by CT was poorly visualized by echocardiography. The pertinent images from two-dimensional echocardiograms and CT scans are presented with a short clinical history, and we present the sources of the false echocardiographic conclusions.

We are using a problem-oriented approach, since the exact incidence of missed diagnoses by echocardiography cannot be determined, partly because the method has achieved a "gold standard" status and CT or pericardiocentesis corroboration is not routinely obtained. This paper represents a sampling of 8 isolated case reports within a 1-year period during which time over 5,000 echocardiograms were performed. These cases illustrate problems faced daily in an active echocardiography department.

The CT scans were performed on a commercially available Siemens Somaton DR-3 scanner using parameters of either 3.2 sec, 230 mAs, 125 kVp, and 8 mm collimation of 5.2 sec, 450 mAs, 125 kVp and 4 mm collimation. Patients were placed supine with scans through the heart obtained at intervals of 10–15 mm. The scans were routinely performed without IV contrast enhancement.

Two-dimensional and M-mode echocardiograms were performed using a commercially available Hewlett-Packard ultrasound imaging system. Scans were routinely performed in long axis, short axis, apical, and subxiphoid planes, with additional sections taken for optimal visualization of pathology.

Representative Case Reports

Case 1

C.P., an 18-year-old black man, was shot at close range in the left chest and abdomen. Serial chest radiographs demonstrated a freely moving bullet fragment in the pericardium and a cardiothoracic ratio that gradually increased. An echocardiogram performed 2 weeks after the gunshot wound failed to reveal a classic hypoechogenic pericardial effusion (Fig. 1A). For definitive study before pericardiocentesis, a CT scan the same day was performed which showed an isodense pericardial collection (Fig. 1B). Pericardiocentesis produced thick clotted blood.
### Table 1

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age</th>
<th>Sex</th>
<th>Clinical diagnosis</th>
<th>Echo findings</th>
<th>CT findings</th>
<th>Cause of discrepancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18</td>
<td>M</td>
<td>Hemopericardium</td>
<td>Negative</td>
<td>Hyperdense pericardial fluid</td>
<td>Hemopericardium</td>
</tr>
<tr>
<td>2</td>
<td>61</td>
<td>F</td>
<td>Cardiac tamponade</td>
<td>Negative</td>
<td>Large pericardial effusion</td>
<td>Loculated hemopericardium</td>
</tr>
<tr>
<td>3</td>
<td>76</td>
<td>M</td>
<td>No effusion</td>
<td>Large pericardial effusion</td>
<td>Hypodense epicardial lipoma</td>
<td>Fat mimicking fluid</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>F</td>
<td>r/o pericardial effusion</td>
<td>Large pericardial effusion</td>
<td>Large left pleural effusion</td>
<td>Pleural versus pericardial</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
<td>F</td>
<td>Pericardial effusion</td>
<td>Equivocal</td>
<td>Large pericardial effusion</td>
<td>Anteriorly loculated effusion</td>
</tr>
<tr>
<td>6</td>
<td>21</td>
<td>M</td>
<td>Pericardial effusion</td>
<td>Pleural effusion</td>
<td>Large pericardial effusion</td>
<td>Concurrent pleural and pericardial fluid</td>
</tr>
<tr>
<td>7</td>
<td>59</td>
<td>M</td>
<td>Cardiac tamponade</td>
<td>Large pericardial effusion</td>
<td>Large left pleural effusion</td>
<td>Pleural versus pericardial</td>
</tr>
<tr>
<td>8</td>
<td>59</td>
<td>M</td>
<td>Hemopericardium</td>
<td>Epicardial fat</td>
<td>Chest radiograph diagnostic for pericardial fluid</td>
<td>Anteriorly loculated effusion</td>
</tr>
</tbody>
</table>

### Case 3

T.D., a 76-year-old black man with a long history of chronic obstructive pulmonary disease, asthma, angina, and hypertension, complained of dyspnea. An echocardiogram performed to evaluate left ventricular function demonstrated an echo-free space posterior to the left ventricle, felt to be a large pericardial effusion (Fig. 2A). Because this did not correlate with clinical suspicions, a CT scan was performed 2 days later and showed a hypodense epicardial lipoma at the site of the presumed effusion (Fig. 2B).

### Case 4

S.H., a 32-year-old white woman, developed pulmonary edema after exploratory laparotomy for an ovarian cyst. An echocardiogram was performed to assess the left ventricular function and was read as showing a large pericardial effusion (Fig. 3A). No intervention was undertaken, because a subsequent CT scan did not demonstrate pericardial fluid but merely revealed a large left pleural effusion (Fig. 3B).

