Normal Values for Left Ventricular Volume in Infants and Young Children by the Echocardiographic Subxiphoid Five-Sixth Area by Length (Bullet) Method

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Background: Left ventricular (LV) end-diastolic volume (LVEDV) can be estimated by the formula (5/6) × area × length, or the "bullet" method. The aim of this study was to determine the range of normal LVEDV values in infants and young children (aged 0–3 years) by the subxiphoid bullet method.

Methods: Echocardiograms from 100 normal subjects aged ≤3 years were retrospectively analyzed. Subjects with systemic disease, abnormal body size, cardiovascular disease, or nondiagnostic subxiphoid images were excluded. Measurements of LV short-axis cross-sectional diastolic area at the midventricular level and LV length were made offline from subxiphoid images. LVEDV was indexed to body surface area (BSA) to the powers of 1.0 and 1.38. Relationships between indexing methods, age, and gender were explored.

Results: The median age was 0.98 years (range, 0–2.9 years), the median weight was 9.5 kg (range, 3.1–16.0 kg), and the median BSA was 0.45 m^2 (range, 0.21–0.66 m^2). The mean LVEDV/$BSA^{1.38}$ was 70.4 ± 9.1 mL/$m^{2.6}$, with an excellent correlation between LVEDV and $BSA^{1.38}$ (r = 0.96, P < .01). There was no residual relationship between LVEDV/$BSA^{1.38}$ and BSA (r = 0.06, P = NS) and no significant relationship between LVEDV/$BSA^{1.38}$ and age (r = 0.10, P = NS) or LVEDV/$BSA^{1.38}$ and gender.

Conclusions: The normal range for LVEDV by the subxiphoid echocardiographic bullet method is reported for newborns, infants, and young children. LVEDV should be indexed to $BSA^{1.38}$, which is consistent with the known relationship between LV size and body size. In children aged ≤3 years, these data can be used to calculate *Z* scores for LVEDV by the subxiphoid bullet technique independent of age or gender. (J Am Soc Echocardiogr 2011;24:214-8.)

Keywords: Left ventricular size, Infants, Children, Echocardiography

Left ventricular (LV) size (and its serial assessment) is frequently used in infants and young children with heart disease as a surrogate marker of the magnitude of left-to-right shunt lesions (e.g., ventricular septal defect, patent ductus arteriosus) to establish indications for closure[1,2] or as one important index of the severity or chronicity of dilated cardiomyopathy.[3] Quantitative methods, including LV end-diastolic dimension, Simpson's method of disks, area × length, three-dimensional LV end-diastolic volume (LVEDV), and the "bullet" method ([5/6] × area × length) have been used to estimate LV size.[4,5] In a specific patient, one method may have advantages over another on the basis of age, available acoustic windows, ease of use, and preference of a given echocardiography laboratory. The subxiphoid bullet method of LVEDV estimation may have advantages over LV end-diastolic dimension in the setting of mildly abnormal ventricular septal position or limited parasternal acoustic windows. Traditionally, the bullet LV size is derived from apical and parasternal views to yield a volume.[4] In children aged ≤3 years, we have found that orthogonal views using the subxiphoid window have advantages over the conventional technique and have validated this method against cardiac magnetic resonance imaging, showing excellent reproducibility and agreement.[6] In the present study, we sought to establish normal values for LVEDV by the subxiphoid bullet method and examined the relationship of LVEDV to body size, gender, and age to confirm a valid indexing method. The findings provide data for simple calculation of *Z* scores for LVEDV in young children.

METHODS

Echocardiograms obtained from January 2007 to March 2010 in consecutive, healthy subjects aged ≤3 years were retrospectively reviewed. Subjects with systemic disease, abnormal body size (height or weight >2 or <2 standard deviations from the mean), cardiovascular disease, or nondiagnostic subxiphoid images were excluded.

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Abbreviations

BSA = Body surface area

COV = Coefficient of variability

CI = Confidence interval

LV = Left ventricular

LVEDV = Left ventricular end-diastolic volume

Candidate subjects were collected until the totals in each age group were 50 for those aged <1 year and 25 each for those aged 1 to 2 and 2 to 3 years. Indications for echocardiography were cardiac murmur, abnormal electrocardiographic results, or follow-up of patent foramen ovale or small atrial septal defect diagnosed in the newborn period. The presence of a patent ductus arteriosus in the first 3 days of life or a small patent foramen ovale was considered normal. Because our laboratory routinely uses chloral hydrate sedation between the ages of 1 month and 3 years, the majority of the studied echocardiograms were performed under sedation. For the subxiphoid bullet calculation, short-axis views were carefully obtained capturing 3 to 5 beats at the midventricular level; modified long-axis views were obtained with careful transducer rotation to define a plane that bisected the aortic annulus and the true LV apex to interrogate the longest LV length (Figure 1A). The aortic annulus was chosen to capture maximum LV length as the saddle shape of the mitral valve brings its annulus and thus the LV cavity up to this level. Imaging data were analyzed by a single observer (J.C.N.) by offline measurement of the largest diastolic short-axis cross-sectional areas and LV lengths from the aortic annulus to the LV apex. Bullet LVEDV was calculated as (5/6) × (cross-sectional midventricular short-axis area) × (LV length). Body surface area (BSA) calculated by the Haycock method,[7] the reason for referral, and demographic data were obtained from echocardiographic reports and chart review. LVEDV was indexed to BSA to both the 1.0 (linear) and 1.38 (nonlinear)[8] powers and then regressed against BSA to examine which method had the least residual relation to BSA. Indexed LVEDV was assessed by gender and age group (<1, 1–2, and 2–3 years).

