Echocardiographic Measurements of Cardiac Structures and Systolic Function in Healthy Nepalese Neonates

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ABSTRACT

Background

Echocardiography is being used routinely to evaluate neonates with suspected heart disease. To detect changes in the structure and function, in heart diseases, it is important to precisely ascertain the normal growth and development on echocardiographic parameters of chamber size, thickness, and function based on local evidence. However, locally established reference values for Nepalese neonates are limited.

Objective

To establish reference echocardiographic measurements of cardiac structures and systolic function in healthy Nepalese neonates.

Method

This prospective observational study included 559 normal neonates ranging from 2 to 7 days of life using 2D and M-mode echocardiography over the period of 18 months, from September 1st 2018 to February 28th 2020. The echocardiographic measurements of the following structures were reviewed (1) LV end-diastolic,end-systolic diameters, interventricular wall thickness, LV posterior wall thickness, Aorta (systolic) and Left atrium (diastolic) using M-mode imaging; (2) the mitral valve annulus evaluated in the apical four-chamber view and parasternal long-axis view and the tricuspid valve annulus evaluated in the apical four chamber view; (3) diameters of pulmonary annulus, main pulmonary artery, and branch pulmonary arteries measured in the parasternal short-axis view; (4) diameters of the aortic annulus evaluated in the parasternal long-axis view.

Result

A total of 559 neonates were included in the study, comprising 287 (51.3%) males and 272 (48.7%) females. The mean gestational age was 38.03 ± 1.76 weeks, and the mean birth weight was 2.90 ± 0.67 kg. Echocardiographic assessment demonstrated a mean mitral valve annulus diameter of 11.39 ± 1.70 mm and a mean tricuspid valve annulus diameter of 13.97 ± 1.88 mm. The mean aortic root diameter was 7.85 ± 1.21 mm, while the mean left atrial diameter was 11.61 ± 1.99 mm. The mean pulmonary valve annulus diameter and main pulmonary artery diameter were 8.34 ± 1.15 mm and 7.98 ± 1.10 mm, respectively. The mean left ventricular internal dimension was 17.11 ± 2.39 mm in diastole and 10.54 ± 1.66 mm in systole.

Conclusion

This study establishes echocardiographic reference values for healthy neonates in a tertiary care center in Nepal. These locally derived reference values may support accurate interpretation of neonatal echocardiography in routine clinical practice.

KEY WORDS

Echocardiography, Infant, Measurement, Neonates, Term births

INTRODUCTION

Echocardiography is a non-invasive imaging method that evaluates the structural components of the heart without radiation exposure.[1] It is routinely used in neonates with suspected cardiac disease to assess chamber dimensions, wall thicknesses, and ventricular function, enabling early detection of structural and functional abnormalities that impact clinical management.[2] Accurate interpretation of echocardiographic measurements requires well-defined normative reference values that reflect expected growth-related changes in cardiac dimensions to differentiate normal developmental variation from pathology.[3] 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 or as one important index of the severity or chronicity of dilated cardiomyopathy.[4,5]

However, most existing reference data are derived from limited populations or single centers, and normative information for healthy term newborns in South Asian settings, including Nepal, remains low. There is a need for region-specific echocardiographic reference values to improve the accuracy of neonatal cardiac assessment in local clinical practice. The clinical application of echocardiography in our institution has been very helpful in the differential diagnosis of newborns presenting in cardiorespiratory distress and/or cyanosis, rapidly separating those neonates with normal hearts from those with cardiac malformations. Therefore, this study aims to establish normative echocardiographic measurements for healthy term newborns in Nepal.

METHODS

This study was an observational cross-sectional study. Healthy normal newborns born at Dhulikhel Hospital with normal hearts both in function and structure were enrolled as the study population, in the post-natal ward of Dhulikhel Hospital, Dhulikhel, Nepal, from September 1st, 2018, to February 29th, 2020, a total period of 18 months.

