Two-dimensional Echocardiographic Recognition of Left Ventricular Pseudoaneurysm

EDWARD CATHERTWOOD, M.D., GARY S. MINTZ, M.D., MORRIS N. KOTLER, M.D., WAYNE R. PARRY, AND BERNARD L. SEGAL, M.D.

SUMMARY Five consecutive patients with proved left ventricular pseudoaneurysm (PA) and 22 patients with true aneurysm (TA) were studied by two-dimensional echocardiography (2DE). In four of the five patients with PA, 2DE successfully displayed the PA. The unique 2DE characteristics of PA include: (1) a sharp discontinuity of the endocardial image at the site of the PA communication with the left ventricular cavity; (2) a saccular or globular contour of the PA chamber; and (3) the presence of a relatively narrow orifice in comparison with the diameter of the PA fundus.

In addition, 2DE detected the presence of thrombotic material within the extraventricular chamber in three of four cases. By deriving the ratios of the end-systolic orifice to diameter measurements for the patients with PA (0.37 ± 0.07) compared with TA (1.00 ± 0.08), we found that 2DE reliably differentiated PA from TA (p < 0.001).

We conclude that 2DE is a useful noninvasive method for revealing left ventricular PAs and for distinguishing PA from TA. Considering the high risk of spontaneous rupture associated with pseudoaneurysms, this noninvasive capability is of paramount clinical importance.

FALSE ANEURYSMS, or pseudoaneurysms, of the left ventricle occur most often after transmural myocardial infarction.1-9 These unusual cardiac lesions, in contrast to true ventricular aneurysms,9,10 are prone to spontaneous rupture.7-9 Thus, the detection of left ventricular false aneurysm is clinically and therapeutically important even in the asymptomatic patient. Although cardiac catheterization is the procedure of choice in diagnosing pseudoaneurysms,11,12 previous reports have described the application of noninvasive techniques, particularly M-mode echocardiography13-18 and gated cardiac blood pool imaging,16-19 in the recognition of this disorder. However, experience with cross-sectional echocardiography in this condition is extremely limited.13,20-22 The purposes of this study are to present the distinctive two-dimensional echocardiographic features of a consecutive series of patients with left ventricular false aneurysms and to emphasize the value of two-dimensional echocardiography (2DE) in the differentiation of false aneurysm from true aneurysm.

Materials and Methods

Patients

Five consecutive patients with a diagnosis of left ventricular pseudoaneurysm were studied. They ranged in age from 52-62 years. The diagnosis of false aneurysm was based on ventriculographic evidence of a uni- or multiloculated chamber communicating with the left ventricle through a relatively narrow orifice, without draping of the coronary vessels around the surface of the aneurysm13 (figs. 1-3). Cardiac catheterization in patient 5 did not include selective coronary arteriography. The etiology of the false aneurysm was transmural myocardial infarction in four patients (secondary to right coronary artery occlusion in two, left circumflex coronary artery occlusion in one, and left anterior descending coronary artery occlusion in one) and severe, nonpenetrating chest trauma in one patient. The apical false aneurysm in patient 3 (fig. 2) was presumably precipitated by a ventriculostomy performed during previous coronary artery bypass surgery.

Four of the five patients presented with various degrees of congestive heart failure or medically refractory angina pectoris. Ventricular tachyarrhythmia was predominant in patient 5. The posterior false aneurysm in patient 2 was complicated by superimposed Salmonella typhimurium infection and had partially ruptured before surgical resection.21 Surgical confirmation was available in patients 1 and 2; in each, the maximal communicating orifice dimension was obtained (3.5 cm and 6.0 cm, respectively) and careful microscopic examination of the fibrous aneurysmal sac failed to reveal any myocardial filaments. Intracavitary clot was present in both pseudoaneurysmal chambers. Because of refusal for surgery or associated medical conditions, the remaining patients are being managed conservatively.

