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Two-dimensional Echocardiographic Diagnosis of Left Atrial Thrombus in Rheumatic Heart Disease
A Clinicopathologic Study

NARSINGH K. SHRESTHA, M.D., FIDELA L. MORENO, M.D., FRANCISCO V. NARCISO, M.D., LUDGERIO TORRES, M.D., AND HOMOBONO B. CALLEJA, M.D.

with the technical assistance of Mae R. Palileo, RMT, Luz W. Esmele, RMT, Alejandro C. Caballero, RMT, and Rodel L. Leano, RMT

SUMMARY Two-dimensional echocardiographic studies were performed in 293 patients with rheumatic heart disease who underwent open-heart mitral valve surgery during an 18-month period. Diagnostic confirmation of a left atrial thrombus was based on direct inspection of the left atrium during surgery and histopathologic examination. Two-dimensional echocardiographic recordings were reviewed. Of the 293 patients, 33 had left atrial thrombi by two-dimensional echocardiographic criteria. This diagnosis was confirmed at surgery and histopathologic study in 30 (specificity 98.8%). A thrombus was not found in three patients. In 21 other patients, left atrial thrombi were present but were not detected by two-dimensional echocardiography (sensitivity 58.8%). Ten of these 21 had thrombi in the left atrial cavity. In 11 patients, thrombi were located in the left atrial appendage, all of which were missed by two-dimensional echocardiography. Excluding these 11 left atrial appendage thrombi, the sensitivity of two-dimensional echocardiography for detecting left atrial cavity thrombi was 75.0%.

ALTHOUGH the grave prognostic significance of left atrial thrombus was recognized almost a century ago, a definite clinical demonstration of left atrial thrombus became possible only recently, with left atrial angio-

From the Departments of Cardiology, Cardiovascular Surgery and Pathology, Philippine Heart Center for Asia, Quezon City, Metro Mani-

ta, Philippines.

Address for correspondence: Narsingh K. Shrestha, M.D., Coronary Care Unit, Medical Building, Sabah Hospital, P.O. Box 4078, Kuwait.

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ly immobile left atrial masses like thrombi. In contrast, two-dimensional, real-time echocardiography (2-D echo) has recently been used successfully in preoperative detection of left atrial thrombus. However, few cases have been reported and the sensitivity and specificity of this technique in diagnosing left atrial thrombi have not been ascertained. Such a determination is important in view of the recent recommendation that patients with pure mitral stenosis need not undergo hemodynamic study preoperatively.

Rheumatic heart disease is still a very common problem in Asia. We have been impressed by the many patients who show left atrial thrombi by 2-D echo, surgery or autopsy. Therefore, this retrospective clinicopathologic study was undertaken to assess the reliability of 2-D echo for diagnosing left atrial thrombi in rheumatic heart disease.

**Materials and Methods**

Five hundred twenty patients had rheumatic heart disease among 2298 subjects who underwent 2-D echo during October 1979 to March 1981 at the Philippine Heart Center for Asia. Of the 520 patients, 348 underwent cardiac surgery for their valvular lesions. One hundred seventy-two patients were not operated and, hence, were excluded from this study. Thirty-six patients had only aortic valve replacement and 19 patients had closed mitral commissurotomy; they were also excluded. Two hundred ninety-three had open-heart mitral valve surgery, and the left atrium was inspected under direct vision. The valvular lesions in these patients are given in table 1.

The diagnosis of valvular lesion was based on clinical, electrocardiographic, radiologic and echocardiographic examinations. Hemodynamic and selective angiographic studies were undertaken in 268 patients. The preoperative diagnosis of valvular lesions was confirmed at surgery in every patient.

**Two-dimensional Echocardiography**

A Toshiba real-time, phased-array sector scanner (Sonolayergraph model SSH-10A) with 78° sector was used. The transducer has 32 elements, each with 2.4-MHz frequency. The transducer locations, imaging planes and technique of recordings were those recommended by the American Society of Echocardiography. Parasternal long- and short-axis views, the apical four-chamber view and apical long-axis view (right anterior oblique [RAO] equivalent) were obtained in real time in all patients. The images were recorded and stored on videotape at a rate of 30 frames/sec using a Victor video cassette recording system (model CR 6060). The illustrations were obtained from Polaroid photographs of stop-action, single-frame scan images.