Normal echocardiographic values were derived noninvasively in normal neonates aged 2 to 7 days of life using 2-D and M-mode echocardiography. The GE Vivid 7 Ultrasound Machine was used with a 7S Phased Array transducer with a Bandwidth of 3.5-8 MHz for recording echocardiographic measurements. The examinations were performed under an infant warmer with a servo controller set to maintain the subject's normal skin temperature. All the examinations were performed without sedation with the subject in a supine position during normal respirations. All the examinations and echocardiography were performed by a single examiner (Principal Investigator). Ethical approval for the study was obtained from the Institutional Review Committee of Kathmandu University School of Medical Sciences (IRC-KUSMS-39/16) before the study was initiated.

Written and verbal consent was taken from the parents after delivery of the newborn in the morning post-natal ward rounds by the examiner (research worker). The research involved healthy term infants born at Dhulikhel Hospital who were assessed within their first week of life. Eligible infants were hemodynamically stable, needed little to no respiratory assistance, and were managed without ionotropic support. Only those infants with structurally normal hearts, as indicated by echocardiography, were included; a hemodynamically insignificant patent ductus arteriosus or patent foramen ovale measuring less than 2 mm was deemed acceptable. Infants born outside the study facility, those who were hemodynamically unstable or required significant respiratory support (such as continuous positive airway pressure or mechanical ventilation) or ionotropic agents, and those with abnormal results from clinical examinations, cardiac auscultations, pulse oximetry, electrocardiography, chest radiography, or echocardiography were not included.

Echocardiographic measurements were systematically reviewed for the following cardiac structures: left ventricular (LV) end-diastolic and end-systolic diameters, interventricular septal thickness, LV posterior wall thickness, aortic root diameter (systolic), and left atrial diameter (diastolic) using M-mode imaging. The mitral valve annulus was assessed in both the apical four-chamber and parasternal long-axis views, while the tricuspid valve annulus was evaluated in the apical four-chamber view. Diameters of the pulmonary annulus, main pulmonary artery, and branch pulmonary arteries were measured in the parasternal short-axis view, and the aortic annulus was measured in the parasternal long-axis view. All detailed information of the enrolled newborn and their echocardiographic values were recorded. Additionally, infants whose parents opted out of consent for participation in echocardiographic study were also excluded. In this study, 559 healthy term newborns born at Dhulikhel Hospital were enrolled by convenience sampling technique. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) software version 27.0. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Reference values were generated using descriptive statistics and percentile distributions. The results are presented as normative echocardiographic measurements for healthy Nepalese neonates.

RESULTS

A total of 559 healthy neonates were enrolled in the study. Of these, 287 (51.3%) were male, and 272 (48.7%) were female, as shown in table 1. The mean gestational age was 38.03 ± 1.76 weeks, and the mean birth weight was 2.90 ± 0.67 kg. Echocardiographic assessment demonstrated a mean mitral valve annulus diameter of 11.39 ± 1.70 mm and a mean tricuspid valve annulus diameter of 13.97 ± 1.88 mm. The mean aortic root diameter was 7.85 ± 1.21 mm, while the mean left atrial diameter was 11.61 ± 1.99 mm. The mean pulmonary valve annulus diameter was 8.34 ± 1.15 mm, and the mean main pulmonary artery diameter was 7.98 ± 1.10 mm. The mean left ventricular internal dimension in diastole (LVEDD) was 17.11 ± 2.39 mm, whereas the mean left ventricular internal dimension in systole (LVESD) was 10.54 ± 1.66 mm. The mean interventricular septal thickness was 3.13 ± 1.04 mm during diastole and 5.19 ± 1.39 mm during systole.

Table 1. Gender Distribution of Neonates

Gender	Count (%)
Male	287 (51.3)
Female	272 (48.7)
Total	**559**

Table 2. Reference Echocardiographic Measurements of Nepalese Neonates in Dhulikhel Hospital.

