Editorial

Left Atrium: Novel Insights and Future Directions

Átrio esquerdo: Novas percepções e direcionamentos futuros

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Introduction

The left atrium (LA) is an intricate chamber with complex geometry and multiple functions, the most important of which is the modulation of LV filling.[1] Recent studies have highlighted our understanding of the contributions of left atrial function to overall cardiac performance in multiple disease states.[2] Both LA size and extent of remodeling are powerful predictors of adverse cardiovascular outcomes in multiple clinical settings, including development of atrial fibrillation, ischemic stroke and congestive heart failure.[3] Accordingly, it is crucial to strictly follow the guidelines[4] when performing measurements of LA dimension, volumes and function to enhance accuracy and reproducibility.

LA assessment on 2D Echocardiography

LA size is still frequently assessed using linear measurements of the anteroposterior diameter of the LA in the parasternal long-axis view perpendicular to the aortic root long axis, at the level of the aortic sinuses using M-mode and 2-dimensional echocardiography (2D).[4] Because this measurement is easy to obtain and highly reproducible, echocardiography laboratories continue to report it despite being strongly discouraged in the latest chamber quantification guidelines.[4,5] The main reason for this recommendation is that the LA is an asymmetrical cavity which does not dilate proportionally in all directions. In fact, it has been shown that the LA tends to enlarge more in the superior-inferior than the antero-posterior direction due to presence of the spine and sternum.[6,7] Consequently, these linear measurements tend to underestimate true left atrial size (Figure 1).

Left atrial volumes can be measured on 2D echocardiography using either the biplane method of discs or the area-length method. The method currently recommended by American Society of Echocardiography (ASE) is the biplane Simpson disk summation technique. While the area-length method is effective, the Simpson method is preferred because it relies on fewer geometrical assumptions. LA volumes should be measured in both the four and two-chamber apical LA focused views at end-ventricular systole. The endocardial contour should be traced up to the connecting juxtaposed points of the mitral annulus, taking care to exclude the tenting area under the mitral valve leaflets as well as the confluence of the left atrial appendage and pulmonary veins.[4]

A few remarks are worth making in reference to the acquisition of 2D LA volumes. First, a dedicated "focused-view" should always be attempted because it provides larger volumes compared with the standard LV chamber acquisition in which usually the LV is elongated but the LA is foreshortened.[8] (Figures 2 and 3). Secondly, it is strongly advised to measure LA volume in both apical two and four chamber views since biplane volume showed better agreement with 3D volume than single plane and also because single-plane method can result in misclassification of patients when the ASE cutoffs are applied.[9] If the acquisition of both the four and two-chamber LA focused views are adequate, the length of the LA long-axis (distance between the midpoint of the mitral annulus plane to the base of the atrium) should be nearly identical avoiding LA foreshorting.[4] Importantly, while LA size is gender-dependent, this inter-gender difference is no longer present after adjusting for body size.[10] Therefore, only the indexed values of LA volumes should be reported.[4] Finally, recent data suggests that the cutoff values used to partition LA volumes should be based on outcomes instead of standard deviation (SD).[3,4] For instance, LA volumes are normally larger in elite athletes and this needs to be accounted for in order to avoid an incorrect diagnosis of LA enlargement in these patients.[9]

LA Volume Assessment on 3D Echocardiography

Three-dimensional echocardiography (3DE) has been shown to have superior prognostic ability and measurement accuracy compared to the 2D biplane Simpson's method.[4,11] This volumetric method has better correlation with cardiac magnetic resonance, the current gold standard to assess LA volumes.[12] This methodology should become the method of choice because it is completely independent of geometric assumptions.[4] 3D LA volumes obtained using semi-automated methods have demonstrated a reduction in intra- and interobserver variability.[8,13] A full volume acquisition acquired from an focused LA apical four chamber view, can be analyzed offline in less than 2 min, avoiding foreshortening by allowing the operator to manually select non-forshortened orthogonal planes and correct minor mistakes on the LA endocardial tracing border made by the software.[5,14] The accurate analysis of a 3D dataset is highly dependent on image quality, more so than analysis of a 2D dataset. Accordingly, during data acquisition, it is encouraged to decrease imaging depth and narrow the sector size so that only the LA is in view. In this

Keywords

Atrial Function; Echocardiography, Left Atrium; Strains; Three-Dimensional.