For comparison, LV length measurements were also attempted from the apical window in the 100 subjects, and the measurements were compared with the LV lengths obtained from the subxiphoid window. LV lengths were measured from both the four-chamber view (mitral valve annulus to LV apex) and the five-chamber view (aortic annulus to LV apex). Subjects with poor apical images, poor endocardial border visualization, or LV foreshortening due to technical limitations, were excluded.

Interobserver error of the bullet LVEDV method was assessed by calculating the coefficient of variability (COV) for two observers (J.Y. and H.H.K.) in 15 separate, consecutive subjects aged ≤3 years. This group consisted of subjects with normal echocardiographic results as well as those with LV dilation to mirror routine clinical practice. The COV is the standard deviation divided by the mean for each pair of measurements. Intraobserver error was assessed by calculating the COV for repeat measurements in the same 15 subjects by one observer (H.H.K.). Additionally, intraobserver errors for cross-sectional area and LV length were separately calculated and compared.

Permission to review and analyze medical data was granted by the institutional review board. All data are presented as mean ± SD or median (range). Ninety-five percent confidence intervals (CIs) were calculated as applicable. The relationship between LVEDV, BSA, age, and indexing methods was analyzed by Pearson's correlation coefficient. Student's t test was used to examine mean differences between gender groups and between different length measurement techniques.

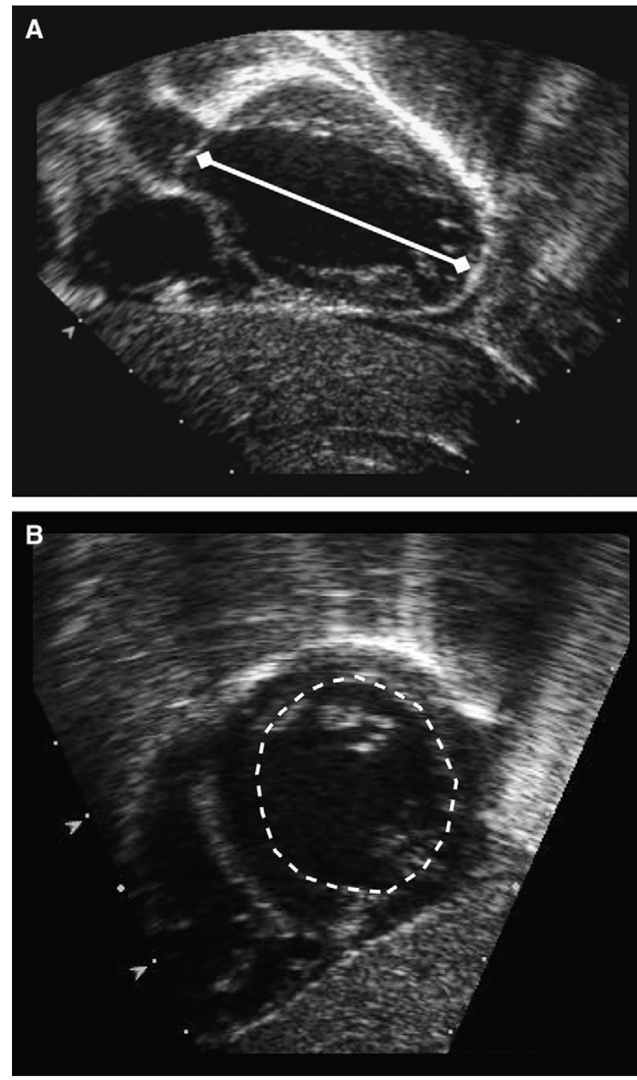

Figure 1 **(A)** Standard subxiphoid long-axis view diastolic frame profiling the LV apex and aortic annular plane. Note that the imaging plane is adjusted slightly by the imager to accurately profile the true diastolic long-axis of the left ventricle. The line is the length used in the subxiphoid bullet calculation (see text). **(B)** Orthogonal short-axis diastolic frame at the midventricular level with the cross-sectional planimetered area in dashed white.

RESULTS

Thirteen subjects were excluded because of inadequate subxiphoid images for measurement. Of the remaining 100 subjects, there were 47 female subjects (mean age, 1.17 years; median age, 1.11 years) and 53 male subjects (mean age, 0.91 years; median age, 0.70 years). For the entire group, the median age was 0.98 years (range, 0–2.9 years), the median weight was 9.5 kg (range, 3.1–16.0 kg), and the median BSA was 0.45 m^2 (range, 0.21–0.66 m^2). The mean LVEDV/$BSA^{1.38}$ was 70.4 ± 9.1 mL/$m^{2.6}$ (95% CI, 68.6–72.2 mL/$m^{2.6}$), with an excellent correlation between LVEDV and $BSA^{1.38}$ ($r = 0.96$, $P < .01$; Figure 2). When LVEDV was indexed to BSA alone ($BSA^{1.0}$, linear), there was a significant residual relationship between LVEDV/BSA and BSA ($r = 0.74$, $P < .01$;