Switching to volumetric left atrial measurements: impact on routine echocardiographic practice

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Aims

To define the change in the prevalence of reported left atrial enlargement (LAE) brought by using volumetric rather than linear measurements and to detect whether individuals with LAE that would have been missed by linear measurements represent a distinct subgroup of patients.

Methods and results

Left atrial (LA) linear dimensions and volumes were obtained and correlated with clinical and echocardiographical variables in 168 consecutive patients (age: 69 ± 10 years) undergoing routine echocardiographic studies. LAE was diagnosed in 109 out of 168 patients (65%) by volume criteria as opposed to 68 out of 168 patients (40%) by linear dimension criteria, resulting in a ‘missing rate’ of 37% for the latter. Patients with LAE diagnosed by volume but not by diameter measurements had a lower left ventricular mass index (LVMI).

Conclusion

Adopting volume measurements for the LA may result in almost 40% increase in the number of patients reported as having LAE. The lower LVMI found in these patients suggests that volume-based measurements are more sensitive and detect LAE at an earlier stage than diameter-based measurements, although the prognostic and management impact of this finding remains to be established.

Keywords

Left atrium • Left atrial volume • Diastolic function

Introduction

The left atrium (LA) fulfils a mechanical role as both a reservoir for continuously incoming pulmonary vein inflow and an active participant to left ventricular (LV) filling. Clinically, LA enlargement (LAE) is associated with mitral valve disease, long-standing atrial fibrillation, increased LV filling pressures, and LV volume overload conditions. A wealth of data suggests that patients with LAE have poorer long-term cardiovascular outcome and that LAE can be used for risk stratification in heart failure, atrial fibrillation, arterial hypertension (AHT), and stroke. Historically, the LA has been measured in its antero-posterior diameter in the parasternal long-axis view using either M-mode or two-dimensional (2D) imaging. The value of these linear measurements is supported by strong clinical correlations reported in the literature. Recent data suggest that LAE defined by LA area or volume rather than by the antero-posterior diameter has an even stronger association with the outcome of cardiac patients and that 2D volume measurements have a better correlation with 3D volumes than other techniques. Updated echocardiographic guidelines refer to both linear and volume measurements but stop short of endorsing volume measurements as the preferred method to assess LAE. Most echocardiographic services still rely on diameter measurements, and volume calculations are used mainly for research purposes. Both long-established practice and uncertainties about the potential alterations on echocardiographic reporting brought by a change in routine measurements may explain the lack of wide-scale espousal of this new approach.

This is a prospective study, designed to assess the potential impact of switching to routine volumetric LA assessment on the reported prevalence of LAE and whether individuals with LAE that would have been missed by linear measurements represent a distinct subgroup of patients.

Methods

Study population

We enrolled 200 consecutive patients aged 50 years or more, referred for echocardiographic scans at the Department of Cardiology, Royal...
Liverpool University Hospital. The presence of AHT, diabetes, and coronary disease was documented by specifically questioning the patient and from the patient’s case file. Arterial hypertension was defined as the systolic or diastolic blood pressure of >140 or >90 mmHg, respectively, or the current use of antihypertensive drugs. Diabetes mellitus (DM) was defined as two documented blood glucose levels >7 mmol/L or post-prandial serum glucose of >11 mmol/L or known diabetes controlled either with diet or antiglycaemic medications. Age above 50 years was the only inclusion criterion due to the expected increased prevalence of LAE in these patients and paced rhythm and poor-quality images were the only exclusion criteria. LA volume measurements were not obtainable in only 12 cases but overall 32 patients had to be excluded due to either paced rhythm, poor-quality studies precluding LA measurements by both longitudinal diameter and volumes, or refuse to participate in the study. The remaining 168 patients (age: 69 ± 10 years, 75 males and 93 females) are the object of this report. The protocol was approved by the hospital Ethics Committee and written informed consent was obtained in each subject.