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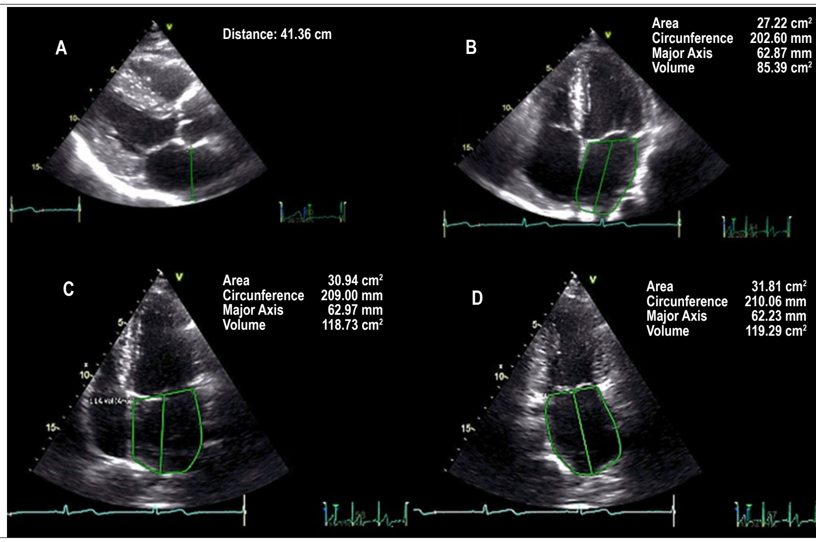

Figure 1 – *The left atrium is seen in the parasternal long-axis view (A), apical four chamber non-focused view (B) and LA focused four- (C) and two chamber views (D). When viewing the images side by side the underestimation of the antero-posterior diameter becomes apparent. The LA remodeling is constricted in the antero-posterior dimension because of the spine and sternum. The underestimation is greater when the LA is assessed in the LV focused view.*

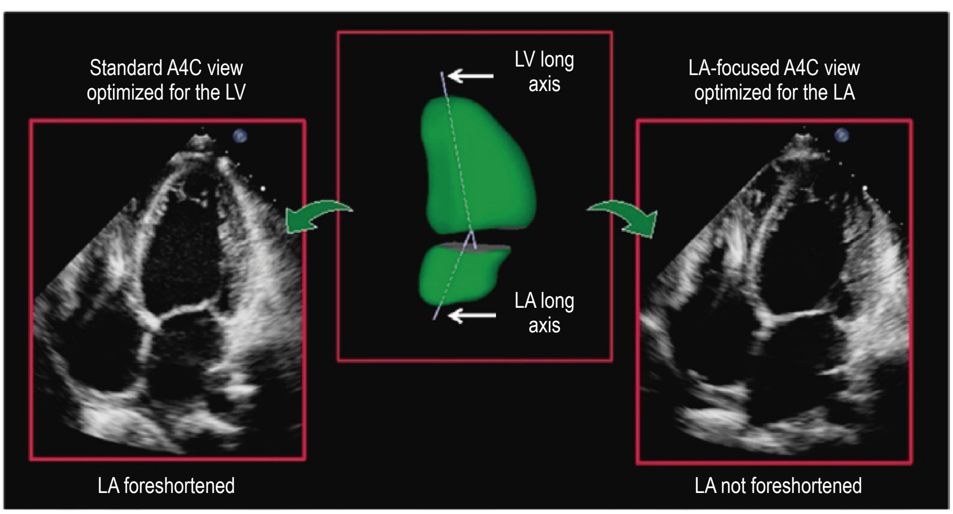

Figure 2 – *The left atrium must be acquired using dedicated focused two and four chamber views, instead of dedicated LV view, to avoid forshortening. The LA and LV longitudinal axis lie in different planes as is clearly illustrated in this image. In a focused view the base of LA should be at its largest dimension and the length maximized to ensure alignment along the true LA long axis.*

window part or most of the LV will also be visible. A multibeat (usually 4-beat) acquisition, will achieve better temporal resolution while maintaining high spatial resolution. This acquisition mode requires patient cooperation and breath-holding to avoid chest motion that can result in stitching artifacts with ultimately sub-volume misalignment. These may be avoided in part with ECG and respiratory gating.[4,14]

