An Improved Method for Echographic Detection of Left Atrial Enlargement

By Owen R. Brown, Donald C. Harrison, M.D., and Richard L. Popp, M.D.

SUMMARY

Echographic dimensions of the aortic root and left atrium were compared in 170 patients in order to assess dilatation of the left atrium with reference to the relatively nondistensible fibrous aortic root. In 50 patients without cause for left atrial or aortic enlargement, the ratio of left atrial/aortic root dimension was 0.87-1.11. In 80 patients with known cause for left atrial enlargement, the left atrial/aortic root ratio was ≥1.17. In 40 patients with isolated aortic valve disease, dilatation of both the aortic root and the left atrium resulted in a left atrial/aortic root dimension ratio <1.17 in some patients. Despite this consideration, the comparison of left atrial and aortic root dimension appears to be as specific as, and more sensitive than, previously proposed methods for the evaluation of left atrial enlargement.

Additional Indexing Words:
Echocardiography
Atrial volume
Ultrasound
Atrial size

The radiological techniques generally employed for assessing left atrial and aortic root dimensions are semi-quantitative. Enlargement of these two structures is usually assessed in posterior-anterior and lateral X-ray films or in oblique views with barium in the esophagus. Their appearance is compared subjectively to the “normals” previously examined by the individual interpreting a particular study. Few standardized means exist for quantitating normal atrial size, other than computation of left atrial volume angiographically. This method for assessing left atrial enlargement requires cardiac catheterization, and a wide range of normal values have been reported.

Recently it has been demonstrated that left atrial dimensions can be measured accurately by ultrasound techniques. Although such data are easily obtainable and useful in many cases, echographic left atrial dimensions also display a wide range of values in normal patients and this range has proven misleading. In the patients with a small heart, enlargement of an originally small left atrium may result in an echographic or angiographic left atrial size appearing within the normal range; likewise, left atrial dimensions outside the normal range may be found in the normal patient with a large absolute cardiac size.

Thus, an improved method for assessing left atrial size is desirable. The measurements should be easy to perform and should provide data for a specific patient, rather than a so-called “normal population.” Ideally, progressive left atrial enlargement would be evaluated best by serial observations of the individual patient. Cardiac ultrasound provides an easy and accurate means for making such serial observations. However, at the time of initial clinical presentation, myocardial failure and/or valvular lesions often have resulted in enlargement of the involved chambers. Our preliminary observations suggest that the normal patient population has cardiac chambers whose dimensions are relatively fixed in proportion to one another. When actual serial observations are unavailable, chamber dimensions then may be evaluated with reference to the remaining undilated cardiac structures in a given heart. We performed the following studies to test this hypothesis further.

Methods

Echograms were performed on 170 patients, 160 of whom had cardiac catheterization for diagnostic evaluation. The remaining ten were considered normal on the basis of clinical examination, electrocardiogram and chest X-ray. Patients were placed in one of three groups. Group A consisted of 40 patients who had totally normal chest X-ray, electrocardiogram and hemodynamic data, as well as clinical examination, and were predominantly patients being evaluated for chest pain. There were an additional 10 patients in this group who were judged normal without car-
diagnostic catheterization, and were healthy, young, college-aged males who underwent a considerable battery of tests prior to their enrollment in a study of normal physiology conducted by the National Aeronautics and Space Administration, in conjunction with our group. Group B included 40 patients with isolated aortic valve disease in whom there was no additional cause for left atrial enlargement. Group C consisted of 67 patients with any degree of mitral valvular disease seen during the period of this study. Thirteen additional patients in this group were judged to have myocardial failure on the basis of the clinical data and hemodynamic study, including resting and exercise cardiac index, arterial-venous oxygen differential, pressure-derived parameters of left ventricular function, and in slightly more than 50% of the cases, assessment of quantitative measurement of left ventricular volumes and ejection fraction. In addition, all patients were segregated with regard to the presence of atrial fibrillation, irrespective of accompanying lesions.

