Use of echocardiographic subxiphoid five-sixth area length (bullet) method in evaluation of adequacy of borderline left ventricle in hypoplastic left heart complex

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ABSTRACT

Indexed left ventricular end-diastolic volume (ILVEDV) is commonly used in evaluating "borderline left ventricle (LV)" in hypoplastic left heart complex (HLHC) to determine if the LV can sustain adequate systemic cardiac output. Commonly used quantification methods include biplane Simpson or the traditional five-sixth area length "bullet" methods, which have been shown to underestimate true LV volumes, when septal position is mildly abnormal. Subxiphoid five-sixth area length method is proposed as a more accurate estimate of true LV volume in the evaluation of borderline LV.

Keywords: Echocardiography, hypoplastic left heart syndrome, left ventricle

INTRODUCTION

Hypoplastic left heart complex (HLHC) describes a wide spectrum of small left heart structures. Patients with severe hypoplasia of left heart structures are managed with univentricular repair (UVR), while those with mild hypoplasia of left heart structures undergo some form of biventricular repair (BVR). Patients in the "gray zone", with so-called "borderline left ventricle (LV)", present a dilemma forcing a dichotomized management decision of UVR versus BVR early in life. The inappropriate pursuit of BVR in borderline LV has been shown to be more consequential than is inappropriate pursuit of UVR,[1] emphasizing the importance of an accurate predictive model of borderline LV.

Existing criteria to evaluate borderline LV in HLHC do not reliably identify neonates who will thrive with a BVR,[2] with many criteria based on studies of infants with critical aortic stenosis.[3,4] Echocardiography is the main diagnostic tool used to predict the adequacy of the LV in supporting systemic circulation. Established criteria used in deciding the adequacy of the LV to sustain BVR include morphometric and functional parameters, hemodynamic data, available surgical options, along with results of institutional experience.[5] Indexed left ventricular end-diastolic volume (ILVEDV) is commonly used in this decision-making process, with many studies quoting an ILVEDV less than 20 mL/m^2 predicting poor survival with BVR.[6-8] LVEDV is commonly calculated using the biplane Simpson or traditional five-sixth area length "bullet" methods, using apical and parasternal views.[9] These methods in patients with HLHC tend to underestimate true LV volumes as the volume-loaded RV may compress the under-filled LV.[10] Subxiphoid "bullet" method has been validated against cardiac magnetic resonance imaging (CMR), showing excellent reproducibility and agreement with established normal values in pediatric patients aged 0-3 years.[11,12] We describe a case of borderline LV who underwent successful BVR, for whom preoperative echocardiographic LV volumes estimation by the traditional biplane Simpson and standard "bullet" methods showed prohibitive size, but had significantly improved estimation by both subxiphoid "bullet" method and CMR, with the latter methods having close agreement.

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CASE REPORT

The patient is a full-term newborn with suspicion of congenital heart disease on a technically limited late gestation fetal echocardiogram. Initial transthoracic

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echocardiogram showed a left sided aortic arch with aberrant right subclavian artery, hypoplastic transverse aortic arch (4 mm, Z-score: –4.4), and discrete coarctation of the aortic isthmus (2 mm). There were mildly hypoplastic unobstructed mitral and bicuspid aortic valves (8 mm, Z-score: –2 and 4.6 mm, Z-score: –4.1, respectively). The LV was moderately hypoplastic and not apex forming, with LV-to-RV long axis ratio of 0.8:1. There was no evidence of endocardial fibroelastosis. LV assessment by Simpson's biplane method showed an ILVEDV of 13 mL/m^2. Traditional "bullet" method showed an ILVEDV of 21 mL/m^2. Retrospectively, subxiphoid "bullet" method showed an ILVEDV of 30 mL/m^2 [Figure 1].

The patient subsequently underwent CMR to better define the borderline LV. Again seen was a significant discrepancy between the LV-to-RV long axis dimension, with a ratio 0.7:1. However, the ILVEDV measured normal at 32 mL/m^2 (Z-score: –1.1) [Table 1]. CMR LVEDV was reassuring, given the prior underestimation of LVEDV on echocardiogram, and with the available data and clinical picture, it was decided to pursue BVR. The patient underwent aortic arch reconstruction with a homograft patch. Postoperatively, the left ventricle showed evidence of diastolic dysfunction (which subsequently improved) and the LV was adept to handle the systemic circulation.

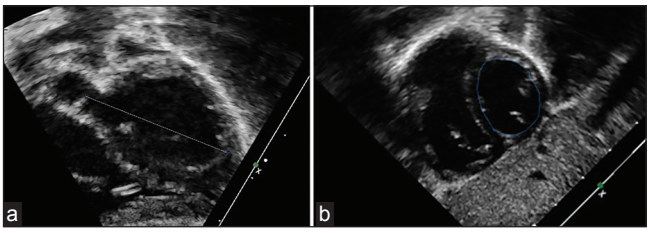

Figure 1: Subxiphoid five-sixth area length echocardiographic assessment of left ventricular (LV) volume. (a) Subxiphoid long axis diastolic frame with aortic annulus to LV apex measurement. (b) Subxiphoid short axis diastolic frame at the midventricular level with area measurement

Table 1: Comparison of Indexed LVEDV

	CMR	Subxiphoid fifth-sixth area length	Traditional fifth-sixth area length	Biplane Simpson
Indexed LVEDV (mL/m^2)	32	30	21	13

LVDEV: Left ventricular end-diastolic volume, CMR: Cardiac magnetic resonance imaging

DISCUSSION

Accurate assessment of infants with borderline LV is crucial in determining the optimal management strategy. Echocardiography derived ILVEDV is commonly used to aid in decision-making in these infants.[6-8] While standard echocardiographic assessment of LV volume in our patient raised questions about its ability to sustain systemic output with BVR, the subxiphoid "bullet" method and CMR demonstrated much improved estimation of LV size.