Previous studies have reported a variety of normal values for LA volumes often in-line with the population studied. The upper limit of 34ml/m² for 2D LA volume proposed by the 2015 ASE Chamber Quantification guidelines and used around the globe, was derived largely from white American and European subjects, despite the fact that it has been suggested that LA values are not universal and that population specific normal values should be used for different geographic groups.[4,5,15] For example, Badano et al[8] reported that in Italian subjects, 3D LA values greater than 43ml/m² should be considered abnormal. The NORRE study,[13] a multi-center study of predominantly white European subjects reported a similar value of 40ml/m². However, Wu et al.,[16] a Japanese cohort study, reported a much smaller value of 33ml/m². While, image optimization, such as the use of a dedicated LA focused view as opposed to the standard four-chamber view acquisition and the software package used

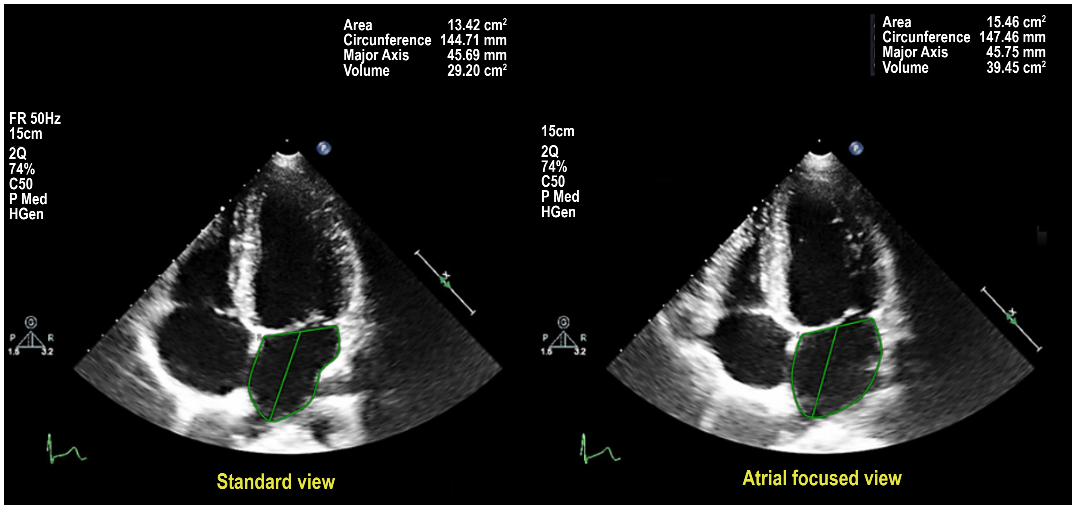

Figure 3 – *This image shows the discrepancy in LA volume measurements when using the standard view, optimized for the left ventricle and the dedicated atrial focused view. See text for additional explanation.*

(i.e. use of dedicated LV instead of LA-based software) can account for some of these differences, it is highly possible that the main reason for these discrepancies lies in differences that exist between ethnicities.[5] This hypothesis will soon be answered with the publication of the LA analysis by the World Alliance Societies of Echocardiography (WASE) Normal Values Study which includes approximately 2 000 subjects from 15 countries, including Brazil.