A comparison group of 22 patients, 20 men and two women (mean age 56 years) with true left ventricular aneurysms secondary to transmural myocardial infarction, was selected. These patients were chosen on the basis of the technical adequacy of biplane ventriculographic and 2DE studies in each. The ventriculographic diagnosis of true aneurysm was based on the presence of akinetic or dyskinetic segments identified from superimposed end-diastolic and end-systolic outlines of the left ventricular chamber. Surgical and pathologic confirmation of the presence of true aneurysm by aneurysmectomy was present in 12 of the 22 patients.
Figure 1. Left ventricular angiogram in the left anterior oblique projection of patient 1 demonstrates the posterior pseudoaneurysm (PA) in communication with the left ventricle (LV) through a narrow orifice (arrows).

Figure 2. End-systolic right anterior oblique left ventriculogram of patient 3. A small pseudoaneurysm (PA) with its narrow neck (arrows) originates on the apical surface of a large true aneurysm (TA). LV = left ventricle.

Figure 3. Left ventriculogram in the right anterior oblique projection of patient 5 displays the anterobasal pseudoaneurysm (PA) and its communication (arrows) with the left ventricle (LV).
In the 12 months of the study, 1050 adult cardiac catheterizations were performed. Of these, 708 patients (67%) had significant coronary artery disease (greater than 50% coronary narrowing in at least one major vessel). Left ventriculography demonstrated an akinetic or paradoxically expandable segment (true aneurysm) in 142 patients (20%). Five patients with left ventricular pseudoaneurysm were examined during this period. As our experience with this unusual cardiac lesion is influenced by tertiary center referral patterns and patient selection, conclusions regarding the prevalence of this entity based on our catheterization data may be misleading.

Echocardiographic Studies

M-mode echocardiographic studies were performed by standard techniques23 using either an Irex System II Echocardiograph or a Smith-Kline Ekoline 20A interfaced with an Irex 101 Continutrace recorder.

Two-dimensional echocardiographic studies were performed using either a Grumman Health Systems RT-400 phased-array sector scanner or a Varian V3000 phased-array sector scanner. Images were obtained in the apical24 (apex four-chamber) view (fig. 4A), two-chamber apical long-axis view (fig. 4B), or short-axis view25 (fig. 4C). Care was taken in the fine adjustment of gain settings and transducer position to produce an optimal image. A simultaneously recorded ECG provided a time reference within the cardiac cycle to identify specifically the end-diastolic frames. The end-diastolic frame was chosen at the peak of the R wave of the ECG. The frame in which the subjectively smallest left ventricular cross-sectional area was recorded was identified as end-systole. The 2DE images were permanently recorded on videotape for further analysis and displayed on a calibrated screen.

The illustrations presented in this report were obtained from Polaroid photographs of stop-action, single-frame scan images made from the videotape recordings. The static images are degraded optically because stop-action pictures show only a single field of a complete two-field video frame. Equally important is the loss of visual integration of motion normally seen with real-time recordings.

The method for analyzing the 2DE left ventricular images of the false and true aneurysms is illustrated in figure 5. Using the two-chamber, apical long-axis projection in slow-motion, frame-by-frame viewing, the end-diastolic and end-systolic endocardial silhouettes were identified and drawn directly on the face of the video monitor with a grease pencil. The extent of the true aneurysmal segment was defined by the overlapping points of the endocardial silhouette tracings (fig. 5A). A straight line joining the two end points was designated as the orifice (O) of the true aneurysm. The end-systolic length of the endocardial segment connecting the end points was defined as the perimeter (P). The largest end-systolic diameter (D) of the true aneurysm, paralleling the orifice and measured from endocardium to endocardium, was determined. Measurements were taken directly from the calibrated video screen using a commercially available Clinical Graphics Analyzer (Nunonics Corporation, Lansdale, Pennsylvania). The end-systolic frame was chosen in order to visualize the entire endocardial silhouette and to display any paradoxical motion of the aneurysmal segment. A similar analysis was used for the false aneurysms (fig. 5B). The maximal zone of discontinuity in the endocardial image was considered to be the orifice (O) of the pseudoaneurysm. The maximal intracavitary diameter (D) and perimeter (P) of the extraventricular chamber were obtained from the same projection demonstrat-
ing the largest orifice. The ratio of O/D and O/P was calculated for each true aneurysm and false aneurysm. The designation of the myocardial segments containing the zone of discontinuity conforms to the method established by Kisslo et al.25