The technical details of recording high quality echograms from the aortic root and left atrium have been previously reported. Studies were conducted with a Smith Kline Ekoline 20 ultrasonoscope, utilizing a 0.50 inch, 2.25 megahertz transducer with 5 cm collimation. All examinations were conducted with the patients in the supine position and with the transducer 1-3 cm lateral to the left sternal border in the second, third, fourth, or fifth intercostal space. The transducer was directed in a posterior, cephalad and medial manner to record the aorta, which was recognized by its characteristic pattern of motion. The transducer was then rocked infero-laterally to the point at which the aortic valve cusps could be visualized. Some portion of the aortic valve cusps was required in the record as a criterion for measurement of the echogram. This requirement established the level of the sound beam. Care was taken not to continue posterior angulation of the transducer to the position at which the motion of the mitral valve replaced the smooth motion of the aortic root. The point of junction of the anterior mitral annulus and posterior aortic annulus was identified (fig. 1). At this point, end-diastolic dimensions of the aortic root and end-systolic dimensions of the left atrium were measured, utilizing the reference depth scale generated by the ultrasonoscope (fig. 2).

End-diastolic dimensions of the aortic root were measured from the outer edge of the anterior aortic wall echo to the inner edge of the posterior aortic wall echo; sensitivity of the ultrasound apparatus was adjusted to clearly record the individual echoes from the aortic walls (fig. 3). The end-systolic dimension of the left atrium was measured from the strong anterior edge of the posterior

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**Figure 1**

An echographic "sweep" of the left ventricular outflow tract utilizing a continuous strip chart recorder (record not retouched). Area A is the central region of the left ventricle (LV) and is characterized by the echoes from the interventricular septum (IVS), left ventricular posterior wall (LVPW), pericardium (P), and the mitral chordae tendineae (aC and pC). Area B is slightly more basal than Area A; in Area B, movement of the anterior leaflet of the mitral valve (MV) replaces echoes from the mitral chordae tendineae seen in Area A. Continuing the sweep toward the base, Area C shows echoes from the anterior leaflet of the MV and eventually from the mitral annulus; in Area C, the left atrium is seen posterior to the mitral valve echo after crossing the annulus. In Area D, the further basal sweep has resulted in replacement of septal echoes by those from the anterior aortic wall. In this area, echoes from the left atrium (LA) are posterior to the posterior wall of the aortic root (AoR). Echoes from a portion of the aortic valve (AoV) are also visualized from this area. Echograms from Area D were used for the computation of left atrial and aortic root dimensions. (Note the differences in pattern of motion between the lateral free-wall of the left atrium in Area C versus the less mobile posterior wall of this chamber recorded in Area D.) RVOT = right ventricular outflow tract; ECG = electrocardiogram.
Figure 2

Two examples of left atrium and aortic root echograms recorded by conventional film techniques (record not retouched). Panel A is from a patient with no known cause for left atrial enlargement: the end-systolic left atrial dimension in this patient is approximately equal to the diastolic dimension of the aortic root. Panel B is from a patient with moderate mitral stenosis: the end-systolic dimension of the left atrium in this patient is obviously larger than the diastolic dimension of the aortic root. By previous echographic criteria, the left atrial dimension is at the upper limits of normal in B. aAoW = anterior aortic wall; pAoW = posterior aortic wall; AoV = aortic valve; pLAW = posterior left atrial wall. Calibration dots are separated by 1 cm vertically and 0.5 sec horizontally.

Results

A summary of the echographic measurements is presented in table 1 and figure 4.

Group A—No left atrial enlargement. In group A, consisting of patients without cause for aortic root or left atrial enlargement, all 50 were found to have end-systolic left atrial dimensions within 11% of their corresponding aortic root dimension (fig. 5). The mean dimension for the aortic root was 3.27 cm, with a