Variable	Mean	Std. Dev.	Min.	Max.
Age (Day)	3.407871	2.962431	2	7
Birth weight (kg)	2.890246	0.6653107	1.35	4.9
Length (cm)	48.9225	3.405744	30	57
BSA	0.1867125	0.052003	0	0.2749545
MV (A4C)	1.139565	0.1703094	0.6	1.9
TV (A4C)	1.3969	0.1876919	0.9	2
Ao (D)	0.7851229	0.1211984	0.4	1.1
LA (S)	1.161909	0.1992646	0.6	1.8
LA/Ao	1.496125	0.2572044	0.89	2.58
PA annulus	0.8344612	0.115022	0.5	1.3
MPA	0.7983365	0.1111999	0.5	1.2
RPA	0.3507372	0.0735235	0.2	0.6
LPA	0.44	0.07	0.3	0.7
Ao annulus (PLX)	0.6646503	0.0833594	0.5	1
MV (PLX)	1.232476	0.171092	0.9	1.8
IVSd	0.3135917	0.103576	0.1	0.8
IVSs	0.5199244	0.1394361	0.2	1
LVIDd	1.711399	0.2395552	1.1	2.4
LVIDs	1.053686	0.1661468	0.6	1.6
LVPWd	0.2510019	0.0696361	0.1	0.5
LVPWs	0.4220416	0.0934867	0.2	0.8
EF	71.80497	5.203486	50	91
FS	38.29626	4.302556	24	59

Assessment of left ventricular systolic function demonstrated a mean ejection fraction of 71.80 ± 5.20% and a mean fractional shortening of 38.29 ± 4.30%. Other echocardiographic reference values are shown in table 2.

Echocardiographic measurements according to gestational age have been listed in table 3. Percentile distributions for all measured cardiac structures and systolic function parameters were generated to establish reference values for healthy Nepalese neonates.

Table 3. Echocardiography summary table by gestational age

Variable	< 37 wks	38 wks	39 wks	40 wks	41 wks	> 42 wks
Mitral valve (A4C view)	1.08 ± 0.15	1.15 ± 0.16	1.18 ± 0.20	1.18 ± 0.17	1.16 ± 0.15	1.17 ± 0.19
Tricuspid Valve (A4C view)	1.29 ± 0.17	1.40 ± 0.17	1.45 ± 0.20	1.44 ± 0.19	1.42 ± 0.17	1.53 ± 0.21
Aorta (D)	0.75 ± 0.13	0.80 ± 0.13	0.79 ± 0.10	0.81 ± 0.12	0.75 ± 0.12	0.83 ± 0.08
Left Atrium (S)	1.08 ± 0.18	1.17 ± 0.19	1.23 ± 0.21	1.16 ± 0.20	1.18 ± 0.19	1.37 ± 0.08
Ratio of Left Atrium and Aorta	1.47 ± 0.23	1.48 ± 0.25	1.57 ± 0.29	1.45 ± 0.24	1.57 ± 0.25	1.67 ± 0.26
Pulmonary Artery annulus	0.78 ± 0.10	0.83 ± 0.11	0.87 ± 0.11	0.86 ± 0.14	0.87 ± 0.11	0.92 ± 0.08
Main Pulmonary Artery	0.75 ± 0.09	0.79 ± 0.11	0.84 ± 0.12	0.84 ± 0.13	0.83 ± 0.10	0.85 ± 0.08
Right Pulmonary Artery	0.33 ± 0.06	0.34 ± 0.07	0.37 ± 0.08	0.36 ± 0.08	0.35 ± 0.05	0.38 ± 0.08
Left Pulmonary Artery	0.42 ± 0.08	0.45 ± 0.08	0.47 ± 0.08	0.46 ± 0.08	0.46 ± 0.07	0.48 ± 0.08
Aortic Annulus (Parasternal Long-Axis View)	0.64 ± 0.07	0.67 ± 0.08	0.67 ± 0.08	0.69 ± 0.10	0.69 ± 0.09	0.67 ± 0.08
Mitral Valve annulus (Parasternal Long-Axis View)	1.16 ± 0.17	1.23 ± 0.17	1.29 ± 0.17	1.26 ± 0.17	1.27 ± 0.17	1.33 ± 0.15
Interventricular Septal Thickness in Diastole	0.27 ± 0.10	0.32 ± 0.10	0.33 ± 0.10	0.32 ± 0.10	0.30 ± 0.12	0.40 ± 0.21
Interventricular Septal Thickness in Systole	0.47 ± 0.13	0.54 ± 0.16	0.52 ± 0.14	0.54 ± 0.13	0.47 ± 0.14	0.62 ± 0.15
Left Ventricular Internal Diameter in Diastole	1.59 ± 0.22	1.73 ± 0.23	1.78 ± 0.22	1.76 ± 0.24	1.71 ± 0.24	1.77 ± 0.29
Left Ventricular Internal Diameter in Systole	0.98 ± 0.14	1.05 ± 0.16	1.09 ± 0.17	1.09 ± 0.17	1.04 ± 0.16	1.07 ± 0.15
Left Ventricular Posterior Wall thickness in Diastole	0.23 ± 0.07	0.25 ± 0.07	0.25 ± 0.07	0.27 ± 0.08	0.24 ± 0.07	0.28 ± 0.08
Left Ventricular Posterior Wall thickness in Systole	0.38 ± 0.09	0.42 ± 0.09	0.43 ± 0.09	0.44 ± 0.11	0.42 ± 0.09	0.47 ± 0.05
Ejection Fraction	71.84± 4.98	72.78 ±5.66	71.88 ± 5.22	71.65 ±5.33	72.44 ± 3.87	73.33 ± 3.67
Fractional Shortening	38.17 ± 4.18	39.18 ±4.97	38.44 ± 4.27	38.23 ±4.22	38.83 ± 3.17	39.33 ± 3.44