Angiographic Analysis

Analysis of the left ventricular angiograms in the patients with false aneurysm included (1) measurement of the diameter of the false aneurysmal orifice, (2) the perimeter of the extraventricular chamber, and (3) the largest internal diameter of the saccular aneurysmal cavity. The orifice dimension was obtained from the ventriculographic projection that best defined the narrow neck of the pseudoaneurysm. Each of these measurements was obtained from an adequately opacified end-systolic frame that was corrected for radiographic magnification.26 A center of field distortion of less than 5% was maintained. Using standard techniques,26 ventriculographic analysis of the true aneurysms was performed by idealizing each aneurysmal silhouette to that of a hemisphere. The end-systolic length of the abnormally contracting segment in the right anterior oblique view, as determined by a map measurer with correction for radiographic magnification, was considered to represent the perimeter of the true aneurysm. A straight line connecting the two end points of the aneurysmal segment was designated as the orifice; the largest end-systolic internal diameter paralleling the orifice was defined. The ratio O/D and O/P was calculated for the false and true aneurysms.

Statistical Analysis

Statistical analysis was performed using the t test for paired and unpaired observations. Values are mean ± SD.

Results

M-mode Echocardiographic Findings

M-mode echocardiography displayed a large, posterior, echo-free space in each of the three patients with false aneurysms originating from the left ventricular posterior wall (fig. 6). Significant hypokinesis or akinesis of LVPW was noted in each case of posterior pseudoaneurysm; a distinct interruption in the LVPW endocardial echoes was detected in two cases. The M-mode recordings were nondiagnostic in

Figure 5. Schematic two-dimensional echocardiographic left ventricular chamber endocardial outlines (two-chamber, apical, long-axis view) for a true aneurysm (A) and a false aneurysm (B). Solid lines indicate end-systole and the broken lines, end-diastole. Arrows designate the orifice (O), diameter (D), and perimeter (P) of the aneurysms. See text.
the patients with the apical (patient 3) and anterobasal (patient 5) false aneurysms.

Two-dimensional Echocardiographic Findings

Two-dimensional echocardiography successfully displayed the left ventricular pseudoaneurysm in four of the five patients studied. The small, calcified anterobasal false aneurysm in patient 5 (fig. 3) was not visualized. In the four other patients, 2DE (figs. 7–9) localized a zone of myocardial discontinuity (site of rupture), the extent of expansion and saccular contour of the false aneurysm. To minimize misdiagnosis secondary to artifact, each pseudoaneurysm was recorded in at least two different views. The details of the 2DE findings are summarized in table 1.

Intracavitary echoes suggestive of thrombotic material were demonstrated in all three posterior pseudoaneurysms. The 2DE study of patient 4 (fig. 7) revealed a large accumulation of clot that lined the posterior portion of the false aneurysm. A distinct interruption of the posterior myocardial segment is evident. Similar zones of myocardial discontinuity, con-
confirmed to be the communicating orifice by contrast angiography, were accurately localized by 2DE in each of the false aneurysms successfully recorded.

As measured in the two-chamber, apical, long-axis view, the size of the communicating orifice ranged from 1.3–5.0 cm (mean 3.2 ± 1.5 cm). The maximal intracavitary diameter varied from 4.6–13.4 cm (mean 8.4 ± 3.7 cm) and the perimeter ranged from 10.0–33.3 cm (mean 19.7 ± 10.8 cm). The ratios O/D and O/P were 0.37 ± 0.07 and 0.17 ± 0.06, respectively.