### Case 5

S.W., a 32-year-old white woman with Budd Chiari syndrome, revealed on echocardiogram an anterior echo-free space, compatible with a loculated pericardial collection but with no posterior fluid identified (Fig. 4A). The absence of posterior fluid led to confusion as to whether the echo-free space represented fluid or fat or a cystic anterior mediastinal lesion. A CT scan requested to evaluate malfunction of her mesoatrial shunt demonstrated a large pericardial and pleural effusion (Fig. 4B).

### Discussion

The M-mode echocardiographic criteria for a pericardial effusion require an echo-free space persisting throughout the cardiac cycle between the left ventricular posterior wall epicardium and the minimally moving or flat pericardial echo [1–9]. An anterior echo-free space between the chest wall and the anterior wall of the right ventricle is felt to represent pericardial fluid only in the presence of a posterior echo-free space [1–3, 5]. Based on these criteria, Horowitz and others showed that M-mode echocardiography could detect as little as 16–50 ml of fluid with great accuracy [1, 9–12].

Unfortunately, M-mode echocardiography produces false-positive scans for several reasons. Technically optimal studies are obtained in less than 90% of patients at the bedside, particularly in postsurgical patients. Low gain settings, improper angulation of the sonographic beam, false identification of normal anatomy, and artifacts from adjacent structures such as mitral annulus calcifications, indwelling right heart catheters, calcific pericarditis, surgical hardware, or pacemaker wires, can produce echo-free areas posteriorly which may simulate pericardial effusions [1, 5–7, 10, 12, 13].

The advent of two-dimensional echocardiography virtually eliminated the technical sources for
error and identified extraneous causes for echo-free spaces produced by catheters or calcifications [3]. Persistent problems continue, however, in five major areas: (1) identifying clotting or clotted blood within the pericardium (cases 1, 2); (2) avoiding false-positive scans where adjacent pleural effusions, lower lobe atelectasis, pericardial cysts, intracardiac masses, or other mediastinal lesions may mimic pericardial effusions (cases 3, 4, 7); (3) distinguishing fluid in the posterior and anterior spaces around the heart from epicardial fat (cases 3, 5, 7); (4) identifying loculated fluid (cases 2, 5, 8); and (5) distinguishing pericardial thickening from pericardial fluid [8–22].

Other causes of false-positive echocardiograms include hernias of the foramen of Morgagni, circumflex artery or descending aortic aneurysms or fistulas, retrosternal lymphoma, posterior pericardial cysts, cystic paraspinal tumors, and left ventricular pseudoaneurysms [20].

The important distinction of whether a retrocardiac echo-free space represents pleural or pericardial fluid may be difficult with two-dimensional echocardiography. Angulation of the sonographic beam through the left atrium is necessary to detect an echo-free space, commonly present with pleural effusions but rarely present with pericardial effusions. However, recent reports of large pericardial effusions demonstrating fluid in the oblique sinus of the pericardium, behind the left atrium, confuse
Fig. 3. (A) Two-dimensional echocardiogram, subcostal view. An echopenic area (E) deep to the left ventricle (LV) was difficult to determine if it was pleural or pericardial in location. It did not layer in decubitus pleural echo views. RV, right ventricle. (B) CT scan at the level of the left ventricle demonstrated a left pleural effusion (PL) with adjacent atelectatic lung (A) which produced the falsely-positive echocardiogram. Note the normal pericardial fat and thin delicate pericardium shown, with no evidence of effusion (arrows). Incidental right pleural fluid and/or thickening is also seen.

Fig. 4. (A) Two-dimensional echocardiogram, parasternal short axis view. An echo-free area (E) anterior to the right ventricle with no evidence of posterior pericardial fluid poses a potential diagnostic dilemma by strict criteria. Differential diagnosis is loculated anterior pericardial fluid, anteriorly located lipoma, or a cystic mass. Abbreviations: lv, left ventricle; rv, right ventricle. (B) A large pericardial effusion (E) collecting both anteriorly and to the right of midline is demonstrated on this CT scan through the heart. The lack of fluid collecting posteriorly could be due to previous pericardial disease with scarring and loculation. This is a cause of false-negative echocardiograms.

Even this "classic" distinction [1, 5, 12, 14, 23]. Alternative findings compatible with pleural fluid include respiratory variation in fluid size, layering in the left lateral decubitus position, normal left atrial wall motion, and normal pericardial systolic-diastolic echo movement [1, 5, 14].