**Echocardiography**

Echocardiography was performed using a commercially available Philips IE 33 ultrasound system. All studies were performed by the same experienced sonographer and included a full 2D and Doppler examination following accepted guidelines. As a rule, measurements were performed with the patient in left lateral decubitus, withheld respiration at the time allowing optimal visualization. End-diastole was defined as the onset of QRS and end-systole as the last frame preceding mitral valve opening. One to three measurements were performed for patients in sinus rhythm and three to five measurements were used for patients in atrial fibrillation. The LA antero-posterior diameter was measured at end-systole in the parasternal long-axis view using either 2D or 2D-guided M-mode measurements. The LA volume was obtained by Simpson’s rule using the built-in software of the machine. For this purpose, LA areas were manually traced at end-systole in apical four- and two-chamber views. No more than 20% atrial wall drop was considered acceptable for tracing. Diastolic function was assessed using both mitral valve inflow pulsed-wave (PW) Doppler and mitral annulus PW tissue Doppler, and LV mass was calculated using M-mode measurements and the Devereux formula. LV systolic function was visually assessed in all patients and the ejection fraction was calculated using the Simpson’s method whenever possible.

### Table 1  Clinical and standard echocardiographic characteristics of study population

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>69 ± 10</td>
</tr>
<tr>
<td>Male gender (%)</td>
<td>75 (45)</td>
</tr>
<tr>
<td>AHT (%)</td>
<td>89 (53)</td>
</tr>
<tr>
<td>DM (%)</td>
<td>29 (17)</td>
</tr>
<tr>
<td>CAD (%)</td>
<td>44 (26)</td>
</tr>
<tr>
<td>VHD (%)</td>
<td>46 (27)</td>
</tr>
<tr>
<td>LVSD (%)</td>
<td>26 (15)</td>
</tr>
<tr>
<td>≥ Grade 2 diastolic dysfunction</td>
<td>55 (37)</td>
</tr>
<tr>
<td>LVMi (g/m²)</td>
<td>102.3 ± 35.4</td>
</tr>
<tr>
<td>LAD</td>
<td>3.8 ± 0.7</td>
</tr>
</tbody>
</table>

AHT, arterial hypertension; CAD, coronary artery disease; DM, diabetes mellitus; LAD, left atrial diameter; LVMi, left ventricular mass index; LVSD, left ventricular systolic dysfunction; VHD, valvular heart disease.

*Data obtained in 150 patients.

*Data obtained in 157 patients.

### Table 2  Proportion of patients with left atrial enlargement by volume, not detected by diameter measurements in subgroups of patients according to heart rhythm, left ventricular systolic function, and the presence of mitral valve disease

<table>
<thead>
<tr>
<th>LAE</th>
<th>All (n = 168)</th>
<th>SR (n = 138)</th>
<th>AF (n = 30)</th>
<th>LVSD (n = 26)</th>
<th>No LVSD (n = 142)</th>
<th>MVD (n = 17)</th>
<th>No MVD (n = 151)</th>
</tr>
</thead>
<tbody>
<tr>
<td>By diameter</td>
<td>68</td>
<td>45</td>
<td>22</td>
<td>17</td>
<td>51</td>
<td>12</td>
<td>56</td>
</tr>
<tr>
<td>By volume</td>
<td>109</td>
<td>79</td>
<td>29</td>
<td>24</td>
<td>85</td>
<td>17</td>
<td>92</td>
</tr>
<tr>
<td>Missed by</td>
<td>41 (37%)</td>
<td>34 (43%)</td>
<td>7 (24%)+</td>
<td>7 (29%)</td>
<td>34 (40%)</td>
<td>5 (29%)</td>
<td>36 (39%)</td>
</tr>
</tbody>
</table>

AF, atrial fibrillation; LAE, left atrial enlargement; LVSD, left ventricular systolic dysfunction; MVD, mitral valve disease (defined as any degree of mitral stenosis or at least moderate mitral regurgitation); SR, sinus rhythm.

