Left Atrial Volume and Left Atrial Function as Predictor of Postoperative Atrial Fibrillation

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LA Volume by Echocardiography

The two-dimensional echocardiographic determination of left atrial (LA) volume could be done using single-plane methods, biplane area length method and biplane Simpson's method of discs using orthogonal views. The single-plane methods have been used but these have been shown to be less accurate.[1] The biplane area-length method and biplane Simpson's method of disc, using orthogonal views, have been well validated against angiography, computed tomography, magnetic resonance imaging.[2-6] Three-dimensional echocardiography is emerging to be the preferred method of LA volume assessment in the future, however, two-dimensional assessment remains the current standard for clinical practice and both the biplane area-length method and the biplane Simpson's method are acceptable.[7-8]

The left atrium is asymmetric, especially when it is enlarged. This makes the single-plane method such as M-mode less reliable; unlike the biplane methods of LA volume assessment that utilizes two orthogonal views of the left atrium, usually 4-chamber and 2-chamber views (*Figure 1*). LA volume measurement is based on maximal LA volume that occurs after the end of ventricular systole, which coincides

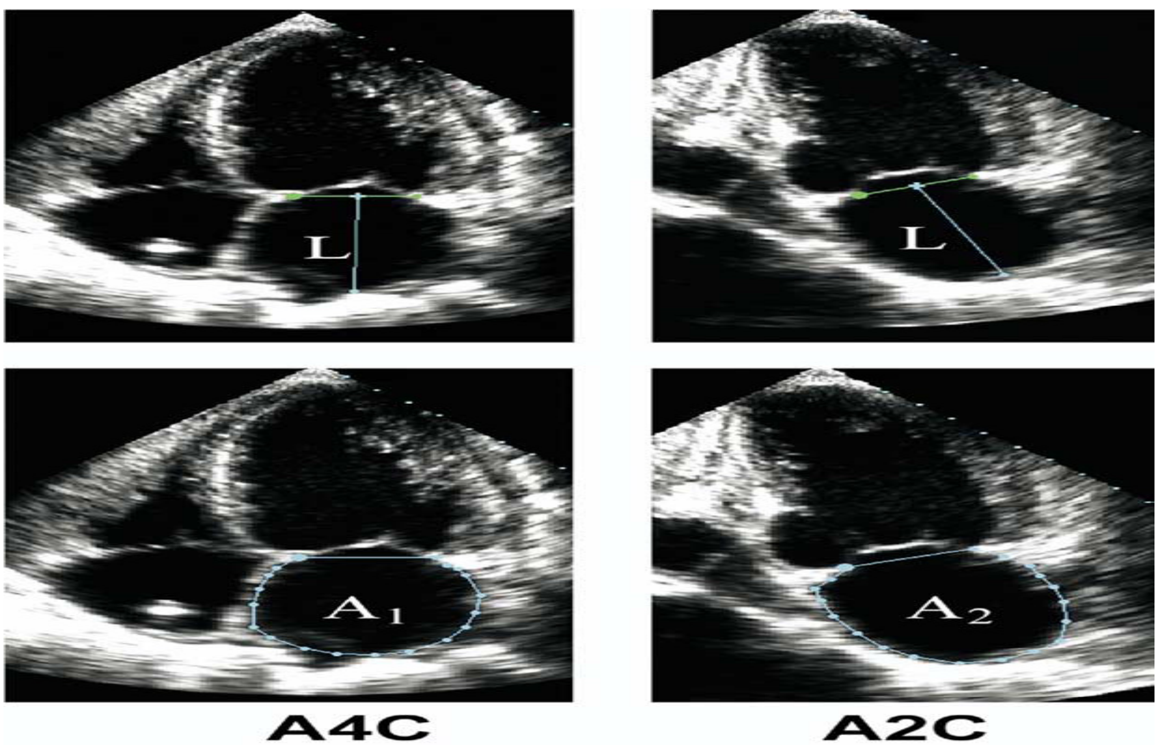

Figure 1. 4 chamber (left) and 2 chamber (right) views at endsystole showing the planimetry of the left atrium and the measurement of the length

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with the end of the T wave on electrocardiography. This also corresponds to the echocardiographic frame immediately prior to the opening of the mitral valve.

Planimetry of the left atrium using this frame is done with the plane of the mitral annulus as the inferior border while the atrial appendage and pulmonary veins are excluded. The length required for the calculation of the volume refers to the axis of the left atrium, which is perpendicular to the plane of the mitral annulus from its midpoint to the superior margin of the left atrium. In theory, when the 4-chamber and 2-chamber views are optimized, the length measured from the two views should be identical. When there is a slight discrepancy because of the variability of chamber orientation, the shorter length is chosen as it would partially compensate for the "underestimation" of LA volume by echocardiography compared to computed tomography or magnetic resonance imaging assessments.[7] It must be emphasized that the key to accurate volume determination is the use of optimized nonforeshortened views, in which case the lengths measured from the two views should be nearly identical.