A study by Grosse-Wortmann *et al.*,[10] showed that echocardiography consistently and significantly underestimated LVEDV and correlated poorly with CMR. If they had made decisions based off of standard echocardiographic LVEDV assessment, more than half of their patients who had successfully undergone BVR would have undergone UVR. They also evaluated the concept of observed versus potential preoperative volumes in the setting of volume-loaded RV, which was introduced by Phoon and Silverman,[13] calculating an average potential volume increase of 23% in their borderline LV patients with HLHC.[10]

The subxiphoid "bullet" method of estimating LVEDV may have advantages in the setting of mildly abnormal ventricular septal position or limited parasternal acoustic windows.[12] The subxiphoid window tends to have better definition of the LV endocardial border. The ability to estimate the true LV length is much better by the subxiphoid "bullet" method, especially in the setting of a large right ventricle wrapping the LV apex. Moreover, because of the saddle shape of the mitral valve, Nielsen *et al.*,[11] proposed and validated that the use of apex-to-LV outflow length, yielded a larger LVEDV than the apex to mitral valve measurement used in the traditional "bullet" method. Our patient's ILVEDV by subxiphoid "bullet" method not only was larger and more reassuring than traditional methods, it also correlated better with CMR.

In conclusion, the subxiphoid "bullet" method may be more accurate in assessing true LV volumes than other more commonly used echocardiographic methods, especially in the setting of HLHC with borderline LV. Even so, if discrepant or borderline measurements are obtained by echocardiographic assessment, CMR should be obtained to help determine the best treatment pathway.

REFERENCES

1. Hickey EJ, Caldarone CA, Blackstone EH, Lofland GK, Yeh T Jr, Pizarro C, *et al.* Congenital Heart Surgeons' Society. Critical left ventricular outflow tract obstruction: The disproportionate impact of biventricular repair in borderline cases. J Thorac Cardiovasc Surg 2007;134:1429-36.
2. Tani LY, Minich LL, Pagotto LT, Shaddy RE, McGough EC, Hawkins JA. Left heart hypoplasia and neonatal aortic arch obstruction: Is the Rhodes left ventricular adequacy score applicable? J Thorac Cardiovasc Surg 1999;118:81-6.
3. Rhodes LA, Colan SD, Perry SB, Jonas RA, Sanders SP. Predictors of survival in neonates with critical aortic stenosis. Circulation 1991;84:2325-35.

4. Colan SD, McElhinney DB, Crawford EC, Keane JF, Lock JE. Validation and re-evaluation of a discriminant model predicting anatomic suitability for biventricular repair in neonates with aortic stenosis. J Am Coll Cardiol 2006;47:1858-65.
5. Corno AF. Borderline left ventricle. Eur J Cardiothorac Surg 2005;27:67-73.
6. Leung MP, McKay R, Smith A, Anderson RH, Arnold R. Critical aortic stenosis in early infancy: Anatomic and echocardiographic substrates of successful open valvotomy. J Thorac Cardiovasc Surg 1991;101:526-35.
7. Schwartz ML, Gauvreau K, Geva T. Predictors of outcome of biventricular repair in infants with multiple left heart obstructive lesions. Circulation 2001;104:682-7.
8. Serraf A, Piot JD, Bonnet N, Lacour-Gayet F, Touchot A, Bruniaux J, *et al*. Biventricular repair approach in ducto-dependent neonates with hypoplastic but morphologically normal left ventricle. J Am Coll Cardiol 1999;33:827-34.
9. Lopez L, Colan SD, Frommelt PC, Ensing GJ, Kendall K, Younoszai AK, *et al*. Recommendations for quantification methods during the performance of a pediatric echocardiogram: A report from the Pediatric Measurements Writing Group of the American Society of Echocardiography Pediatric and Congenital Heart Disease Council. J Am Soc Echocardiogr 2010;23:465-95.
10. Grosse-Wortmann L, Yun TJ, Al-Radi O, Kim S, Nii M, Lee KJ, *et al*. Borderline hypoplasia of the left ventricle in neonates: Insights for decision-making from functional assessment with magnetic resonance imaging. J Thorac Cardiovasc Surg 2008;136:1429-36.
11. Nielsen JC, Lytrivi ID, Ko HH, Yau J, Bhatla P, Parness IA, *et al*. The accuracy of echocardiographic assessment of left ventricular size in children by the 5/6 area x length (bullet) method. Echocardiography 2010;27:691-5.
12. Lytrivi ID, Bhatla P, Ko H, Yau J, Geiger MK, Walsh R, *et al*. Normal values for left ventricular volume in infants and young children by echocardiographic subxiphoid five-sixth area by length (bullet) method. J Am Soc Echocardiogr 2011;24:214-8.
13. Phoon CK, Silverman NH. Conditions with right ventricular pressure and volume overload, and a small left ventricle: "Hypoplastic" left ventricle or simply a squashed ventricle? J Am Coll Cardiol 1997;30:1547-53.

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