A left atrial mass was suspected whenever a conglomeration of echo densities was seen in left atrial cavity that persisted despite multiple alterations in gain and reject settings. A left atrial thrombus was suspected when the mass of densities showed any of the following characteristics: (1) a relatively well-circumscribed, defined border; (2) some motion throughout the cardiac cycle; (3) demonstrable in two or more echocardiographic views taken in different anatomic planes, showing the constant and reproducible position of the echo mass in the left atrial cavity; (4) a surface attachment to the left atrial wall in at least one echocardiographic projection; or (5) an acoustic density of echo mass different from that of adjoining cardiac structures.

The videotape recordings (VTRs) from all the patients were reviewed by the same observer. The reviewing was done blindly. The date and identification numbers displayed in the top of TV screen were covered by a sheet of paper. A scoring system was used during the review of VTR. Each of the five echocardiographic characteristics suggestive of left atrial thrombus was given a score of 1 and the total obtained by each patient was summed.

**Surgical Technique**

All the patients were operated within 1 week after the 2-D echo recordings. A median sternotomy incision was used. After institution of cardiopulmonary bypass, elective ischemic cardioplegia was used by cross-clamping the ascending aorta. Moderate systemic (28°C) and local hypothermia were used for myocardial preservation. The left atrium was opened with a longitudinal incision along the interatrial groove. With the help of a malleable retractor, adequate exposure of the left atrial cavity was achieved and a careful search for thrombi was made, especially inside the atrial appendage. When the thrombus was present, its location, size, consistency and degree of organization was noted. The thrombus was completely removed, taking care to avoid fragmentation, and the specimen was immediately taken to the histopathologic laboratory.

**Histopathologic Technique**

The gross characteristics of the mural thrombi were noted and external and cut surfaces described. At least two sections were taken from each specimen and stained with hematoxylin-eosin and Verhoff’s elastic tissue stain. Recent thrombi consisted of platelet aggregates forming lamellar structures across lakes of red thrombi.
blood cells and leukocytes enmeshed in fibrin. The stages observed in the organization of thrombi were similar to those described previously. In the early stages of organization, the periphery of the thrombi were invaded with plump fibroblasts and small vascular channels. Thrombi in late stages of organization showed prominent collagen and elastic fibers.

Results

Surgical Findings

At surgery, left atrial thrombi were found in 51 patients. Clinical data of these patients are summarized in table 2. In 40 patients, the thrombi were located in the left atrial cavity. Besides the main thrombi, 21 of these 40 patients had associated thrombi in the left atrial appendage. In another 11 patients, the thrombi were confined solely to left atrial appendage.

The left atrial cavity thrombi were attached to the posterior and lateral walls of left atrium well above the mitral annulus in 34 patients. Some of these thrombi also extended to the superior and medial (septal) walls. Five patients had thrombi attached to left atrial walls just above the mitral annulus. In one patient, the thrombus adhered to the anterior and superior left atrial walls.

Pathologic Findings

The average size of the thrombus was $4 \times 3 \times 2$ cm; the largest was $12 \times 6 \times 3$ cm and the smallest 3 mm in diameter. Some thrombi consisted of a homogenous, dark red mass; others had pale gray lines inter-

<table>
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<tr>
<td></td>
<td>Aortic 23</td>
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<tr>
<td></td>
<td>Tricuspid 1</td>
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<tr>
<td>Mitral valve area (2-D echo)* (cm²)</td>
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<td>Mean 0.67</td>
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* Mitral valve area was measured by the method of Henry et al. (Circulation 51: 827, 1975). Abbreviations: AF = atrial fibrillation; MS = mitral stenosis; MR = mitral regurgitation.