*P < 0.05.
Data analysis
LAE was diagnosed by linear measurements if the antero-posterior diameter was >4 cm in males or >3.8 cm in women, by area if the planimetry area was >20 cm², and by volume if LA volume was >58 mL in males or >52 mL in women. For body surface area (BSA)-indexed measurements, an antero-posterior diameter >2.3 cm/m² and a volume >28 mL/m³ were taken as diagnostic of LAE. Results were dichotomized for the presence or absence of LAE, without subgroup analysis for various degrees of LAE.

An LVMI > 102 g/m² for males and >88 g/m² for females was considered diagnostic for LV hypertrophy (LVH). Diastolic function was assessed using PW flow Doppler interrogation of the mitral inflow and PW tissue Doppler with the sample volume placed at the septal side of the mitral annulus. Diastolic dysfunction was diagnosed in the presence of $E'$ velocity <8 cm/s. An $E/E'$ ratio >9 was indicative of ≥Grade 2 diastolic dysfunction.

Statistical analysis
t-test for continuous variables and $\chi^2$ test for categorical variables were used for group comparison. P-value was considered significant at $\alpha = 0.05$.

Results
Clinical and standard echocardiographic characteristics of the study group
Eighty patients had been referred for LV function assessment, 39 patients for evaluation of valvular heart disease or murmurs, 30 patients for arrhythmia work-up, and 19 for various other indications. One hundred and thirty-seven patients were in sinus rhythm at the time of the study. Clinical and echocardiographic characteristics are detailed in Table 1. LAE by the standard measurement of the antero-posterior diameter was found in 68 patients (40%). When compared with patients with normal size LA, patients with LAE had a higher LVMI (113.95 ± 39 vs. 94.75 ± 30 g/m², $P < 0.01$), higher $E/A$ and $E/E'$ ratios (0.99 ± 0.35 vs. 0.85 ± 0.26, $P = 0.02$ and 15.59 ± 6.8 vs. 12.28 ± 5, $P < 0.01$, respectively) and a higher proportion of Grade 2–3 diastolic function (47 vs. 30%, $P = 0.04$).

Frequency of left atrial enlargement by different methods
The prevalence of LAE in the study population rose from 68 (40%) when diagnosed by the antero-posterior diameter, to 85 (50%) by LA area, 109 (65%) by LA volume, and 126 (75%) by LA volume indexed for BSA, $P < 0.001$. Indexing the diameter measurement for BSA did not improve the detection rate (Figure 1). The use of volume calculation resulted in a 60% increase in the number of patients diagnosed with LAE when compared with the use of diameter measurement. The proportion of patients with LAE by volume but missed by diameter was higher in patients with normal LV contractility, sinus rhythm, and no mitral valve disease (Table 2). The concordance for the presence of LAE by the diameter and volume was 111 of 168 (66%). Out of the 57 patients in whom the methods were in disagreement, 49 had LAE by volume but not by diameter (Figure 2), whereas 8 had LAE by diameter but not by volume.

Comparison of patients with left atrial enlargement by left atrial volume but not by left atrial diameter
As for diameter measurements, LAE by volume was associated with increased LVMI, higher $E/E'$ ratios, and higher proportion of LVH and advanced diastolic dysfunction, but with consistently stronger statistical significance than for LAE by diameter measurements (Table 3). Patients with LAE by volume but not by diameter measurements had a smaller BSA, LVMI, and prevalence of LVH and systolic dysfunction, but there was no difference in age.

Figure 2 Left atrial measurements in parasternal long-axis view (A) and in apical views (B and C). Comparison with the aortic root dimensions suggests left atrial enlargement, but the actual antero-posterior diameter measurements are within the normal range. Volume calculations in the apical views demonstrate the true magnitude of severe LAE in this case.
Table 3  Left ventricular mass and prevalence of advanced diastolic dysfunction in patients with and without left atrial enlargement by diameter and by volume measurements

<table>
<thead>
<tr>
<th>LAE</th>
<th>By LAD</th>
<th>By LA volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>LVMI</td>
<td>94.75 ± 30.16</td>
<td>113.95 ± 39.69</td>
</tr>
<tr>
<td>LVH</td>
<td>42/95 (44%)</td>
<td>36/62 (58%)</td>
</tr>
<tr>
<td>E/E'</td>
<td>12.28 ± 5.05</td>
<td>15.59 ± 6.84</td>
</tr>
<tr>
<td>≥ Grade 2 LVDD</td>
<td>30/97 (30%)</td>
<td>25/53 (47%)</td>
</tr>
</tbody>
</table>

