Left Ventricular Strain in Neonates using 2-dimensional speckle tracking: Normal range and relation with bi-plan Ejection fraction.

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Abstract

Objectives: Echocardiographic assessment of Left ventricular systolic function is traditionally being performed by estimation of fractional shortening and Ejection fraction. Speckle tracking echocardiography (STE) is a promising tool for assessment of myocardial function. The aim of this study is to evaluate the global longitudinal strain (GLS) using 2D-STE in healthy neonates to establish normal reference ranges. **Method:** it is a retrospective study through an analysis of transthoracic echocardiogram of normal healthy neonates. We enrolled all neonates in our institution from 1 st January 2021 to 28 th February 2021. 2-D STE was used to assess left ventricular global longitudinal strain from the apical views. **Results:** 185 neonates were enrolled. Mean value for left ventricle GLS (%) was -19.9 $\pm$ 1.2, GLS-derived ejection fraction (%) was 60.0 $\pm$ 2.7; while the left ventricle ejection fraction by biplane Simpson's method (%) was 61.0 $\pm$ 3. There is a good positive correlation between the Left Ventricle EF by biplane Simpson's method and EF by 2-D STE, which was statistically significant ($r = 0.294$, $n = 102$, p=0.003). Apical 4-chamber longitudinal strain and strain derived EF is significantly correlated with GLS and bi-plan EF respectively. **Conclusion:** 2-STE is feasible technique for analyzing newborn myocardial systolic function. The normal range of GLS in neonates is not much different than reported for the pediatric. There is a good positive correlation between the Left Ventricle EF by 2-D STE and EF by biplane method.

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All data of this study are available on Xcelera R3.3 cardiology PACS system at Prince Sultan Cardiac Center, Riyadh, KSA

Abstract:

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Method: it is a retrospective study through an analysis of transthoracic echocardiogram of normal healthy neonates. We enrolled all neonates in our institution from 1st January 2021 to 28th February 2021. 2-D STE was used to assess left ventricular global longitudinal strain from the apical views.

Results: 185 neonates were enrolled. Mean value for left ventricle GLS (%) was -19.9 ± 1.2, GLS-derived ejection fraction (%) was 60.0 ± 2.7; while the left ventricle ejection fraction by biplane Simpson's method (%) was 61.0 ± 3. There is a good positive correlation between the Left Ventricle EF by biplane Simpson's method and EF by 2-D STE, which was statistically significant (r = 0.294, n = 102, p =0.003). Apical 4-chamber longitudinal strain and strain derived EF is significantly correlated with GLS and bi-plan EF respectively.

Conclusion:

2-STE is feasible technique for analyzing newborn myocardial systolic function. The normal range of GLS in neonates is not much different than reported for the pediatric. There is a good positive correlation between the Left Ventricle EF by 2-D STE and EF by biplane method.

Key words: Infant myocardial strain, global longitudinal function, left ventricular function, echocardiography

1 Introduction:

With advancement in technology, echocardiographic evaluation of cardiac function is rapidly changing, and newer promising techniques are being identified. The traditional tools for assessment of left ventricular function are fractional shortening (FS) and ejection fraction (EF).

Fractional shortening (FS) includes assessment of maximum dimensional changes of the left ventricular cavity in diastole and systole in relation to the end diastolic dimension. Normal values for FS in infants and pediatrics has been established and are typically between 28-46%[1, 2]

Ejection fraction, on the other hand, is calculated via assessing volumetric changes of the left ventricular cavity between diastole and systole in relation to end diastolic volume.

Both modalities (FS and EF) encounter several challenges related to assumption of left ventricular geometry. Both are pressure dependent, and they are not accurate in estimating LV function in case of myocardial regional dyskinesia and in case of paradoxical motion of the interventricular septum. Moreover, FS and EF mainly assess circumferential fiber shortening and did not consider the longitudinal motion of the LV.