The 2DE assessment of the 22 patients with true left ventricular aneurysms (fig. 10) is summarized in table 2. The true aneurysmal end-systolic orifice (mean 4.2 ± 1.3 cm) and the maximal diameter (mean 4.5 ± 1.3 cm) were similar (p = NS). The endocardial perimeter ranged from 5.4–11.7 cm (mean 8.5 ± 2.1 cm). The ratio O/D was 1.00 ± 0.08 and the ratio O/P was 0.48 ± 0.13.

Angiographic Findings

The ventriculographic results in the five patients with left ventricular pseudoaneurysms are given in table 3. The false aneurysm orifice (mean 2.3 ± 0.09 cm) was considerably smaller than the diameter (mean 6.5 ± 3.4 cm) of the extraventricular chamber (figs. 1–3). The perimeter ranged from 9.0–26.0 cm (mean 16.4 ± 7.9 cm) and the ratios O/D and O/P were 0.36 ± 0.06 and 0.14 ± 0.04, respectively.

The results of the angiographic analysis in the patients with true aneurysms are listed in table 2. The

Figure 8. Two-dimensional echocardiographic short-axis view in patient 2 displays the orifice (open arrow) of the pseudoaneurysm (PA) and the extent of expansion and presence of intracavitary echoes suggestive of thrombus. LV = left ventricle; A = anterior; P = posterior; R = right; L = left.

Figure 9. Two-dimensional echogram in the apical four-chamber view of patient 3 demonstrates the small pseudoaneurysm (PA) communicating with the left ventricle (LV) through a narrow orifice (open arrow). R = right; L = left; RV = right ventricle; RA = right atrium; LA = left atrium.
TABLE 1. 

<table>
<thead>
<tr>
<th>Location of extraventricular chamber</th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Patient 3</th>
<th>Patient 4</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone of myocardial discontinuity</td>
<td>Posterolateral</td>
<td>Posterolateral</td>
<td>Posterior</td>
<td>Posterior</td>
<td></td>
</tr>
<tr>
<td>Detection of intracavitary material</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Optimal views</td>
<td>ALA/SAX</td>
<td>ALA/SAX</td>
<td>ALA/4-chamber</td>
<td>ALA/SAX</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALA dimensions (cm)</th>
<th>Orifice (O)</th>
<th>Diameter (D)</th>
<th>Perimeter (P)</th>
<th>Ratio O/D</th>
<th>Ratio O/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice (O)</td>
<td>3.2</td>
<td>7.0</td>
<td>12.1</td>
<td>0.45</td>
<td>0.26</td>
</tr>
<tr>
<td>Diameter (D)</td>
<td>5.0</td>
<td>13.4</td>
<td>33.3</td>
<td>0.37</td>
<td>0.15</td>
</tr>
<tr>
<td>Perimeter (P)</td>
<td>3.2</td>
<td>4.6</td>
<td>10.0</td>
<td>0.28</td>
<td>0.13</td>
</tr>
<tr>
<td>Ratio O/D</td>
<td>3.2 ± 1.5</td>
<td>8.4 ± 3.7</td>
<td>19.7 ± 10.8</td>
<td>0.37 ± 0.07</td>
<td>0.17 ± 0.06</td>
</tr>
</tbody>
</table>

Abbreviations: ALA = two-chamber, apical, long-axis view; SAX = short-axis or cross-sectional view; 4-chamber = apical four-chamber view.