LA Phasic Function

Assessment of LA function provides valuable insight into the pathophysiology of numerous cardiovascular disorders. LA phasic function can be assessed using 2D echocardiography either using tissue Doppler velocities, or spectral Doppler combined with transmitral, pulmonary venous, and LA appendage flow. Lately, 2D deformation analysis of longitudinal LA strain and strain rate, using speckle-tracking (2D STE) has also been effectively used to determine LA phasic function.[1, 17, 18] Alternatively, LA phasic function may be derived from 3D LA volume vs. time curves, obtained from measurements of the largest (at LV end-systole, at the end of the T wave), minimal (at LV end-diastole, at the beginning of QRS) and pre-A (prior to atrial systole, before the P wave) volumes. These volumes will provide estimates of total (reservoir), passive (conduit) and active (booster) emptying LA volumes and fractions (Figure 4).[1, 14]

Of the two reference ECG landmarks (onset of QRS complex or P wave) that can be used for LA volume curves or deformation imaging, numerous authors recommend using the first because the majority of studies used to obtain normative values have used it.[18] In the case of deformation imaging, if the ventricular cycle is used, the zero reference will be LV end-diastole and the first phase of the curve will be represented by the peak positive longitudinal atrial strain corresponding to reservoir function, followed by the early diastolic strain wave representing the conduit phase and finally the late diastolic strain wave representing the booster pump function (Figure 5).[1, 17]

In addition to image quality, 2D STE is also dependent on a relatively high frame rate (50-70 frame/sec) for accurate tracking.[17] The far-field position of the LA in the acoustic window, mobility of the interatrial septum and thin LA walls constitute additional challenges for STE assessment.[19] Accordingly, at present this technique is challenging and heavily depends on the expertise of the operator.[1] The other key drawback rests in the lack of uniform normative values that currently appear to be dependent on the echocardiographic equipment used with their unique STE algorithms and software packages.[1, 13] The reproducibility are being address with efforts to reduce intervendor variability and standardize deformation imaging.[20] While there has been improvement between inter-vendor concordance of LV strain, less is known about atrial strain.[18, 20] Although a novelty today, 3D STE has a prospect of become a great asset in LA evaluation in the future (Figure 4).

Studies have shown that changes in LA phasic behavior occur early in disease processes and might provide early diagnostic clues compared to the assessment of LA size such as in diastolic dysfunction,[21] heart failure with preserved ejection fraction (HFpEF),[22] as well as new-onset of atrial fibrillation (AF),[23, 24] hypertension, diabetes,[25] amyloidosis and hypertrophic cardiomyopathy,[26] to cite a few. More importantly, it can predict outcome before or independently of volume augmentation in certain disorders, such as in acute myocardial infarction,[27] asymptomatic rheumatic mitral stenosis,[28] recurrence of AF after ablation and acute embolism in patients with paroxysmal or persistent AF.[23] Accordingly, question has been raised as to the helpfulness of LA functional assessment in guiding clinical decision-making in certain scenarios regarding rhythm vs rate control strategies, use of anticoagulation and others.[1]

Conclusion

In summary, echocardiography remains the imaging modality of choice for LA assessment due to its wide availability

