Three methods for evaluation of left atrial volume

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Aim To compare and contrast 3 different echocardiographic methods used to measure left atrial (LA) volume: biplane area length (AL), biplane modified Simpson (SIMP), and prolate ellipse (PE) methods.

Methods and results A review of consecutive patients who presented to our outpatient echocardiography laboratory for a resting transthoracic study between April 2006 and May 2006 was performed. Echocardiograms were reexamined and LA volume measured using the AL, SIMP, and PE methods. Of 102 consecutive patients evaluated, 97 had a measure of LA volume using all 3 methods. A significant difference in the measurement of mean $\pm$ SD LA volume was noted among the 3 different methods: 37 $\pm$ 16 mL/m² for AL, 34 $\pm$ 14 mL/m² for SIMP, and 27 $\pm$ 12 mL/m² for PE. The PE method yielded routinely smaller values compared with either the AL or SIMP method (P < 0.001). Differences increased with increased LA volume. The SIMP method derived consistently smaller (<5 mL/m²) values than those of the AL method, consistent across the full range of LA volumes.

Conclusion Significant differences exist among these 3 commonly used methods for measuring LA volume. Standardization of the measurement of LA volume is recommended.

KEYWORDS Cardiac volume; Echocardiography; Heart atria

Introduction

Remodeling of the left atrium (LA) is a reflection of the burden and chronicity of underlying, often occult, cardiovascular disease. The presence of LA enlargement portends clinically significant risk of adverse cardiovascular consequences for the patient.1–5 A measure of LA size is therefore requisite for any complete transthoracic echocardiographic evaluation. The advent of M-mode echocardiography revolutionized the non-invasive evaluation of cardiac morphologic conditions. Cardiac chamber sizes were subsequently characterized by unidimensional measurements. For the LA, an anteroposterior dimension was measured. However, for this measurement to accurately represent the true LA size, it must be assumed to bear a consistent relation to other LA dimensions, which is incorrect.6,7 Thus, volume-based methods of chamber quantification have evolved. The Guidelines and Standards Committee of the American Society of Echocardiography has taken the position that biplane volume determinations are preferable for measurement of LA size in clinical practice.8

Three commonly used methods for evaluation of LA volume are the biplane area length (AL), the biplane modified Simpson (SIMP), and the prolate ellipse (PE) methods. Each mathematical calculation assumes the LA to be a fixed shape, which may result either in over- or underestimation of true volume. Despite the burgeoning understanding of the clinical significance of an accurate measurement of LA volume, whether these 3 methods derive similar unit values has not been formally reported. We sought to compare and contrast the values obtained by these 3 commonly used measures of LA volume.

Methods

Approval for this study was obtained from the Mayo Foundation Institutional Review Board. A computerized search of the echocardiogram database identified consecutive patients who had a transthoracic echocardiogram at Mayo Clinic, Scottsdale, Arizona, between April 2006 and May 2006. Echocardiographic data were retrieved electronically from the Echocardiography Laboratory Database.

For each patient, a measurement of LA volume was calculated by the AL, SIMP, and PE methods (Figures 1–3). Twenty percent of these patients were randomly selected for repeat measurements to assess the intraclass correlation coefficient of each measurement technique between 2 readers.

Statistics

Continuous variables were reported as mean $\pm$ SD. Categorical variables were reported as percentages. Results of LA volume and the LA...
The paired \( t \) test was used to test for mean differences among LA volumes by each method. Bland–Altman graphs were used to plot the difference between 2 observations versus the mean of the observations to look for overall bias as well as for systematic variation with increased measurement of LA volumes.

For 10 patients, border tracing was repeated by the same observer and also by an independent observer. To assess the reliability of the measurements, we calculated intraclass correlation coefficients using the method of Shrout and Fleiss, which assumes that the persons whose measurements were taken were from a random subset of all possible persons.