Correlation with 2-D Echo

Twenty-four patients received a 2-D echo score of 4 or more. All of them were confirmed to have thrombi at surgery (specificity 100%). However, 27 patients with confirmed left atrial thrombi failed to receive a score of 4 or more (sensitivity 47.0%). Thirty-three patients had score of 3 or more, 30 of whom were confirmed to have thrombi (specificity 98.8%). A thrombus was not found in three patients who each had score of 3. Also, 21 patients with thrombi failed to receive a 2-D echo score of 3 or more (sensitivity 58.8%). Sixty-three patients received a score of 2 or more, but thrombi were present in only 32 of them (specificity 88.6%). Nineteen patients with confirmed thrombi received a score of less than 2 (sensitivity 62.7%).

This correlation of 2-D echo score received by individual patients with their operative findings showed that the most reasonable cutoff point was a score of 3, which gave a specificity of 98.8% and sensitivity of 58.8%. Hence, presence of 2-D echo score of 3 or more was considered echocardiographically diagnostic for left atrial thrombus.

With this diagnostic criterion, a left atrial thrombus was diagnosed by 2-D echo in 33 patients, 30 of whom were confirmed to have had thrombi at surgery. The thrombi in these 30 patients were located in left atrial cavity with or without associated thrombi in the appendage (fig. 1). Two-dimensional echocardiography failed to detect left atrial thrombi in 21 patients. This group included 10 who had left atrial cavity thrombi; the largest was $8 \times 5 \times 3.5$ cm and the smallest 3 mm in diameter. In another 11, thrombi were limited to the left atrial appendage. Excluding these 11 patients with left atrial appendage thrombi, the sensitivity of 2-D echo for left atrial cavity thrombus is 75.0%.

Among the 10 patients with left atrial cavity thrombi with a false-negative diagnosis, four had small thrombi (less than 1 cm in diameter). Three patients had mural thrombi lining the posterolateral wall of the left atrium, with no part of the thrombus projecting into the left atrial cavity. Two patients had large spherical thrombi measuring $5.5 \times 3 \times 1.5$ cm and $5 \times 4 \times 1$ cm, respectively. One patient had a technically inadequate 2-D echo recording. The thrombus in this patient measured $8 \times 5 \times 3.5$ cm.

The smallest thrombus that was correctly diagnosed by 2-D echo was $2 \times 1.5 \times 1.5$ cm and the largest was $12 \times 6 \times 4$ cm.

Echocardiographic Characteristics

The echo mass in 24 of the 30 patients with correct 2-D echo diagnosis had well-defined borders (fig. 1).
In six patients, the echo mass did not have a clear border. All 30 exhibited some motion throughout the cardiac cycle.

In only 16 of the 30 patients were thrombi demonstrable in all four standard views (fig. 2). However, left parasternal long-axis or short-axis views demonstrated thrombi in 28. Apical four-chamber or long-axis (RAO equivalent) views showed the thrombi in 21 patients. In two patients, thrombi were noted only in apical long-axis (RAO equivalent) views.

In 21 patients, the echo from the left atrial thrombi was less dense than that from the aortic wall (fig. 3).

However, four patients had denser left atrial thrombi echoes compared with the aortic wall. Five thrombi had echo densities similar to the aortic wall.

Surprisingly, four of the eight patients with highly organized thrombi in histologic sections had an echo density lower than that of the aortic wall. Two patients had an echo density similar to the aortic wall and another had higher density than the aortic wall. One thrombus in the late stage of organization was located in the left atrial appendage and was not detected by 2-D echo.

Discussion

Only a few cases have been reported of left atrial thrombi detected successfully by 2-D echo. These reports have originated from countries in which rheumatic heart disease is less common than coronary artery disease. For instance, in a major university hospital in the United States, left atrial thrombus was detected by 2-D echo in only one patient during a 4-year period. However, successful use of 2-D echo for imaging left ventricular thrombi has been reported more frequently. Martin questioned whether atrial thrombi were as echo reflective as ventricular thrombi. He postulated that because of higher left ventricular pressure, thrombi in left ventricle tend to be more firm and echo reflective than the left atrial thrombus. Our experience indicates that this may not be the case. We see more cases of left atrial thrombi than left ventricular thrombi. This, we believe, is because we examine more cases of rheumatic heart disease by 2-D echo than of coronary artery disease. Over a period of only 1½ years, we detected 30 cases of left atrial thrombi by 2-D echo.