Myocardial strain is a relatively new echocardiographic tool using speckle tracking echocardiography (STE). It has been successfully used in adult population to evaluate the regional and global systolic function of the left ventricle. This technique consists of frame-by-frame tracking of the ultrasound signals of the myocardial speckles. Strain is a dimensionless parameter representing the deformation of an object, in relation to its original shape. It is expressed as percent change from the original dimension.

$Strain\ (s) = \frac{L1-L0}{L0}$

Where S is the longitudinal strain, L1 is the length at a given point of time, and L0 is the baseline length.

Adapting this ultrasound tool in pediatrics and particularly in neonates faces many problems including small heart size and fast heart rate. Nevertheless, some studies have been performed in pediatrics and showed relatively good reproducibility and feasibility. This is mainly due to the fact that the investigation could be adjusted at higher frame rate and the independency of the STE from the angle of incidence in contrast to tissue Doppler derived signals which have shown to be angle dependent. [(3)]

Another advantage of STE is the ability to assess longitudinal motion of the left ventricle, in contrast to fractional shortening and ejection fraction which assess only the circumferential fiber shortening and radial thickening. This is particularly important, as some cardiac lesions are known to affect longitudinal motion of the left ventricle before it progress to global systolic dysfunction [(4, 5)] Therefore, it is important to establish a diagnostic tool to assess longitudinal function of the LV to detect early signs of functional impairment. The utility of STE in assessing the left ventricular longitudinal motion was studied in adult and pediatric population, however, only few studies with small patient number have documented the utility of speckle tracking echocardiography in assessment of myocardial longitudinal strain in neonates. [(6, 7, 8)] The aim of our study is to evaluate 2-DTE longitudinal strain of the left ventricle in neonates, to establish the reference values for our population and to compare the global longitudinal strain-derived EF to the commonly used tools for assessment of left ventricular systolic function (FS and EF).

2: Method:

2. 1: Study design:

We conducted a retrospective study through analysis of the offline measurements obtained from 2D transthoracic echocardiographic images of normal healthy neonates. We enrolled all neonates from the post -natal ward in Prince Sultan Military Medical city (PSMMC) in Riyadh who were referred to pediatric cardiology service for evaluation over the period from 1st January 2021 to 28thFebruary 2021.

2. 2: Study population:

A total of 185 neonates were eligible for study enrollment during this period. Subjects were eligible for inclusion if they were born term (37-42 weeks), birth weight above 2.2 kg, normal vital signs and 12-leads ECG for age and normal cardiac structure on echocardiography examination except for hemodynamically insignificant small patent ductus arteriosus or small atrial septal defect /patent foramen ovalle. Exclusion criteria are neonates with significant structural heart lesions or abnormal cardiac rhythm on 12-leads ECG. Seventeen babies were excluded due to presence of significant congenital heart lesion and three babies were excluded due to abnormal electrical cardiac rhythm. (Figure 1). Another 63 patients were excluded due to suboptimal echocardiographic image quality i.e. ECG not connected during the study or missing of any of the required apical views: apical 4-chamber view, apical 3 chamber view and apical 2 chamber view.

Demographic data for the participants were documented and complete transthoracic echocardiography study was done for each of them.

2. 3: Echocardiography:

Transthoracic echocardiographic study was performed for the neonates using IE 33 platform scanner (Philips Medical ultrasound systems, Washington, USA). Matrix-array transducer (S12) and (S8) were used for the 2D, M Mode and Doppler study. The studies were performed without sedation with babies asleep or suckling on bottle of milk.

Studies included recording of apical four chamber, three chamber and two chamber 2D views for quantification of global longitudinal strain and calculating ejection fraction. M-mode was used in parasternal short axis views for calculating fractional shortening. Images were stored in digital format for off-line analysis. The echocardiograms were downloaded to Xcelera R3.3 Cardiology PACS system (Philips Medical ultrasound systems, Washington, USA) and were analyzed and reported offline.