LAD, left atrial diameter; LAE, left atrial enlargement; LVDD, left ventricular diastolic dysfunction; LVH, left ventricular hypertrophy; LVMI, left ventricular mass index.

gender distribution, and the severity of diastolic dysfunction, when compared with patients with LAE by both methods (Table 4).

Discussion

The reported independent prognostic and risk stratification value of LAE in cardiovascular diseases is well established, although the relationship for cardiac events may be weaker in patients with atrial fibrillation. The LA is an asymmetric 3D structure and may not dilate equally along its three axes, but there is no clear explanation why, in some patients, the anterior–posterior diameter is spared. The LA antero-posterior diameter is a readily available and time-established index of LAE with a proven prognostic value. When compared with magnetic resonance, 3D echocardiography or computed tomography, LA 2D volumes have been consistently shown to be more accurate than linear dimension to diagnose LAE. LA volume measurements are advocated of late as being superior to linear measurements for prognostic purposes, although the evidence for better prognostic and risk stratification power for the latter is scarce. In the paper of Tsang et al., the LA-indexed volumes were superior by receiver-operating curve areas, but there was no difference in the hazards ratio of the two methods as predictors of cardiovascular events. Also, Pritchett et al. report a better association with hypertension, heart failure, and atrial fibrillation for LA volumes, but there are no data on a possible prognostic value of LAE by volume as opposed to diameter. Whether volumetric measurements will become the established routine technique to diagnose LAE depends on feasibility and on the balance between the impact of a potential increase in the number of patients with reported abnormal findings and the real clinical benefits of adopting this method.

This paper

LA volume measurements could be obtained in 188 out of 200 patients, translating in a feasibility rate of 94%. LAE by both diameter and volume measurements was associated with higher LV mass and more advanced diastolic dysfunction, with the volume measurements showing a stronger statistical significance (Table 2). The two methods were in agreement in only two-thirds of the patients for the diagnosis of LAE, mainly due to under-diagnosis by diameter measurements (86% of non-agreement cases). If LA volume rather than LA diameter was used, there was an abrupt increase (60%) in the percentage of patients reported to have LAE. These patients had lower LV mass and prevalence of LVH and systolic dysfunction and were less likely to be in atrial fibrillation or to have significant mitral valve disease, with borderline statistical significance. In 12 of them (24%), the LAE by volume measurement was the only echocardiographic abnormality. These results suggest that LA volume is a more sensitive marker than LA diameter for detecting LAE. Very little is known in the literature about the percentage of patients with LAE who are potentially missed by using linear measurements only and what are the determinants of discrepancies between the two methods. Badano et al. report a 43% under-diagnosis rate of LAE by diameter measurements when compared with 3D volume reconstruction and in their study, indexing the LA anterior–posterior diameter to BSA also fails to improve diagnostic accuracy. To the best of our knowledge, this is the first paper to specifically address the impact on LAE reporting of switching from linear measurements to a 2D volumetric approach.
Conclusions

LA volume can be easily obtained in the great majority of cases. The use of LA volume rather than the anterior–posterior diameter is expected to result in a sharp increase in the number of patients diagnosed with LAE. Patients with LAE by volume but not by diameter seem to have fewer pathological features such as LVH and systolic dysfunction, but what the clinical implications are of diagnosing LAE by volume but not by diameter is not clear. Reporting an echocardiographic abnormality, especially as an isolated finding, may result in additional investigations, patient anxiety, and insurance status change. Further prospective head-to-head comparative follow-up studies are needed to clarify whether the marked increase in the percentage of patients reported as having LAE due to the widespread use of volume instead of diameter criteria is paralleled by prognostic and risk stratification clinical benefit.

Conflict of interest: none declared.

References


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