Sensitivity

Schweizer et al. detected correctly four of 12 left atrial thrombi by 2-D echo. Among their eight patients whose left atrial thrombi were missed preoperatively by 2-D echo, four had small thrombi limited to the atrial appendage only. Since the present 2-D imaging technique does not allow adequate visualization of left atrial appendage, it is not surprising that we and others have failed to detect thrombi located in the appendage. However, our sensitivity of 75.0% (excluding left atrial appendage thrombi) is higher than that reported by Schweizer et al. The present report has limitations of a retrospective study. With a prospective search for left atrial thrombi in every case of mitral valve disease using multiple tomographic sections by 2-D echo beam, particularly in parasternal long- and short-axis views, the sensitivity may increase.

Specificity

Using the present diagnostic criteria, only three of 293 patients were incorrectly diagnosed as having left atrial thrombi. Previous reports do not mention the specificity of 2-D echo for detecting left atrial thrombi.

Echocardiographic Characteristics

Our results indicate that an abnormal echo mass in the left atrium that persists despite multiple alterations
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FIGURE 2. Left parasternal long-axis view (A) and short-axis view (B) from a patient with mitral stenosis show a well-defined thrombus (Th) attached to posterior and superior walls of left atrium (LA). The thrombus is also well visualized in the apical four-chamber (C) and right anterior oblique equivalent (D) views. Abbreviations are as in figure 1.

In echocardiographic gain and reject settings is highly specific for left atrial thrombus if all five diagnostic criteria are present. A well-defined border of the echo mass is the most specific sign among the five diagnostic signs. None of our three false-positive cases had well-defined margins in their left atrial echo densities.

The left parasternal (long- and short-axis) views are the 2-D echo views of choice for the detection of left atrial thrombus. In these views, we could visualize thrombi in 28 of our 30 cases, whereas apical views (four-chamber and RAO equivalent) demonstrated thrombi only in 21 patients. We also noted that echo from the thrombus was better defined in parasternal views. The four-chamber view in particular was disappointing because of frequent ill-defined echoes seen in atrial cavities that were not present in other views.

In most cases, there were denser echoes from the surface of the thrombus than from its interior. Since the surface of the thrombus is of relatively recent origin, a newly formed thrombus is probably more echo reflective than old, organized thrombus. This view is supported by Mikell et al. However, Ports et al. reported that more organized thrombi have higher acoustic impedance than recent thrombi.

Limitations

In this study, 2-D echo failed to detect left atrial appendage thrombi in all 11 patients. Small left atrial cavity thrombi with a diameter of less than 1 cm and mural thrombi without cavitary projection were not detected. Poor resolution resulted in inability to see a big thrombus in one patient. We could not explain our failure to detect large and spherical thrombi in two patients. It is unlikely that the degree of organization of the thrombi is related to the failure of producing adequate echo. Our seven patients with advanced thrombus organization did not have, as a group, higher echo density. Left atrial thrombi have been detected by 2-D echo within days of their formation. Other than collagen and elastin, echo reflection from thrombus may depend also on other factors, such as the fibrin content.
We have included only rheumatic heart disease patients in the present study. Whether our findings will also be applicable to left atrial thrombi arising in other cardiac conditions, such as cardiomyopathy, is not known. We looked for 2-D echo signs of left atrial thrombus in every case of rheumatic heart disease. If this is not done, as is likely in a routine setting, sensitivity could be less than that we obtained.

We did not undertake left atrial angiography in this study; thus, we could not compare it with 2-D echo for sensitivity and specificity. However, previous reports indicate that the specificity and sensitivity of left atrial angiography for thrombi are comparable to those of our 2-D echo study. Hence, we believe that patients with rheumatic mitral stenosis need not undergo cardiac catheterization for demonstration of left atrial thrombi. The role of cardiac catheterization for levophase left atrial angiography in patients with clinical evidence of systemic embolism and a negative 2-D echo for left atrial thrombus is not known.

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