Results

Patient population

Baseline clinical and echocardiographic characteristics of the study population are summarized in Table 1. A retrospective review identified 102 consecutive patients who had presented to our outpatient echocardiography laboratory for a resting transthoracic study. Five patients (5%) were excluded because their echocardiograms were not

Table 1 Baseline clinical and echocardiographic characteristics of the study group

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value(^a)</th>
</tr>
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<tbody>
<tr>
<td>Age, y</td>
<td>66 ± 16</td>
</tr>
<tr>
<td>Men, %</td>
<td>57</td>
</tr>
<tr>
<td>BMI</td>
<td>28 ± 6</td>
</tr>
<tr>
<td>BSA, m²</td>
<td>1.96 ± 0.3</td>
</tr>
<tr>
<td>Rhythm Sinus, %</td>
<td>79</td>
</tr>
<tr>
<td>AF, %</td>
<td>19</td>
</tr>
<tr>
<td>Ventricular paced, %</td>
<td>1</td>
</tr>
<tr>
<td>Heart rate, beats/min</td>
<td>70 ± 14</td>
</tr>
<tr>
<td>LV wall thickness, mm</td>
<td>11 ± 2</td>
</tr>
<tr>
<td>Septal</td>
<td>11 ± 2</td>
</tr>
<tr>
<td>Posterior wall</td>
<td>11 ± 2</td>
</tr>
<tr>
<td>LV dimensions, mm</td>
<td></td>
</tr>
<tr>
<td>LVEDD</td>
<td>48 ± 7</td>
</tr>
<tr>
<td>LVESD</td>
<td>31 ± 7</td>
</tr>
<tr>
<td>LVEF, %</td>
<td>60 ± 11</td>
</tr>
<tr>
<td>Valvular heart disease, %</td>
<td>25</td>
</tr>
</tbody>
</table>

\(^a\)Values are mean ± SD unless indicated otherwise.
suitable for measurement of LA volumes by all 3 methods. Of the remaining 97 patients, 55 (57%) were men (mean ± SD age, 66 ± 16 years).

Echocardiographic data
A significant difference in the measurement of the mean ± SD LA volume index was noted among the 3 different methods: 37 ± 16 mL/m² for AL, 34 ± 14 mL/m² for SIMP, and 27 ± 12 mL/m² for PE. Compared with either the AL method or the SIMP method, the PE method of measurement of LA volume routinely yielded smaller values [−9.9 ± 6.8 mL/m² (P < 0.001) and −6.3 ± 5.1 mL/m² (P < 0.001), respectively]. The Bland–Altman graphs (Figures 4–6) for each of the pairwise comparisons show how the difference between the AL and SIMP methods increased in relation to the PE method as the LA became enlarged (Figures 4 and 5). Compared with the AL method, the SIMP method yielded smaller values that were nonetheless significant (−3.6 ± 3.3 mL/m²; P < 0.001). The difference between these 2 methods was constant across the entire range of LA volumes (Figure 6).

In our study population, 21 patients were noted to have left ventricular (LV) enlargement, defined as a LV end-diastolic dimension of ≥54 mm.8 In this group, the measurement of LA volume by the SIMP method again consistently yielded smaller values (−3.2 ± 2.4 mL/m²; P < 0.001) (Figure 7).

Reproducibility of measurements
Intraclass correlations for the replicated measurements are presented in Table 2. All 3 methods of measurement showed excellent agreement.

Discussion
The principal finding of this study is the significant (P < 0.001) variance in the unit value of the measurement of LA volume by 3 commonly used techniques. The PE method routinely yields smaller values compared with either the AL or SIMP method. This difference in value determination was most pronounced when the LA was enlarged. The AL and SIMP methods also yielded small (<5 mL/m²) but significant differences (P < 0.001) in value determination, with the SIMP method deriving smaller values. However, in this instance, the magnitude of the difference was constant throughout the entire range of LA and LV size.