2.3.1: Speckle tracking strain imaging:

Speckle tracking strain analysis was used to assess left ventricular longitudinal strain. We performed the offline analysis using 2-D images from apical four chamber, three chamber and two chamber views to quantify the global longitudinal strain (GLS) using the Xcelera Q-Lab software. Images were selected to find clear myocardial border with frame rate between 100-140 fps. The echo contrast for the selected images was adjusted and manual tracing of the endocardial border at end diastole was performed to set the region of interest (ROI). The operator identifies and selects the hinge points of the mitral valve annulus and LV apex. The software allows a semi-automated detection of the LV borders. The system allows manual adjustment of the endocardial and epicardial surfaces.

Initially a 3-chamber view is selected; the first step is to select a point just below the aortic valve, then lateral hinge point of the mitral valve annulus and lastly the LV apex. The ROI is then automatically analyzed by the software and divided into six segments as well as the Aortic valve closure time for further analysis. The process is followed for the apical 4-chamber view with 3 points selections at the hinge points of the MV annulus and LV apex. In the 4-ch view, the six segments represent the basal, mid and apical segments of the left ventricular lateral wall and inter ventricular septum. Similar steps were applied to obtain speckle tracking of apical two chamber views.

Data from speckle tracking were displayed in longitudinal time-strain curves for each of the six segments and segmental peak strain was obtained from each curve. The peak longitudinal strain was defined as the most negative strain value at any time point during cardiac cycle. The mean strain of the of six segments were calculated to yield the strain value of that specific view. Aortic valve closure time and GLS is obtained in the apical 3-chamber view while GLS and EF are displayed numbers from the 4-chamber and 3-chamber views. The software then calculates the cumulative GLS as the average longitudinal strain value for the readings obtained from all the three views; and is displayed as bull eye pattern with 16 segment distributions.[12,13] (Figure 2)

2.3.2: Ejection fraction:

Left ventricular ejection fraction was calculated from apical four and two chamber views using biplane disc summation method (Modified Simpsons method) by tracing the endocardial border manually at end-diastole and end-systole (planimetry). Ejection fraction was calculated using the following formula:

$$\mathrm{EF} = \frac{EDV - ESV}{\mathrm{EDV}} \quad X \quad 100$$

Where EDV represent left ventricular end-diastolic volume, ESV represents left ventricular end-systolic volume

2.3.3: M-mode:

$$FS\ \% = \frac{EDD - ESD}{\mathrm{EDD}} \quad X \quad 100$$

3. Statistical Analysis:

The data was analyzed using SPSS software version—- . Descriptive analysis was used to summarize data. Continuous variables were expressed as means ± standard deviation with their minimum and maximum values. Categorical variables were presented as counts and percentages. Comparison between groups was performed by independent Students T-test for continuous data or Pearson's chi-square test for categorical data.

4. Results:

The study population comprised of 102 neonates; mean age 1.5±0.8 days (Min:1 day, Max:5 days), 65 (63.7%) were age 1 day old at time of echo and 59 (57.8%) neonates were males. Atrial septal defect vs. patent foramen ovale were found in 67 neonates (65.7%) (Table 1).

Averaged GLS (%) was -19.9 ± 1.2 while GLS-derived ejection fraction (%) was 60.0 ± 2.7(Table 2).

Fractional shortening (%) was 34± 3. EF using Biplane Simpsons method (%) 61.0 ± 3,

A Pearson correlation was used to determine the relationship between LV EF by biplane Simpson's method and Left Ventricle EF by strain. There is a small positive correlation between the LV EF by biplane and LV EF by strain which was statistically significant (r = 0.294, n = 102, p =0.003). On the other hand, there is a small negative correlation between the FS and LV EF by strain which shows inconclusive evidence about the significance of the association between the variables (r = -0.142, n = 102, p =0.). Apical 4-chamber strain and 4-chamber strain-derived EF was significantly correlated with GLS and GLS-derived EF (r = 0.756 , n =102, p<0.001) and (r = 0.735 , n = 102, p<0.001.) respectively . Additionally, there is weak but statistically significant correlation between 4-ch strain-derived EF and biplane Simpson EF (r = 0.204 , n = 102, p=0.039) (Table 3). Comparison of demographic data and echo variables showed no significant difference between male and female (Table 4). By using linear regression analysis, there was a small positive correlation between average EF by biplane method and EF by strain, which was statistically significant (R^2 = 0.087, p =0.003) (Figure 3)

5. Discussion:

The deformation imaging using speckle tracking echocardiography is used as tool of assessment of the LV function in the diagnosis and management of several cardiopulmonary diseases in children. The ASE and EACVI guidelines consider STE derived GLS as feasible and reproducible for routine clinical use.