<table>
<thead>
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<th>Table 1</th>
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<td><strong>Echocardiographic Values</strong></td>
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<table>
<thead>
<tr>
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<th>Group A (No LAE)</th>
<th>Group B (Aortic disease)</th>
<th>Group C (LAE)</th>
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<td><strong>Number of patients</strong></td>
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<td>40</td>
<td>80</td>
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<tr>
<td><strong>Range (cm)</strong></td>
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<td>2.2 - 5.2</td>
<td>1.7 - 3.9</td>
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<tr>
<td><strong>Mean (cm)</strong></td>
<td>3.27</td>
<td>3.40</td>
<td>2.96</td>
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<tr>
<td><strong>Standard deviation (cm)</strong></td>
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<td>±0.65</td>
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<td><strong>Ao</strong></td>
<td><strong>LA</strong></td>
<td><strong>Ao</strong></td>
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<tr>
<td><strong>P</strong></td>
<td><strong>NS</strong></td>
<td><strong>P &lt; 0.001</strong></td>
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Abbreviation: LAE = left atrial enlargement.
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range of 2.1 cm to 4.4 cm. The mean end-systolic left atrial dimension was 3.23 cm, with a range of 2.3 cm to 4.4 cm. Seven patients in this group had an end-systolic left atrial dimension outside the normal range previously reported for left atrial dimension index (1.2-2.0 cm/m²), and one patient had an absolute dimension of >4.0 cm. 

Group B — Aortic valvular disease without other cause for left atrial enlargement. In group B, consisting of patients with aortic valvular lesions but without other hemodynamic or clinical cause for left atrial enlargement, 28 of 40 had end-systolic left atrial dimensions within 11% of their corresponding aortic root dimension. The mean aortic dimension in these 28 patients was 3.4 cm, with a range of 2.2 cm to 5.2 cm. The mean left atrial dimension was 3.41 cm, with a range of 2.4 to 5.1 cm. Two of these 28 patients had an end-systolic left atrial dimension greater than the previously reported normal limit (4.0 cm). Each of the remaining 12 patients in group B had a left atrial dimension at least 17% greater than the correspond-

ing aortic root dimension. The mean aortic dimension in these 12 patients was 2.95 cm, with a range of 2.2 to 3.6 cm. The mean left atrial dimension was 3.97 cm, with a range of 3.2 cm to 5.0 cm.

Group C — Left atrial enlargement. In group C, consisting of patients expected to have left atrial enlargement due to mitral valve lesions and/or myocardial failure, all 80 were found to have endsystolic left atrial dimensions at least 17% greater than the end-diastolic dimension of their aortic root (fig. 5). The mean aortic root dimension was 2.96 cm, with a range of 1.7 to 3.9 cm. The mean left atrial dimension was 4.6 cm, with a range of 3.1 cm to 9.9 cm.

Separation of those patients with sinus rhythm from those with atrial fibrillation revealed that all 23 patients in groups B and C with atrial fibrillation had a left atrial dimension at least 17% greater than that of their corresponding aortic root dimension. However, 69 of the remaining 147 patients with normal sinus rhythm also had left atrial dimensions at least 17% greater than their corresponding aortic root dimensions. Two of the 23 patients with atrial fibrillation had normal left atrial dimensions by existing echographic criteria. Of the 80 patients in group C, thought to have hemodynamic or clinical cause for left atrial enlargement, 56 had left atrial dimensions >4.0 cm and 70 had an index >2.0 cm/m² (fig. 6). Eight patients had left atrial dimensions ≤3.5 cm at end-systole. Further, of the 28 patients in group B with aortic valvular disease graded as severe, only 7 had a left atrial dimension greater than the outer limit of normal by existing echographic criteria; 12 of the 28

Figure 4
A plot of the left atrial end-systolic dimensions of all patients studied. Note the overlap of values among the patient groups.

Figure 5
A comparison of end-diastolic aortic root and end-systolic left atrial dimensions. Patients without hemodynamic cause for left atrial enlargement (group A) had left atrial/aortic ratios of less than or equal to 1.17. The vertical line indicates upper limit of the normal range by previously proposed criteria of 4.0 cm. 

