Volumetric Assessment is More Precise than Diameter for Determining Left Ventricular Size

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Abstract

The assessment of left ventricular size is a fundamental component of echocardiography. This is typically performed by measuring the end-diastolic diameter of the left ventricle in the parasternal long-axis image. There are published norms for end-diastolic diameter, as well as thresholds that correspond with mild, moderate and severe left ventricular enlargement. Despite the reliance on end-diastolic diameter to determine left ventricular size, end-diastolic diameter does not always accurately reflect the left ventricular end-diastolic volume. This is especially the case in remodeled ventricles associated with aortic or mitral insufficiency. As left ventricular volumes continue to become easier to obtain, with improved accuracy and reproducibility, when will they become the primary echocardiographic technique for assessing left ventricular size?

Introduction

The accurate assessment of left ventricular size is a fundamental component of echocardiography. The primary technique is left ventricular end-diastolic diameter (LVEDD) measured in the parasternal long-axis image. While LVEDD correlates with left ventricular end-diastolic volume (LVEDV), this relationship is not linear and is undermined by very large confidence intervals (1). A LVEDD of 6 cm is shown to correlate with a predicted LVEDV, as assessed by biplane, of 216 ml, but with a 95% confidence interval range of 149-313 ml (1). This range corresponds with normal left ventricular size at 149 ml to a severely enlarged left ventricle at 313 ml, according to the 2015 American Society of Echocardiography (ASE) Guidelines on chamber size (2). Thus, it is not surprising that the large confidence intervals associated with LVEDD can result in clinically significant left ventricular size misinterpretation.

The gold standard for left ventricular volumetric assessment is typically considered to be cardiac magnetic resonance imaging (MRI) (3). The LVEDV and left ventricular end-systolic volume (LVESV) calculated with cardiac MRI correlate very strongly with mitral and aortic regurgitant volume calculated with MRI techniques (4). Conversely, LVEDD and left ventricular end-systolic diameter (LVESD) correlate less strongly with mitral and aortic regurgitant volume (4).

Echocardiography has been shown to significantly underestimate both LVEDV and LVESV compared to MRI regardless of whether the biplane method or 3D echocardiography is utilized (5). 3D echocardiography underestimates LVEDV by 19.1 ml and LVESV by 10.1 ml, while the biplane method underestimates LVEDV by 48.2 ml and LVESV by 27.7 ml. The difference between the biplane method and 3D echocardiography is also statistically significant, with smaller LVEDV and LVESV values reported for the biplane method (5).

The most recent ASE Guidelines on chamber size suggest reporting LV volumes, with preference given to 3D echocardiography (2). Supplemental table 3 in these Guidelines provides categorical ranges for biplane LVEDV, LVESV, and LVEDD. While the biplane method may significantly underestimate LVEDV derived by MRI, it provides an accurate estimate of size than LVEDD does (1).

While echocardiographically derived volumes have been shown to be more accurate than diameter, left ventricular diameter measurements are still focused on in the timing of surgery for mitral and aortic insufficiency (1,6). In accordance with the 2017 ACC/AHA Guidelines surgery should be considered when the left ventricular end-systolic diameter (LVESD) is [?] 4 cm in severe mitral insufficiency and in severe aortic insufficiency surgery should be considered with a LVESD [?] 5 cm or a LVEDD [?] 6.5 cm (6).

Clinical Case – Aortic Insufficiency

A seventy-seven year old male presented to cardiology after an echocardiogram, ordered for heart murmur, revealed significant aortic insufficiency. Aortic insufficiency was graded as moderate-severe. LVEDD was measured at 5.7 cm (figure 1a), which is the upper limit of normal for LVEDD (2). It is important to note that this patient's body surface area was 1.8 m^2, with a height of 66 inches and a weight of 152 pounds. His LVESD was measured at 4 cm (figure 1b), which is nowhere near the guideline threshold for surgery in severe aortic insufficiency (6).

A cardiac MRI was ordered to objectively quantify his aortic insufficiency and assess left ventricular size. Aortic insufficiency was determined to be severe, with a regurgitant volume of 86 ml and regurgitant fraction of 58%. LVEDV was 286 ml with an LVEDV index of 161 ml/m^2, consistent with moderate left ventricular enlargement.