DISCUSSIONS

This study establishes reference echocardiographic measurements of cardiac structures and systolic function in 559 healthy Nepalese neonates during the first week of life. Given the scarcity of population-specific neonatal echocardiographic reference data from Nepal, these findings provide an important foundation for interpreting neonatal echocardiograms in routine clinical practice.

The demographic characteristics of our cohort were comparable to those reported by Singh et al. in a cohort of 142 healthy Indian term neonates, whose mean birth weight was 2.89 ± 0.39 kg compared with 2.90 ± 0.67 kg in our study.[6] The similarity in anthropometric characteristics allows meaningful comparison of echocardiographic measurements between the two South Asian populations.[6]

The mean mitral annular diameter in our cohort was 11.39 ± 1.70 mm, while the mean tricuspid annular diameter was 13.97 ± 1.88 mm. These findings are consistent with the observations of Singh et al. who demonstrated comparable atrioventricular valve dimensions in healthy Indian neonates.[6] The larger tricuspid annular dimension compared with the mitral annulus observed in our study is physiologically expected and reflects right ventricular dominance during the transitional neonatal circulation. Similar findings have been reported in an Indian neonatal echocardiographic study.[6] Also, the mean tricuspid valve annulus diameter in our study was 13.97 ± 1.88 mm, which is similar to a study by Bulbul et al.[7]

The mean aortic root diameter in our cohort was 7.85 ± 1.21 mm. This measurement is broadly comparable to values reported by Güzeltaş et al. in their study of 250 healthy Turkish newborns, although slight differences were observed.[8] Such variations may be explained by differences in body weight distribution, ethnicity, and timing of echocardiographic examination after birth.[8] Similarly, the mean left atrial dimension of 11.61 ± 1.99 mm was comparable to values reported in both Turkish and Indian neonatal populations. These findings suggest that left atrial dimensions are relatively conserved across geographically distinct neonatal populations when adjusted for body size.[6,8]

The mean pulmonary annular diameter (8.34 ± 1.15 mm) and main pulmonary artery diameter (7.98 ± 1.10 mm) observed in our study were also within the ranges reported by Singh et al. in term-Indian neonates.[6] This finding supports the applicability of South Asian normative data for evaluating right ventricular outflow tract structures.[6] Also, Imai et al. documented larger pulmonary valves and trunks relative to systemic structures and a smaller aortic isthmus in early life.[9] Our data corroborate these patterns and provide updated reference values for the aortic isthmus and arch, which may aid early detection of coarctation or hypoplasia.