The normal reference range of values for 2DSTE-derived LV LS in pediatric and adult population has been described by many authors· The reference range of values for 2DSTE and 3DSTE derived LV LS, in neonatal age has been reported in few studies and that with limited enrollment. [13] This study establishes reference ranges of values of LV global LS in a cohort of 102 normal full-term neonates.

This is a retrospective study, and we enrolled all neonates with transthoracic echocardiograms during the period of study. These were all routine 2-d echocardiographic studies and some of them did not have all the three apical views in particular the 2-chamber view which is sometimes technically demanding. Therefore, we had to drop many studies from inclusion. We performed the M-Mode analysis to get FS and EF and also the EF by bi-plan Simpson's method to make sure that all the enrolled population have normal function by conventional methods, so that our 2DSTE analysis would truly indicate a dependable reference for normal neonates.

Our study revealed fractional shortening that ranges between 27 and 42 % (mean 34± 3) which is correlated well with several studies performed in neonates. Similarly, Biplane Simpson method-derived ejection fraction was ranging between 55 and 73% (mean 61± 3).

The volume-based measurements of left ventricular function are different from direct measurement of myocardial motion by myocardial deformation (strain) using speckle tracking echocardiography. Our study revealed myocardial global longitudinal strain in normal healthy neonates ranging from -13.5 to -22.9 % (mean -19.9- ± 1.2), (Table 3). These values are correlated well with the values presented by Jashari et al, in their meta-analysis for normal ranges of left ventricular strain in children and neonates when they found normal values between –12.9 and 26.5% (mean -20.5%).[9,14]

Most of the studies reported longitudinal strain, an extremely sensitive sign of deteriorating LV systolic function especially in neonates with aortic valve stenosis, aortic coarctation or hypertrophic obstructive cardiomyopathy. Therefore, establishing normal values and routine performance of myocardial longitudinal strain is crucial on those patients to predict the early signs of myocardial dysfunction.[9, 15]

Our study shows that 2D-STE analysis is feasible in neonatal period. We observed a positive correlation between Biplane Simpson method-derived ejection fraction and myocardial strain-derived ejection fraction in healthy neonates (Table 3). This may suggest potential advantage of using myocardial strain-derived EF over the volumetric-based EF which is load dependent as well as geometry-dependent compared to myocardial strain.

Performing GLS for the left ventricle necessitate assessment of LV myocardial strain in all the three views for the LV; 4-ch, 3-ch and 2 chambers views which is felt by some practitioners to be time consuming process. Despite all the advantages of the technique for performing LV myocardial strain assessment, we modeled to evaluate whether apical 4-chambers view alone could be a reasonable reflector for the LV global longitudinal strain. We observed a statistically significant correlation between 4-ch longitudinal strain and the cumulative GLS for the left ventricle, (Table 3)

Moreover, 4ch 2DSTE derived EF was significantly correlated with GLS-derived EF as well as the EF calculated by biplane Simpson method. These observations of the 2DSTE apical 4-chambers values may suggest the usefulness of 4 chamber view alone to be a good reflector for the GLS instead of performing all the three views for the left ventricle (in patients with missing 3 chamber or 2 chamber apical views). This would make it possible to get the quantification of LV longitudinal strain from the apical 4 chamber view alone and then to follow that very patient with the same parameters to detect any change in myocardial function. It is easy to perform, and post-processing time has decreased with the newer automated systems.