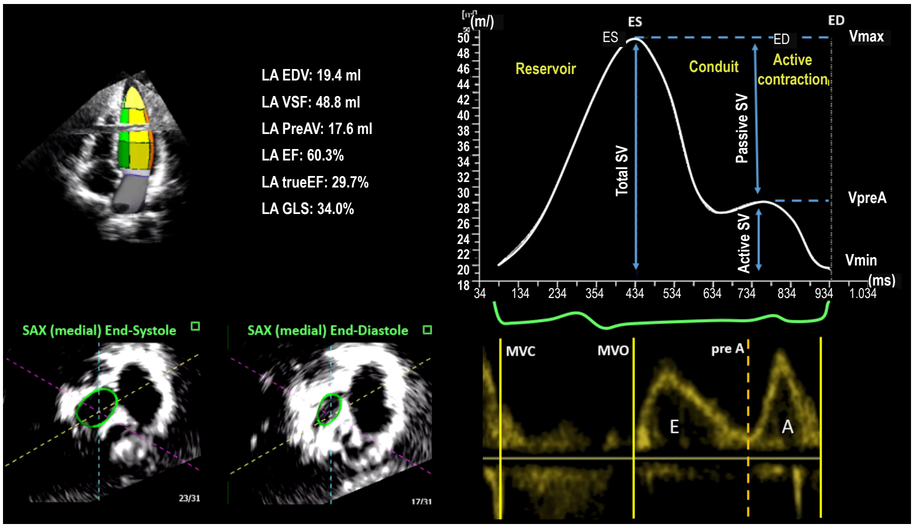

Figure 4 – *Function of the left atrium and its relationship with the cardiac cycle. When the mitral valve closes (MVC), at LV end-diastole (at the beginning of QRS), the LA is in its minimum volume (V min). In this phase (reservoir) the LA stores venous flow from the pulmonary veins and starts to increase in size until it reaches its maximum volume (V max), just before mitral valve opening (MVO) at the LV end-systole (at the end of the T wave). Thereafter, the conduit phase occurs wherein the LA passively transfers blood to the LV and the LA volume slightly decreases until it reaches the pre-contraction volume (V pre-A) (before the P wave), just prior to atrial systole. From these volumes the total atrial stroke volume (total SV =Vmax – Vmin), passive atrial stroke volume (passive SV = Vmax – Vpre-A), and active atrial stroke volume (active SV = Vmax – V pre-A) can be calculated. The ejection fractions (or emptying) can also be calculated: LA total emptying fraction (LA EF: Vmax – Vmin/V max), LA true emptying fraction (LA trueEF = V pre-A – Vmin/V pre-A) and LA passive emptying fraction (LA passive EF = Vmax – V pre-A/ V pre-A).*

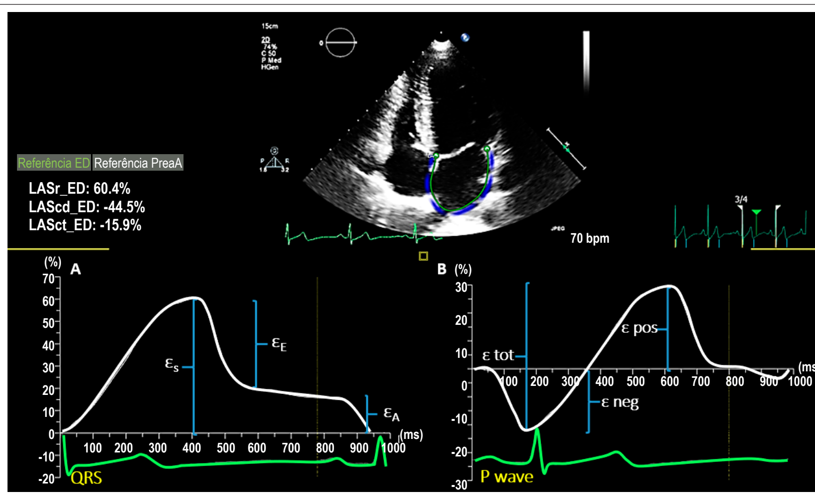

Figure 5 – *Measurement of LA phasic function with 2D speckle tracking using the QRS as a timing reference (A) versus the P wave (B). When the QRS is used as the reference point, the phasic curve starts with the peak positive longitudinal atrial strain (εs) corresponding to the reservoir function (LASr_ED), followed by the early diastolic strain waves (εe) representing the conduit phase (LAScd_ED) and finally the late diastolic strain wave (εa) expressing the booster pump function (LASct_ED). In contrast, when using the P wave, the first negative peak strain (εneg) expresses the booster pump function, followed by the positive peak strain (εpos) and later the total longitudinal strain (εtot) representing the conduit and reservoir functions, respectively.*

and cost-effectiveness. Although the biplane Simpson technique is currently recommended for the assessment of LA size, newer echocardiographic techniques such as 2D STE and 3DE volumes will soon assume a protagonist role in LA analysis due to their ability to measure LA size and phasic function more accurately and reproducibly providing risk stratification and evaluation of therapeutics.

Conflict of Interests

Dr Lang received a research grant from Phillips Healthcare (Phillips Imaging Systems) outside the submitted work.

Authors' contributions

CCS, KA, and RML drafted and revised the article.

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