We reviewed the initial echocardiogram. No 3-dimensional imaging was performed. 2-dimensional images were of good quality and allowed for biplane assessment to be performed off-line (video 1 and 2). His biplane LVEDV was 264 ml, which corresponded well with the 286 ml calculated on MRI. His LVEDV index by biplane assessment was 147 ml/m^2, which also corresponded well with the LVEDV index of 161 ml/m^2 calculated on MRI. The biplane calculations are consistent with a severely enlarged left ventricle, which is much larger than would be predicted by his LVEDD of 5.7 cm. LVEDD indexed yields a value of 3.2 cm/m^2, which would be consistent with mild left ventricular enlargement. Incorporating left ventricular volumes into his echocardiographic findings would have better defined his left ventricular size and provided similar findings to those reported on cardiac MRI.

Clinical Case – Mitral Insufficiency

A forty-one year old male presented to cardiology in follow-up of mitral valve prolapse with mitral insufficiency. He had not seen a cardiologist for almost a decade, but was recently diagnosed with hypertension and was referred to cardiology to follow-up on this, as well as his mitral valve disease. Echocardiography demonstrated severe mitral valve insufficiency with bi-leaflet prolapse. His LVEDD was 5.5 cm (figure 2a) and his left ventricle was reported as being normal size. His left ventricular ejection fraction was visually estimated to be 55%. Interestingly, his LVESD was 4 cm, which just meets the ACC/AHA criteria for LVESD in the setting of severe mitral insufficiency (figure 2b). A cardiac MRI also demonstrated bi-leaflet mitral valve prolapse, with severe mitral insufficiency, with a regurgitant volume of 108 ml and a regurgitant fraction of 58%. LVEDV was 288 ml, with a LVEDV index of 157 ml/m^2, consistent with moderate left ventricular enlargement. His calculated ejection fraction was 65%.

His transthoracic echocardiogram was reviewed. There was no 3-dimensional imaging performed. Image quality was good (video 3 and 4) and biplane assessment was performed off-line. His biplane LVEDV was 170 ml, which significantly underestimated the 288 ml calculated on MRI. His LVEDV index was 94 ml/m^2 also significantly underestimated the LVEDV index of 157 ml/m^2 calculated on MRI. Despite both of these variables underestimating his MRI results, his biplane LVEDV was consistent with a mildly enlarged left ventricle, and his LVEDV index was consistent with a moderately enlarged left ventricle. This is in contrast to the finding of normal left ventricular size by LVEDD measurement and the borderline-mildly enlarged LVEDD indexed. The addition of biplane assessment for this patient would have identified his left ventricular enlargement, and also provided an objective ejection fraction that in retrospect proved to correlate well with cardiac MRI.

Discussion

Our two cases exemplify scenarios where the echocardiographically derived LVEDD measurement inaccurately categorized left ventricular size as essentially normal compared to the significantly enlarged LVEDV calculated on cardiac MRI. This is not surprising given the wide margin of error associated with LVEDD measurements for predicting LVEDV, and particularly in the setting of left ventricular remodeling where the basal parasternal long-axis measurement does not reflect global left ventricular dimension and volumes (1, 7).

Significant aortic insufficiency is associated with large increases in preload, as well as increased afterload. Reflective of this relationship, there is a strong linear correlation between LVEDV and aortic regurgitant volume (4). Conversely, the correlation between LVEDD and aortic regurgitant volume is only moderate (4). Thus, the pathophysiologic relationship between aortic insufficiency and left ventricular size is better evaluated by LVEDV.

Significant mitral insufficiency is also associated with large increases in preload. The correlation between LVEDV and mitral regurgitant volume is quite strong (4). Unfortunately, it seems less established if LVEDD has this same strong relationship with mitral regurgitant volume.

In the valvular heart guidelines LVESD is used as a trigger for surgical intervention in severe mitral insufficiency (6). This is despite the fact that the relationship between LVESD and mitral regurgitant volume is weak (4). Conversely, the relationship between LVESV and mitral regurgitant volume is moderate (4). A cardiac MRI study on left ventricular remodeling in mitral insufficiency found spherical remodeling in the mid and apical segments that was better assessed by LVESV than LVESD (7). Thus, it seems that LVESV may be a better clinical indicator for the timing of mitral valve surgery than LVESD. Unfortunately, there is currently no data to support LVESV in a surgical timing role for valvular heart disease.