6. Limitations:

Our study is a single-center experience. Although our study of left ventricular GLS has the largest of the published neonatal cohort, still the limited number of participants would have been acceptable.

We analyzed the apical views only to assess Global Longitudinal Strain. Assessing left ventricular circumferential and radial strain would add more information to the understanding the LV strain.

7. Ethical Standard:

An ethical approval for this study was approved from ethical approval committee in PSCC research department. All authors had no conflict of interest. This research did not receive any funds.

8. Conclusion:

Speckle tracking echocardiography is feasible technique for analyzing newborn myocardial systolic function. This study revealed the mean reference value for GLS -19.9 ± 1.2 and strain-derived EF 60 ± 2.7.Apical 4-chamber 2DSTE derived values for LV -LS and LV-EF may be used as a reasonable representative of the GLS and EF. Further prospective studies that include larger number of patients is needed to evaluate this novel modality and to compare the reference ranges to pediatric and adult population. follow up for those newborns is needed to evaluate the changes of myocardial strain as they grow up.

Authors contributions: Dr. K. Alnahili performed data collection and acquisition. Dr. S. Ahmad conceived the idea of the project and designed the final revision of the manuscript. Dr. N. Al raja assigned for data analysis and interpretation. Dr. E. Ahmed and Dr. I. Saleem contributed in writing and editing the manuscript.

References:

(1) Gutgesell HP, Paquet M, Duff DF, McNamara DG: Evaluation of left ventricular size and function by echocardiography. Results in normal children. *Circulation* (1977) 56:457–62. Doi: Doi: 10.1161/01.CIR.56.3.457

(2) , L.I.H. Overbeek, L. Kapusta: New reference values for echocardiographic dimensions of healthy Dutch children*European Journal of Echocardiography* , Volume 7, Issue 2, March 2006, Pages 113 121, https://doi.org/10.1016/j.euje.2005.03.01

(3) Matsui H, Germanakis I, Kulinskaya E, Gardiner HM: Temporal and spatial performance of vector velocity imaging in the human fetal heart. Ultrasound Obstet Gynecol 2011 ;37 :150–7.

(4) Marcus KA, de Korte CL, Feuth T, et al: Abnormal two-dimensional strain echocardiography findings in children with congenital valvar aortic stenosis. *Ultraschall Med* 2012 ;33 : E283–292.

(5) Marcus KA, de Korte CL, Feuth T, et al: Persistent reduction in left ventricular strain using two-dimensional speckletracking echocardiography after balloon valvuloplasty in children with congenital valvular aortic stenosis. *J Am Soc Echocardiogr* 2012; 25:473–485.

(6) C Bussadori, A Moreo, M Di Donato: A new 2D-based method for myocardial velocity strain and strain rate quantification in a normal adult and paediatric population: assessment of reference values *Cardiovascular Ultrasound* 2009, 7:8 doi:10.1186/1476-7120-7-8

(7) Annelies E van der Hulst , Victoria Delgado: Relation of left ventricular twist and global strain with right ventricular dysfunction in patients after operative "correction" of tetralogy of fallot, PMID: 20723653, DOI: 10.1016/j.amjcard.2010.04.032**.**

(8) Marcus KA, Mavinkurve-Groothuis AM, Barends M,van A Dijk, et al: Reference values for myocardial two-dimensional strain echocardiography in a healthy pediatric and young adult cohort. J Am Soc Echocardiogr 2011; 24:625-36. doi: 10.1016/j.echo.2011.01.021

(9) Haki Jashari, Annika Rydberg, Pranvera Ibrahimi, et al: Normal ranges of left ventricular strain in children: a meta-analysis. Cardiovascular Ultrasound (2015). DOI: 10.1186/s12947-015-0029-0

(10) Lang RM, Badano LP,Mor-Avi V, et al: Recommendations for cardiac chamber quantification by echocardiography in adults: An update from the American Society of Echocardiography and European Association of Cardiovascular Imaging. Eur Heart J Cardiovasc Imaging 2015; 16:233-70.