LA volume by biplane are-length method is caculated using the formula as follows then indexed to body surface area:

0.85 (4-chamber area x 2-chamber area)/length

The modified Simpson's method of measuring maximal LA volume depends on the summation of the volumes of smaller figures of similar shape with a known height and orthogonal major and minor axes. Again, optimal 4-chamber and 2-chamber views (*Figure 2*) without foreshortening are necessary.

This method provides very comparable LA volumes with those obtained using the area-length method.[7] Both biplane methods are simple and accurate. A distinct advantage of the Simpson's method is its reliance on the computerized summation of discs for the total volume, and it does not require input of a specific length for volume calculation, as in the area-length method. However, the drawback of Simpson's method is that it is not available in the application packages of most machines.

The use of "prolate-ellipsoid" method, which involves measuring 3 axes (typically the anterior-posterior diameter from the parasternal long-axis view, length from the 4-chamber view from the midpoint of the mitral annular plane to the superior aspect of the left atrium, and the transverse axis perpendicular to the length from the 4- chamber view) tends to give significantly smaller volumes compared with volumes obtained using the biplane area-length or Simpson's method,[7] which were the ones used for establishing normal values.

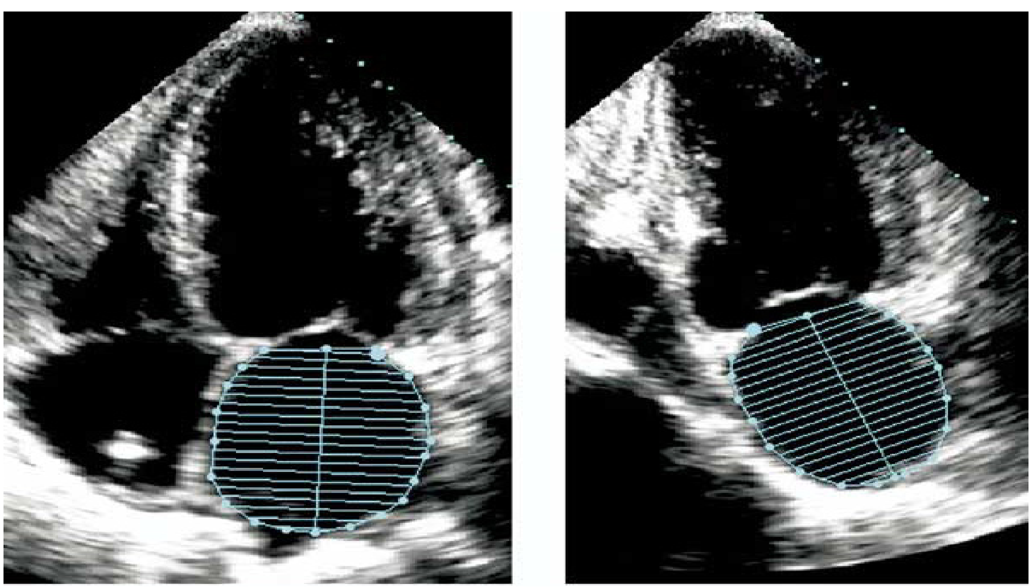

Figure 2. Measurement of left atrial (LA) volume from biplane method of discs (modified Simpson's rule) using apical 4-chamber (left) and apical 2-chamber (right) views at ventricular end systole (maximum LA size).

Table 1. Two-dimensional volumetric assessment of LA physic function

FUNCTION	PARAMETER	FORMULA
Reservoir Function	Total emptying volume	LAV_{max} - LAV_{min}
	Total emptying fraction	[LAV_{max} - LAV_{min}]/ LAV_{max} x100%
Conduit Function	Passive emptying volume	LAV_{max} - LAV_{PRE-A}
	P passive emptying fraction	LAV_{max} - LAV_{PRE-A}]/ LAV_{max} x100%
	Conduit volume	Stroke volume - total emptying volume
Pump Function	Active emptying volume	LAV_{PRE-A} - LAV_{min}
	Active emptying fraction	[LAV_{PRE-A} - LAV_{min}]/LAV_{PRE-A} x 100%

LAV_{max} Maximal LA volume; LAV_{min} Minimal LA Volume; LAV_{PRE-A} volume immediately before atrial contraction.

The mean normal LA volume is 22 ± 6 mL/m^2.[13,14] The left atrium is enlarged when the volume is > 28 mL/m^2, which is about 1 standard deviation from the normal mean value. This value has been shown to be 87% sensitive and 93% specific for identifying the presence of diastolic dysfunction by Doppler.[13] An LA volume of 32 mL/m^2, a cutoff that has been used repetitively in studies, represents approximately 2 standard deviations from the normal mean value. The left atrium is more than mildly enlarged when > 32 mL/m^2, which has been reproducibly associated with adverse outcomes.