In a study by Lopez-Sendon et al. in 1984, heparinized blood was injected into the pericardium of a dog, and an echocardiogram was performed [10]. Instead of an echo-free space, areas of irregular echotexture of variable impedance were detected by echocardiography. When the blood was allowed to clot, the acoustic impedance rose so that the echodensity exceeded even that of the myocardium. These findings repeated Kerber and Payvandi's earlier work, in which relative sonolucency was detected after the injection of saline or heparinized blood into a dog's pericardium [21]. However, after thrombin stimulation of clot formation, the echo-free areas decreased markedly or disappeared completely [21, 22, 24]. In cases of postoperative cardiac surgery, where 53-85% of patients may have hemorrhagic effusions, this potential for false-negative echocardiograms is grossly disturbing [25, 26]. Weitzman et al. found that 25% of postoperative pericardial effusions were denser than the left ventricular blood pool and that, among the 75% of cases in which the effusion did present as an echo-
free space, 69% became echodense with time [25]. Similarly, Clapp et al. found that 90% of postoperative pericardial effusions were echodense and more difficult to detect echocardiographically [26]. Often a plane separating epicardium and pericardial pathology may still be detectable even with echodense lesions.

Distinguishing between loculated fluid versus lipomas and between pericardial thickening and effusions may sometimes be possible by detecting fluid movement in decubitus positions or by characteristic locations. Sometimes, however, a differential diagnosis must be given, and no definitive identification is possible by two-dimensional echocardiography.

CT demonstration of the pericardium as a narrow band visualized between layers of epicardial and pericardial fat was first described by Houang et al. [27]. Subsequently, Silverman and Harell [28] and Doppman et al. [29] noted that the normal pericardium can be seen in 95–98% of patients on thoracic CT scans with a mean width of 2.2 mm. A pericardial width of 4 mm was determined to be abnormal and was found after infection, radiation, pericardial surgery, neoplastic invasion, or collagen-vascular diseases [29–31]. Pericardial effusions were often associated with a thickened pericardium, compressed underlying epicardial fat, and a water density [27, 30].

Wong et al. reproduced Kerber's experimental work on echocardiographic detection of pericardial fluid in dogs using CT [32]. After the injection of 50 ml of normal saline into the dog's pericardial sac, a CT scan detected the fluid in all cases. Similarly, CT detected all cases of heparinized whole blood injected into a dog's pericardium, more easily detected when intraoperative contrast was employed. Wong et al. also demonstrated the ability of CT to detect fluid in human subjects before pericardiocentesi [32]. Thus the sensitivity of CT for pericardial fluid detection approaches that of echocardiography.

Computed tomography readily detects acute bleeding within the pericardium as a hyperdense collection [30, 32–34]. Because clotted blood is only briefly equal in density to myocardium, CT scanning may track the hemorrhage from a hyperdense, recent bleed to an isodense clot, to clot lysis with a hypodense pericardial remnant. The detection of a localized intrapericardial hematoma is of more than academic interest. A clot adjacent to the low-pressure right atrium can cause tamponade with as little as 25–50 cc of fluid and may be seen in 3–6% of patients after cardiac surgery [35, 36].

Tomoda et al. have demonstrated another advantage of CT in diagnosing pericardial effusions: CT may suggest the etiology of the fluid collection. They found that the density of the pericardial fluid was high not only in hemorrhagic effusions but also in myxedema and was of relatively low density in effusions from heart failure, renal failure, and nonhemorrhagic carcinomatous invasion [34]. One case of a pericardial myxosarcoma with a density of 6–15 Hounsfield units has been falsely reported as a pericardial effusion; false-positive CT scans are otherwise extremely rare [37]. CT also has the ability to distinguish pericardial thickening from pericardial fluid, based on the former's nodular density, anterior location, lack of movement in the decubitus position, and occasional contrast enhancement.

Finally, the ability of CT to distinguish anatomic boundaries between intracardiac, pericardial, pleural, and mediastinal structures eliminates the false-positive studies from disorders cited above which plague echocardiography. Thus, epicardial fat and pericardial lipomas are readily detected by their location and negative CT attenuation. Hernias, aneurysms, cysts, pleural effusions, mediastinal neoplasms, and intracardiac masses are easily distinguishable by the fat planes that separate them from the pericardium, or through the use of oral or intravenous contrast agents.

Because CT can detect pulmonary, mediastinal, and pericardial pathology, we feel it is the study of choice in stable patients following surgery or trauma, where pericardial fluid and/or other mediastinal fluid collections and pulmonary pathology are all suspected. In the great majority of cases, echocardiography should be the sole study required to detect pericardial effusions. However, CT should be used promptly when the clinical suspicion of pericardial disease does not correlate with echocardiographic findings.

References

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