(11) Lai WW, Geva T, Shirali GS, et al: Guidelines and standards for performance of a pediatric echocardiogram: A report from the task force of the Pediatric Council of the American Society of Echocardiography. J Am Soc Echocardiogr 2006; 19:1413-30. doi: 10.1016/j.echo.2006.09.001

(12) Jens-Uwe Voigt, Gianni Pedrizzetti, Peter Lysyansky, et al: Definitions for a common standard for 2D speckle tracking echocardiography: consensus document of the EACVI / ASE /Industry Task Force to standardize deformation imaging. European Heart Journal – Cardiovascular Imaging 2015;16(1), pages 1-11.Doi.org/10.1093/ehjci/jeu184

(13) Holly Geyer, Giuseppe Caracciolo, Haruhiko Abe, et al: Assessment of Myocardial Mechanics Using Speckle Tracking Echocardiography: Fundamentals and Clinical Applications, Journal of the American Society of Echocardiography, Volume 23, Issue 4, 2010,351-369. https://doi.org/10.1016/j.echo.2010.02.015.

(14) Philip T. Levy, MD, Aliza Machefsky, BA, Aura A. Sanchez, MD et al: Reference Ranges of Left Ventricular Strain Measures by Two-Dimensional Speckle-Tracking Echocardiography in Children: A Systematic Review and Meta-Analysis, J Am Soc Echocardiogr 2016;29:209-25.

http://dx.doi.org/10.1016/j.echo.2015.11.016

(15) Arvind Sehgal, Flora Wong, Samuel Menahem, Speckle tracking derived strain in infants with severe perinatal asphyxia: a comparative case control study. Cardiovascular Ultrasound 2013 11:34. doi: 10.1186/1476-7120-11-34

Table I: Baseline demographic and clinical characteristics of 102 neonates enrolled in this study:

Variables	Values
Demographic Data	
Age (days)	1.5 ± 0.8
Male, n%	59 (57.8)
Female, n%	43 (42.2)
Weight (kg)	3.2 ± 0.5
Height (cm)	50.0 ± 2
BSA (m^2)	0.2 ± 0.08
Reason for referral	
FH CHD	23 (22.5)
IDM	14 (13.7)
Murmur	64 (62.7)
Fetal echo showing echogenic foci	2 (2.0)
Findings	
ASD vs. PFO	67 (65.7)
Closing PDA	30 (29.4)
Normal	5 (4.9)

Table II: Echocardiographic characteristics of the study population

Variables	Mean ± SD	SEM	Variance	Minimum	Maximum
End diastolic diameter (cm)	1.62 ± 0.23	0.022	0.052	1.12	2.35
End systolic diameter (cm)	1.10 ± 0.16	0.016	0.027	0.64	1.7
Fractional shortening (%)	34 ± 3	0.339	0.1	27	42
Biplane Simpson method EF (%)	61.0 ± 3	0.326	0.1	55	73
LV 4ch strain	-20.03 ± 1.43	0.141	2.038	-23.8	-13.5
LV 3ch strain	-19.4 ± 3.6	0.357	12.977	-22.5	-14.4
LV 2ch strain	-19.60 ± 4.1	0.406	16.814	-25.0	-17.4
LV GLS	-19.9 ± 1.2	0.115	1.362	-22.9	-13.5
Ejection fraction strain (%)	60.0 ± 2.7	0.265	0.1	52	67
Strain rate	-0.050 ± 0.003	0.0003	0.00	-0.074	-0.044

LV left ventricle, **GLS** global longitudinal strain,**SEM** standard error of the mean

Table III: Correlations between Fractional shortening (FS), ejection fraction (EF) and longitudinal strain EF:

Correlations

		FS	EF strain
FS	Pearson Correlation	1	-.142
	Sig. (2-tailed)		.155
	N	102	102
EF strain	Pearson Correlation	-.142	1
	Sig. (2-tailed)	.155	
	N	102	102

A)

A Pearson correlation was used to determine the relationship between fractional shortening and left ventricular ejection fraction by strain. There is a small negative correlation between the FS and LV EF by strain which shows inconclusive evidence about the significance of the association between the variables (r = -0.142, n = 102, p =0.).