Comparison of Ventriculographic Data by Angiography and Two-dimensional Echocardiography

Table 4 is a summary of the ventriculographic findings by angiography and 2DE for the false and true aneurysms. There was no statistical difference between the 2DE and angiographic dimensions in the false aneurysm group. Although the orifice, diameter and perimeter measurements were slightly larger by 2DE in these patients, the ratios O/D and O/P correlated accurately (NS). In the majority of patients with true aneurysms, 2DE underestimated (p < 0.001) the aneurysmal orifice and diameter dimensions compared with left ventricular angiography. The perimeter measurements compared favorably (NS). The resultant ratio O/D remained statistically comparable (NS) but the ratio O/P was disparate (p < 0.001). Despite the frequent overlap of the absolute value of the dimensions, the derived ratios successfully differentiated (p < 0.001) false from true aneurysms by 2DE and angiography.

Discussion

Ventricular rupture usually precipitates massive hemopericardium and sudden death from cardiac tamponade. In rare instances, adherent pericardial tissue confines the hemopericardium to a small adjacent area. Subsequent organization of the contained hematoma results in a distended, thin-walled sac or false aneurysm, which is connected to the left ventricle by a narrow neck. The clinical and pathologic features of left ventricular pseudoaneurysm have been previously described. In contrast, the more common true aneurysm results from a localized outpouching of
the ventricular cavity, with the wall principally composed of fibrous connective tissue interspersed with myocardial elements. The mouth of the deformity is usually not sharply demarcated from the main ventricular chamber and is as large as the greatest diameter of the aneurysm.

Congestive heart failure, ventricular tachyarrhythmias and systemic embolization are complications common to true and false aneurysms. Pseudoaneurysms, however, have an increased tendency for delayed rupture. This risk of rupture is present even with small pseudoaneurysms. Thus, considering the potential for successful surgical resection, the differentiation of true from false ventricular aneurysms is very important.

Several authors have described the value of M-mode echocardiography in the noninvasive detection of false aneurysms. The M-mode echocardiographic features suggestive of a posterior pseudoaneurysm include an echo-free space behind the left ventricular posterior wall and a discontinuity of the left ventricular myocardium in the region of the aneurysmal orifice. If the scan does not traverse the orifice, as noted in one of our three patients with a posterior false aneurysm, no discontinuity will be evident. Therefore, the M-mode echocardiographic differential diagnosis should include a pericardial effusion, a pleural effusion or a pericardial cyst. In addition, the value of the M-mode study is limited in the detection of false aneurysms in echocardiographically "silent" zones, as evidenced by the anterobasal and apical pseudoaneurysms in our study.
Botvinick and associates\textsuperscript{17} first reported the usefulness of radionuclide angiography in the recognition of false aneurysm. Since their communication, others\textsuperscript{16, 18, 19} have described the first-pass scintigraphic characteristics of pseudoaneurysms as an extraventricular chamber communicating with left ventricle in an "hourglass" or "bottleneck" configuration. Occasionally, however, the localization of a small communicating orifice may exceed the limits of resolution of the scintigraphic technique.\textsuperscript{19}

Although 2DE is of value in defining true left ventricular aneurysms,\textsuperscript{27} the literature regarding the capabilities of this technique in recognizing pseudoaneurysms is limited to case reports.\textsuperscript{15, 20-22} In 1975, Roelandt et al.\textsuperscript{19} first reported the multiscan, sagittal, cross-sectional image of a posterior false aneurysm. Their long-axis multicroystal recording displayed a globular, echo-free space behind the left ventricular cavity; a narrow communicating orifice was not clearly identified. More recently, Sears and associates\textsuperscript{20} detailed the 2DE detection of a large posterolateral pseudoaneurysm quite similar to that in our patient 4 (fig. 7). These authors emphasize the superiority of 2DE compared with left ventricular angiography in documenting the presence of a narrow neck to the false aneurysm. We\textsuperscript{21} described the 2DE features of the posterior pseudoaneurysm in patient 2, which was complicated by superimposed Salmonella typhimurium infection.