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Figure 6
Comparison of end-systolic left atrial dimensions from group A and group C with body surface area. Note the overlap between groups in the area where left atrial dimension/body surface area is 2.0 cm/m² (solid line), the previously proposed criteria for the upper limit of the normal range. There is a great deal of scatter in the relationship between body surface area and left atrial dimension in the normal group (group A).
had left atrial enlargement by the proposed criteria. Of the 50 patients in group A thought to have no hemodynamic or clinical cause for left atrial enlargement, 7 had enlargement of the left atrium by the best existing echographic criteria of a left atrial dimension index of \( >2.0 \text{ cm/m}^2 \) (fig. 6).6

**Discussion**

We are proposing a technique for more simple and accurate assessment of left atrial enlargement by comparing echographic aortic and left atrial dimensions. In this laboratory, existing echographic criteria for the detection of left atrial enlargement often appeared insensitive to or inconsistent with the anatomic consequences of the patient's condition. Of 40 patients with mitral disease classed as moderate to severe, 12 had no left atrial enlargement by the existing criteria (<4.0 cm), and in 3 the index was \(<2.0 \text{ cm/m}^2\). Eight patients with moderate to severe mitral disease had a left atrial dimension \( \leq 3.5 \text{ cm} \). Figure 4 demonstrates the overlap of normal echographic absolute left atrial dimensions with those dimensions found in patients with clinical and hemodynamic reason for left atrial enlargement. Past studies have demonstrated a similar overlap angiographically.4,6,7 Obviously, a given left atrial size may be normal for one patient and abnormal for another. The extent of this overlap points out the poor specificity which results from use of an absolute "normal" range for the assessment of abnormal size. Variable cardiac size, associated with variable chamber size, in the normal patient population has been recognized in previous studies of left atrial size.4,8

Hirata attempted to compensate for this factor in his original work on echographic left atrial dimensions by correction for body surface area.8 Figure 6 demonstrates the limited usefulness of this correction factor. It should be noted that Hirata's attempt to compensate for the wide range of normal left atrial size by consideration of body surface area is similar in concept to the technique proposed here. That is, both systems attempt to compare absolute left atrial dimensions to factors that indicate the cardiac size before the existence of conditions causing cardiac enlargement. The proposed method is based upon the presumption that anatomic dimensions within the normal heart are proportional to each other, and that this relationship is constant from subject to subject, regardless of absolute cardiac size. The question then becomes one of selecting a structure within the heart that can be observed accurately echographically and which does not enlarge as the result of common forms of cardiac disease. These studies suggest that the fibrous portion of the aortic root is such a structure.

The proposed technique compares the echographic size of the aortic root at end-diastole with the end-systolic dimension of the left atrium. End-systole was chosen to examine the *maximal* left atrial dimension during the cardiac cycle. The end-diastolic dimension of the aortic root was chosen for measurement in order to avoid slight and variable alterations in root dimension which occur during systole.12

It must be emphasized that patient grouping in this study was on the basis of cardiac lesion, rather than the presence or absence of angiographic left atrial enlargement. Angiographic studies have demonstrated an overlap in left atrial size between patients with mitral valvular disease and the normal patient population.4,6,7 This overlap is seen both angiographically and echocardiographically when an arbitrary upper limit of atrial size is chosen. Since a different system for evaluation of atrial enlargement is proposed here, left atrial angiograms were not used as a standard in evaluating the proposed technique. As a result, the apparent sensitivity of this technique should not be negated by a previous "gold standard" other than the reader's understanding of the cardiac lesions in groups B and C and their potential effect on the size of the left atrium. In Murray's study, the data did not show a relationship between left atrial size and body surface area,8 while such a relationship is shown in both Hirata's study8 and the present one. Even though the effects of some valvular lesions were thought to be minimal, from previous studies using angiography and ultrasound, it would seem unlikely that such a clear separation of normals (group A) from those with mitral valve disease (group C) would occur by coincidence. Indeed, these results indicate that even mild mitral valvular disease leads to mild left atrial enlargement.

Our results demonstrate a consistent left atrial/aortic root proportion in the range of 0.87 to 1.11 in the patients without hemodynamic or clinical cause for left atrial enlargement. Left atrial/aortic ratios of 1.17 or greater were found to be indicative of left atrial enlargement in all patients who had mitral valvular disease, regardless of the associated rhythm. Figure 5 demonstrates the distinct separation between left atrial/aortic root ratios in patients with and without cause for left atrial enlargement.