Real time 3D echocardiography has emerged and expected to be more accurate than 2D imaging, which are based on geometric assumptions. Measurement of LA maximal volume by 3D imaging provides direct measurement of volumes. Three-dimensional data sets are obtained, then offline analysis is done using a machine specific program. Using a Q Lab System, a semi-automated tracing of the left atrial border is performed by marking five atrial points: the anterior, inferior, lateral, septal mitral annuli and the left atrial apex.[9] Volumes of the left atrium could then be obtained at end-systole and end-diastole in order to obtain left atrial function indices, such as total left atrial stroke volume and left atrial emptying fraction. Investigators confirmed improved accuracy and reproducibility of the 3D approach when compared with 2D echocardiographic measurements of left and right atrial volumes against an independent gold standard such as magnetic resonance imaging.[10-12]

Volumetric LA Function Assessment

Maximal LA volume can be timed to the end of the T wave on electrocardiogram, just before the opening of the mitral valve. Minimal LA volume occurs at mitral valve closure, which can be timed to QRS on electrocardiography, while "pre-A" volume is simply the volume immediately before atrial contraction, timed to the onset of the P wave. The left atrium acts as a reservoir when the valve is closed, as a conduit when the mitral valve is open, until the start of atrial contraction when it acts as a pump. LA function assessment based on echocardiographic volumetric formula are shown in Table 1.

The normal total emptying fraction has been shown quite consistently to be 63 ± 7%.[14,15] Passive emptying accounts for greater, and active emptying less, of total emptying with advancing age. The active emptying fraction, equivalent to the LA ejection fraction, has been reported to be within the range of approximately 30% to 51%[14-16] and the passive LA emptying fraction in the range of 33% to 43%.[14-16] LA emptying fraction has been shown to be incremental to indexed LA volume, LV diastolic dysfunction, and clinical risk factors for the prediction of first atrial fibrillation or atrial flutter in persons aged ≥65 years.[17] The combination of poorer LA function and larger LA volume appeared especially hazardous with respect to the development of atrial fibrillation. Moreover, LA emptying fraction has been shown to predict first ischemic stroke, independent of clinical stroke risk factors.[33]

Clinical Relevance of LA Volume

Left atrial volume is a more robust predictor of clinical outcome than LA area or M-mode LA diameters.[18] Several papers show that LA size is an independent predictor of atrial fibrillation,[19-21] stroke,[22] heart failure,[23,24] survival after myocardial infarction,[25,26] prognosis in cardiomyopathies,[27,28] and total as well as cardiovascular mortality.[29,30]

LA volume correlates well with the degree of left ventricular (LV) diastolic dysfunction.[13] The increased filling pressure that is associated with LV diastolic dysfunction leads to increased pressure load to the left atrium resulting to stretch of its wall and the pulmonary veins. This leads to functional, structural and electrical changes that predispose to first atrial fibrillation.[31]

Heart failure develops with similar mechanism. Left atrium dilates to a certain point beyond which its function starts to deteriorate with diminishing contribution to ventricular filling. Diminishing LA contribution to ventricular filling leads to both a reduction of cardiac output and an increase in pulmonary congestion with development of overt heart failure.[32]

Postoperative atrial fibrillation incidence. Possible mechanisms

Postoperative atrial fibrillation (POAF) is the most common arrhythmic complication after cardiothoracic surgery (coronary artery bypass grafting or valve repair or replacement surgery), occurring in up to 50% of patients without prophylaxis.[34] Since postoperative atrial fibrillation increases the risk of hemodynamic instability and stroke while lengthening intensive care and total hospitalization time,[35] it is important to predict preoperatively its occurrence. The occurrence of first atrial fibrillation (AF) in the nonsurgical setting has been predicted by left atrial volume (LAV).[19-21] In the study done by Osranek et al,[36] postoperative atrial fibrillation was shown in 41.4% at a median of 1.8 days after cardiac surgery. The LAV was significantly larger in patients in whom AF developed ($49 \pm 14 ml/m^2$ vs. $39 \pm 16 ml/m^2$, p=0.0001. Patients with LAV $>32 ml/m^2$ had an almost five-fold increased risk of POAF, independently of age and clinical risk factors.

The possible mechanism of postoperative atrial fibrillation could be due to increased susceptibility of a remodeled cardiovascular system to increased adrenergic stress and dynamic volume changes associated with surgery. Chronic myocyte stretch increases the intercellular matrix, collagen production and fibrosis, mediated through the renin-angiotensin-aldosterone system.[37] Enlarged atria reflect the remodelling process, and represent a quantifiable surrogate of the arrhythmogenic substrate.

Thus, increased left atrial volume and decreased left atrial function could be used to predict postoperative atrial fibrillation, which could potentially increase hospital stay and cost. Preoperative use of β-Blocking agents and amiodarone, which have been found to be successful strategies for preventing POAF,[35] may be given prophylactically.

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