As the LA remodels, a small increase in the anteroposterior dimension may be associated with a disproportionately larger change in volume.11–13 As the atria enlarge, the lack of a constant relation between the major axes of the LA becomes pronounced.11,14 The PE method of calculating LA volume is strongly influenced by an anteroposterior measure (Figure 3); therefore, it is not surprising to find that it yields smaller values that are most pronounced when the LA is enlarged. The assumption that the similarity of the AL method and the SIMP method of measurement of LV volume might apply to the measurement of the LA is incorrect because of the geometric differences in form between the LV and the LA. There are small but consistent differences in the measure of LA volume by the AL method and the SIMP method. The disk method assumes that each disk is perfectly cylindrical. The volume of each disk is calculated by area (πr²) × length. The non-circular geometry of the LA will result in non-uniformity of the elliptical disk shape and thus the radius measurement may exclude small portions of each disk, which leads to an underestimation of volume. In contrast, the AL method measures the true dimensional area from which the length is derived and thus it can be assumed to reflect LA size more accurately.
determining LA size. Standardized quantification must be the AL or the SIMP method be adopted as the standard for important is that measurement of LA volume using either method) may poorly reflect the extent of LA remodeling and thus inappropriately characterize an individual patient’s risk for an adverse cardiac event. Therefore, what is most important is that measurement of LA volume using either the AL or the SIMP method be adopted as the standard for determining LA size. Standardized quantification must be adopted to not only for accurate communication between health care providers but also for external validity of clinical trial data.

Clinical implications

The presence of LA remodeling has profound clinical implications with outcome data based on a 2-dimensional echocardiographic measure of LA volume, most often derived by the AL method. The method of determining LA size should be volume based. Methods of calculation that rely heavily on unidimensional measurements (e.g., the PE method) may poorly reflect the extent of LA remodeling and thus inappropriately characterize an individual patient’s risk for an adverse cardiac event. Therefore, what is most important is that measurement of LA volume using either the AL or the SIMP method be adopted as the standard for determining LA size. Standardized quantification must be adopted to not only for accurate communication between health care providers but also for external validity of clinical trial data.

Limitations

This study was designed to compare and contrast various commonly used echocardiographic methods with which to derive a measurement of LA volume and did not compare these against a yet-to-be definitively determined preferred ‘gold standard’ method such as magnetic resonance imaging or 3-dimensional echocardiography. However, the recommendations for chamber quantification put forth by both the European Society of Cardiology and the American Society of Echocardiography neither compared nor contrasted values obtained by these 3 commonly used clinical methods to derive LA volume. Such an understanding is clinically important because the reference limits and absolute values of LA volume put forth in these documents do not reconcile unit value differences of different methods of measurement.

The absence of a preferred method with which to compare and contrast the 2-dimensional methods for determination of LA volume that were evaluated in this study may in fact represent a limitation if the question is ‘What is the absolute unit value of LA volume?’ It is our view that, in fact, such a standard should not be mired in the debate about which method provides the closest approximation of the truth but rather should be grounded in the standard of patient care and clinically important information. Clearly, the robust outcome data based on LA size is noted from a 2-dimensional biplane method of calculation (primarily AL) of LA volume. What is clear is that the SIMP and AL methods are consistent with each other at all ranges of LA volume. Subtle and consistent differences in the values obtained by the Z methods require some translation in the discussion of LA volume measurements according to which method is adopted. It is unlikely that a potential small unit value in LA volume difference obtained by a standard will add demonstrably to the profound clinical information provided by the LA volume measurement. What is important is for the universal tool of echocardiography to be used to its maximum potential with a 2-dimensional biplane measurement of LA volume adding significantly to its utility. Respirophasic changes in LA volume may be observed. This study did not attempt standardization of the phase of respiration in which the LA image was captured. However, each of the 3 methods for calculating LA volume was based on the same images, which would negate any influence of respiration on the comparison of methods. From the apical views, the LA is in the far field of the ultrasound beam where lateral resolution is most limited, thus leading to potential sources of error in 2-dimensional planimetry of the LA. The lack of significant interobserver variation in either the AL or the SIMP method relegates this limitation to a theoretical one only.

Conclusion

Significant differences exist among these 3 commonly used methods for measuring LA volume. Standardization of the measurement of LA volume is recommended not only to ensure accurate communication among health care providers but also to ensure individual external validity of clinical trial data.

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