B)

Correlations

		EF strain	AVE EF
EF strain	Pearson Correlation	1	.294**
	Sig. (2-tailed)		.003
	N	102	102
AVE EF	Pearson Correlation	.294**	1
	Sig. (2-tailed)	.003	
	N	102	102

**. Correlation is significant at the 0.01 level (2-tailed).

A Pearson correlation was used to determine the relationship between LV EF by biplane Simpsons method and LV EF by strain. There is a small positive correlation between the LV EF by biplane and LV EF by strain which was statistically significant (r = 0.294, n = 102, p =0.003).

C)

Correlations

		LV 4ch strain	LV GLS
LV 4ch strain	Pearson Correlation	1	.756**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	205.887	127.187
	Covariance	2.038	1.259
	N	102	102
LV GLS	Pearson Correlation	.756**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	127.187	137.541
	Covariance	1.259	1.362
	N	102	102

**. Correlation is significant at the 0.01 level (2-tailed).

A Pearson correlation was used to determine the relationship between LV 4 chamber strain versus LV global longitudinal strain. There is a moderate positive correlation between the LV4 chamber strain and LV GLS which is statistically significant (r = 0.756 , n = 102, p <0.001.).

D)

Correlations

		EF strain	EF (4 ch)
EF strain	Pearson Correlation	1	.735**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	.072	.074
	Covariance	.001	.001
	N	102	102
EF (4 ch)	Pearson Correlation	.735**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	.074	.140
	Covariance	.001	.001
	N	102	102

**. Correlation is significant at the 0.01 level (2-tailed).

A Pearson correlation was used to determine the relations hip between 4 chamber EF and LV EF by strain. There is a moderate, positive correlation between the two variables which was statistically significant. (r = 0.735 , n = 102, p <0.001.).

E)

Correlations

		EF (4 ch)	EF (sp4)
EF (4 ch)	Pearson Correlation	1	.204*
	Sig. (2-tailed)		.039
	Sum of Squares and Cross-products	.140	.029
	Covariance	.001	.000
	N	102	102
EF (sp4)	Pearson Correlation	.204*	1
	Sig. (2-tailed)	.039	
	Sum of Squares and Cross-products	.029	.142
	Covariance	.000	.001
	N	102	102

*. Correlation is significant at the 0.05 level (2-tailed).

A Pearson correlation was used to determine the relationship between 4 chamber EF and LV EF by biplane. There is weak, positive correlation between the two variables which is statistically significant (r = 0.204, n = 102, p =0.039.).

Table IV: Comparison of demographic data and echo variables between male and female:

Variable	Male (n=59)	Female (n=43)	p-value
Age (days)	1.51 ± 0.751	1.45 ± 0.861	0.729
Male, n%			
Female, n%			
Weight (kg)	3.246 ± 0.479	3.078 ± 0.582	0.113
Height (cm)	50.1 ± 1.98	49.81 ± 1.98	0.470
BSA (m^2)	0.211 ± 0.097	0.187 ± 0.042	0.136
Echo variables	**Echo variables**	**Echo variables**	**Echo variables**
End diastolic diameter (mm)	1.62 ± 0.242	1.61 ± 0.208	0.745
End systolic diameter (mm)	1.07 ± 0.171	1.04 ± 0.155	0.336
Fractional shortening (%)	33.78 ± 3.348	33.58 ± 3.554	0.774
Biplane Simpson EF (%)	60.92 ± 3.454	61.20 ± 3.725	0.681
LV 4ch strain	-19.90 ± 1.57	-20.21 ± 1.209	0.284
LV 3ch strain	-19.20 ± 4.603	-19.65 ± 1.355	0.544
LV 2ch strain	-19.58 ± 5.30	-19.62 ± 1.278	0.962
LV GLS	-19.93 ± 1.37	- 19.81 ± 0.81	0.614
Ejection fraction strain (%)	59.79 ± 2.530	60.26 ± 2.879	0.393
Strain rate	-0.051 ± 0.004	-0.051 ± 0.002	0.920

FIGURE 1: Cohort flowchart of neonates assessed in the study.