Cardiac MRI is an excellent tool for assessing left ventricular size (5). Echo volumes underestimate MRI, but they still provide a more accurate assessment of left ventricular size than LVEDD (1,5). There is no denying that LVEDD is an easy measurement to quickly perform, and is a standard component of the echo report, but volumetric assessment continues to become quicker, easier, more reproducible, and correlates with MRI (5, 8-10). The more recent 3D volume software programs automatically identify diastolic and systolic borders with excellent accuracy (8). The entire time to perform this analysis takes an average of 26 seconds (8). And while biplane volumes underestimate cardiac MRI and 3D echocardiography, and take longer, with an average of 1.5 minutes to perform, their objective assessment is worth the minimal time addition when 3D echocardiography is unavailable (5, 10).

There are currently no guideline recommendations regarding surgical timing in mitral or aortic insufficiency that utilize left ventricular volumes in the decision-making process. The use of LVEDD in the guidelines results in some patients with significant left ventricular enlargement being misclassified as having a normal size left ventricular (demonstrated in our two clinical cases), and conversely some patients with a normal left ventricular size likely get misclassified as having left ventricular enlargement. Despite no role in the current valve guidelines, left ventricular volumes likely better identify remodeled left ventricles than LVEDD. The left ventricular enlargement identified by MRI, and retrospectively by biplanes, for our two cases changed the clinical course for each of these patients.

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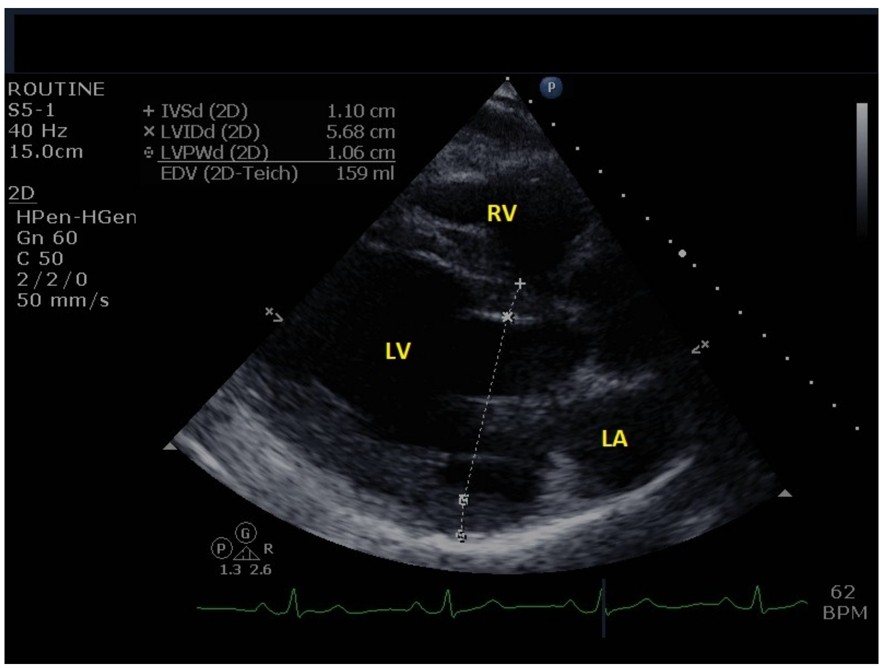