The mean left ventricular internal dimension in diastole (17.11 ± 2.39 mm) and systole (10.54 ± 1.66 mm) observed in our cohort were comparable to those reported in previous neonatal reference studies. Güzeltaş et al. similarly demonstrated a strong positive correlation between body weight and left ventricular dimensions among healthy newborns.[8] The interventricular septal thickness measured 3.13 ± 1.04 mm in diastole and 5.19 ± 1.39 mm in systole. These values fall within the normal ranges reported in international neonatal echocardiographic literature.[8] One study found that the interventricular septum (IVS) and left ventricular posterior wall were thicker than the anterior right ventricular wall by about 0.7 mm and that the pulmonary artery (PA) was consistently larger than the aortic root.[10] The similarity of septal dimensions across studies suggests that myocardial wall thickness is relatively consistent among healthy term neonates despite ethnic and geographic differences.[8]

Assessment of systolic function demonstrated preserved left ventricular performance, with a mean ejection fraction of 71.80 ± 5.20% and a mean fractional shortening of 38.29 ± 4.30%. These values closely resemble those reported by Güzeltaş et al., who found that ejection fraction and fractional shortening remained stable across different birth-weight categories and were not significantly influenced by sex.[8] Our study showed a mean ejection fraction of 71.8%, which is higher than the 54.6% reported by Bulbul et al.[7] This means that the difference in mean ejection fraction between our study 71.8% and the 54.6% reported by Bulbul et al. may be due to differences in the study populations and their clinical characteristics.[8] Variations in the methods used to assess ejection fraction may also have contributed to the difference. Factors such as age, underlying cardiac conditions, and differences in echocardiographic assessment can influence the measured ejection fraction. Therefore, the higher mean ejection fraction observed in our study may reflect differences in participant characteristics and assessment methods rather than a direct disagreement between the two studies.

Another study from Romania showed ejection fraction of 68.73% which closely matches with our neonatal population.[11] Doni et al. described stable stroke volumes and cardiac indices in early infancy which also aligns with our study.[12]

Our findings support the concept that locally derived reference values may improve the accuracy of neonatal echocardiographic interpretation. The use of Nepal-specific normative data may reduce the risk of misclassification when evaluating chamber dimensions, valve annuli, and ventricular function in clinical practice.

This study has several limitations. First, it was conducted at a single tertiary-care center and may not fully represent all ethnic and geographic populations within Nepal.

Second, measurements were reported as absolute values rather than body surface area-adjusted Z-scores. Finally, interobserver and intraobserver variability analyses were not performed. Future multicenter studies involving larger neonatal populations from different regions of Nepal are warranted to develop comprehensive Nepalese echocardiographic nomograms and Z-score equations. Such reference standards would further improve diagnostic precision and facilitate comparison with international neonatal echocardiographic databases.

CONCLUSION

This study establishes normative echocardiographic measurements of cardiac structures and systolic function in a large cohort of healthy Nepalese neonates during the first week of life. The observed cardiac dimensions and functional parameters were generally comparable to those reported in international neonatal populations, while providing locally relevant reference values for clinical practice.

These findings may help clinicians interpret neonatal echocardiograms more accurately, recognize cardiac abnormalities at an early stage, and rely less on international reference values that may not accurately represent the local neonatal population.Further multicenter studies incorporating larger and more diverse neonatal populations are warranted to develop Nepal-specific echocardiographic nomograms and Z-score equations.

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