In our small series, 2DE displayed the ventriculographic features suggestive of false aneurysm in four of five patients. These unique 2DE characteristics include: (1) sharp discontinuity of the endocardial image at the site of the pseudoaneurysm communication with the left ventricular cavity; (2) a sacular or globular contour of the false aneurysmal chamber; and (3) the presence of a relatively narrow orifice compared with the diameter of the pseudoaneurysm fundus. A muscular ventricular diverticulum or congenital sacular aneurysm may produce a similar 2DE image.\textsuperscript{23} In acquired cardiac disease, however, these characteristics appear to be quite distinctive.

Our study also evaluated the accuracy with which 2DE left ventricular images reflect the contrast angiographic findings in false aneurysms. Qualitatively, the site of the communicating orifice and the anatomic location of the paraventricular chamber was reliably demonstrated in four of the five cases. The anterobasal false aneurysm, possibly because of its high basal position, small size or calcification, could not be recorded. Compared with left ventriculography, the orifice and diameter measurements were all slightly larger by 2DE. The perimeter of the extraventricular chamber by 2DE was smaller in two patients and larger in two patients than on contrast study. Overall, however, the measurements by 2DE did not differ significantly from their angiographic counterparts (NS). Further, the O/D ratio of 0.37 ± 0.07 (mean ± sd) observed by 2DE confirmed the salient left ventriculographic feature of a narrow ostium relative to the size of the pseudoaneurysm cavity.\textsuperscript{11, 12}

To assess the usefulness of 2DE in differentiating true aneurysms from pseudoaneurysms, we studied a series of patients with true aneurysms on biplane left ventriculography. An easily identifiable hinge point or junctional area between the normally contracting myocardium and akinetic or dyskinetic segments\textsuperscript{27} was visualized on 2DE in each case. This transition zone tended to be gradual and in no instance was there a sudden interruption of the endocardial image. In general, 2DE measurements were smaller than those obtained from the ventriculograms. Despite this discrepancy, the 2DE O/D ratio (1.00 ± 0.08 by 2DE; 1.00 ± 0.03 by angiography) confirmed the wide-mouthed-orifice characteristic of true aneurysms.\textsuperscript{10}

Technical limitations inherent in 2DE and left ventriculography may explain the measurement discrepancies noted in our study. Proper echocardiographic technique is crucial to obtaining a true tomographic image of the left ventricle. Nonstructural echoes or echo dropout may artificially decrease or increase the size of the pseudoaneurysm orifice. Tangential echoes may fail to define the maximal limits of either a true or pseudoaneurysm. With ventriculography, overlap of contrast material tends to obscure the true margins of the communicating orifice and intracavitary clot may prevent accurate visualization of the perimeter of the extraventricular cavity. In addition, distortion secondary to radiographic magnification, greatest at the perimeter of the x-ray field, may cause overestimation of the diameter or perimeter measurements. Any one or combinations of these factors could account for the discrepancies in our data.

In summary, the location, contour, and extent of expansion of four angiographically confirmed left ventricular pseudoaneurysms were recorded and characterized by real-time 2DE. Furthermore, 2DE appears to be useful in differentiating true aneurysms from pseudoaneurysms. Although experience is limited, 2DE may be a better method for the noninvasive recognition of this unusual cardiac lesion.

Acknowledgment

The authors are grateful to Dr. J. Krachow, Dr. W. Schwartz, and Dr. T. McGarry for referring their patients to the noninvasive cardiac laboratory. We are also indebted to Ellen Swam for her expert secretarial assistance.

References

2. Cone RB, Hawley RL: Pseudoaneurysm of the heart following infarction. Arch Pathol 77: 166, 1964
dial infarction. Am Heart J 77: 677, 1969
Two-dimensional echocardiographic recognition of left ventricular pseudoaneurysm.
E Catherwood, G S Mintz, M N Kotler, W R Parry and B L Segal

Circulation. 1980;62:294-303
doi: 10.1161/01.CIR.62.2.294
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1980 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/62/2/294

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/