A variety of cardiac disorders were studied in an attempt to reveal variations in the fibrous portion of the aortic root from which the aortic dimensions were obtained. There was a statistically significant \( (P > .001) \) difference between the aortic root dimensions *within* the group of patients with aortic disease; those who were thought to have no left atrial enlargement showed a larger aortic root dimension than those thought to have left atrial enlargement. Therefore, it is possible that true left atrial enlargement did exist in
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some patients with left atrial/aortic root ratios less than 1.17. Group B consisted of 40 patients with aortic valvular disease, including 28 patients who were thought to have severe aortic stenosis and/or regurgitation. The aortic root dimensions in this group were not statistically different from those of group A, which had no aortic disease. However, two patients in group B, one with mild and one with severe aortic valvular disease (aortic root dimensions of 5.2 cm and 4.5 cm, respectively) may represent masking of left atrial enlargement by dilatation of the aortic root. Therefore, caution must be exercised in comparison of aortic root and left atrial dimensions in patients with aortic valvular disease, where dilated aortic roots may mask left atrial enlargement. Despite such possible masking, left atrial enlargement was predicted by the proposed criteria of proportional comparison in 12 of the 40 patients studied with aortic valvular disease. Existing criteria predicted left atrial enlargement in only 7 of the 40 patients in group B. There are no good hemodynamic or angiographic parameters by which to clearly define the presence of left atrial enlargement associated with aortic valvular disease, and therefore the accuracy of the ratio of the dimensions in group B is not readily discernible. However, it would appear that proportional comparison of the left atrial/aortic root dimensions may greatly improve echographic sensitivity to left atrial enlargement in the majority of patients with aortic valvular disease. In order to avoid masking of atrial enlargement by aortic enlargement, and not decrease sensitivity, a left atrial dimension greater than 4.2 cm is assumed to be enlarged in any patient. Further comment should also be made about aortic root size found in the patients with known cause for left atrial enlargement. The aortic root dimensions among the sub-groups with mild mitral disease, moderate to severe mitral disease, and heart failure, were not statistically different. However, the mean aortic dimension in group C was 2.96 cm, as compared to a mean value of 3.27 cm in group A. The difference between aortic root dimensions in these two groups was statistically significant (P = .02), although it is not clinically apparent. Indeed, the slightly smaller size of the aortic dimension in patients with mitral valve lesions and cardiac failure may further add to the sensitivity of the criteria. The sensitivity of the technique was such that systolic left atrial enlargement was detected in cases of minimal (1+) mitral regurgitation judged angiographically, while it was sufficiently specific to differentiate such patients from those without cause for left atrial enlargement. Unfortunately, no existing standards are capable of resolving the question of left atrial enlargement in cases of mild mitral disease. Nevertheless, it is reasonable to assume that the combination of some left atrial enlargement and diminution in aortic root size does occur in such cases, and that it is this combination which the proposed criteria reveals, rather than an aorta 2 mm smaller than normal.

It should be noted that some degree of caution must be exercised, from a technical standpoint, when utilizing this method. In theory, it is possible to overestimate the aortic root size by recording along a path which is not perpendicular to the long axis of the aorta; however, this does not appear to be a significant problem. The aortic root dimension is quite reproducible in serial studies if a relatively high chest wall position is used for transducer placement.9, 10 The specular reflection of ultrasound seems to prevent recording of aortic wall areas unless these areas are nearly perpendicular to the sound beam. However, care must be taken to assure echographic recording of the fibrous portion of the aortic root and to avoid other distal aortic regions more subject to dilation from aortic valvular disease.

The technique of proportional comparison of cardiac chamber dimension to the fibrous ring of the aortic root in the individual patient is a promising means for evaluating chamber enlargement. The wide range of normal chamber dimensions and the consequent overlap with pathologically enlarged chambers are reduced by this method, resulting in improved sensitivity. Echocardiography may be used noninvasively to obtain these left atrial and aortic root dimensions in approximately 95% of the patient population. The sensitivity of this method to left atrial enlargement appears to greatly exceed that of present echographic techniques in most cases and removes the requirement of consulting a chart to obtain body surface area in each case. This system of comparing the left atrial dimension with that of the aortic root promises to improve the clinical utility of the former measurement.

References


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