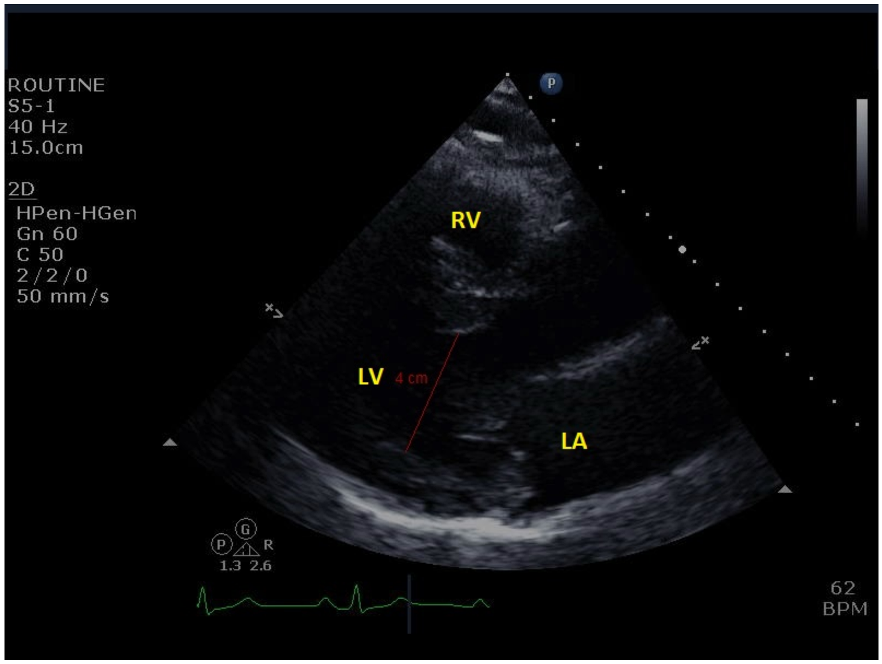
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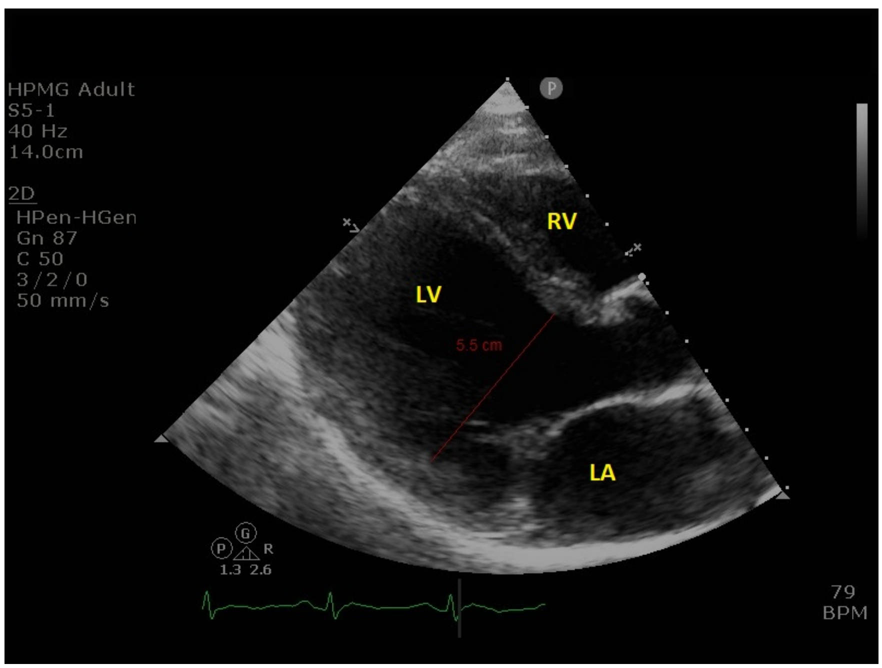
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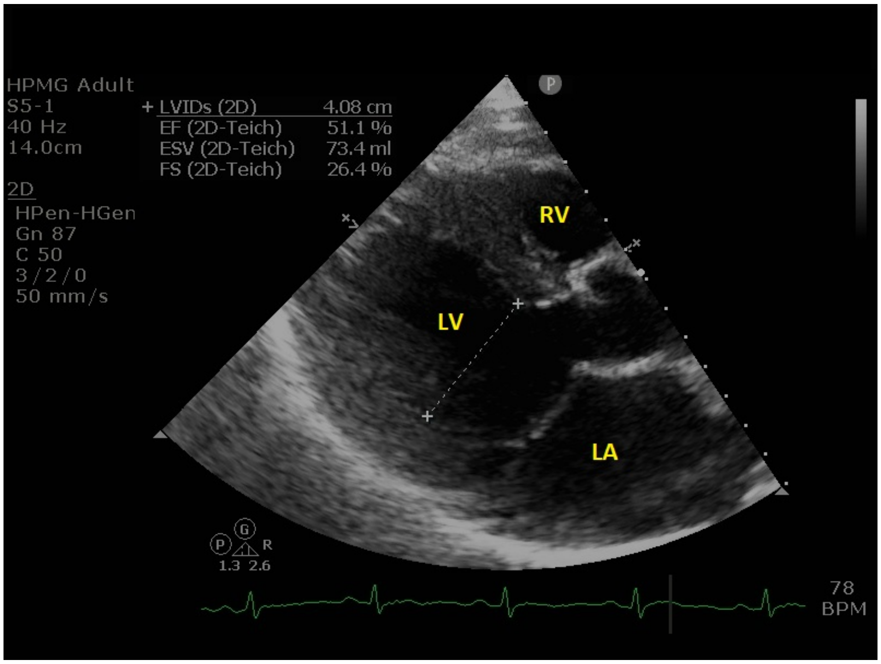

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