Inclusion criteria:

Full term (37-41weeks)

Birth weight > 2.2 kg

Normal vital signs for age

Normal ECG

Normal cardiac structure

Figure 2: Demonstration of longitudinal strain using 2D-Speckle Tracking Echocardiography.

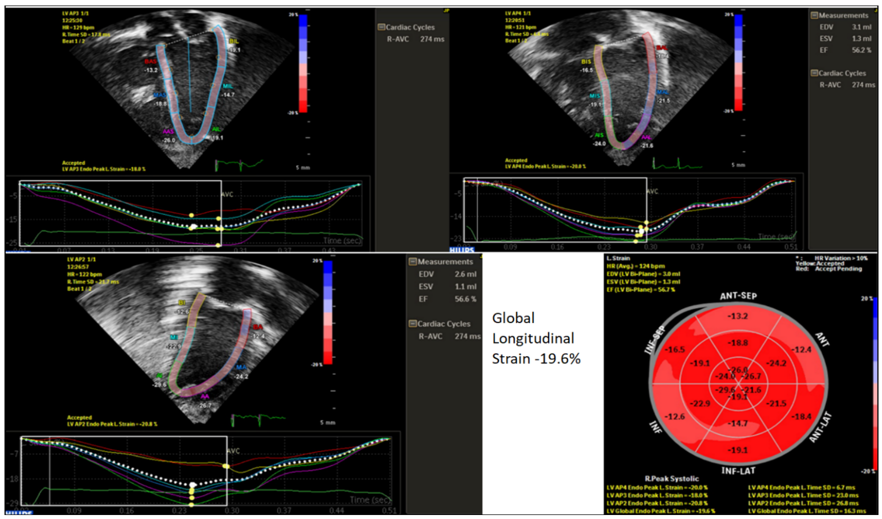


Figure 3: Relationship between average EF by strain and by biplane method among all patients included in the study.

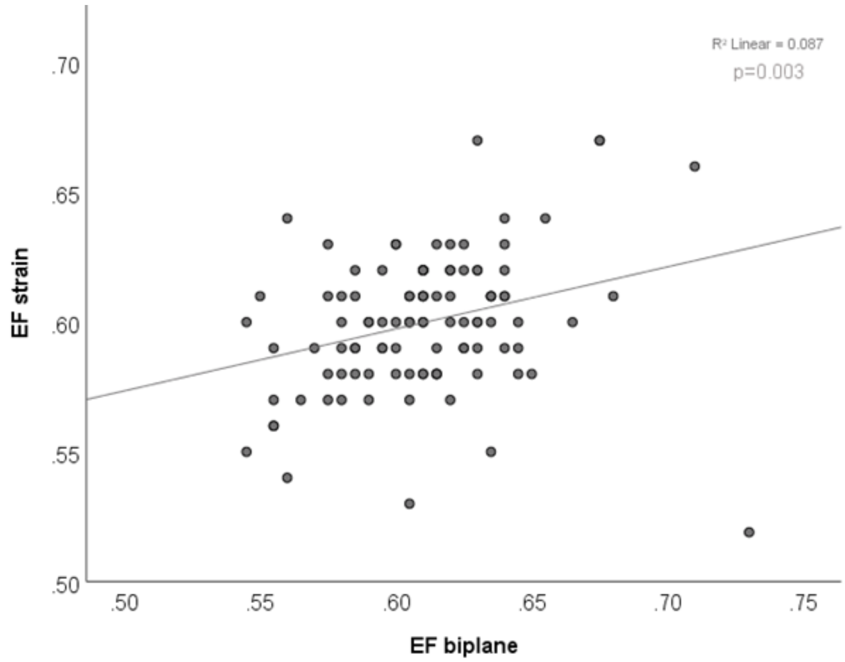
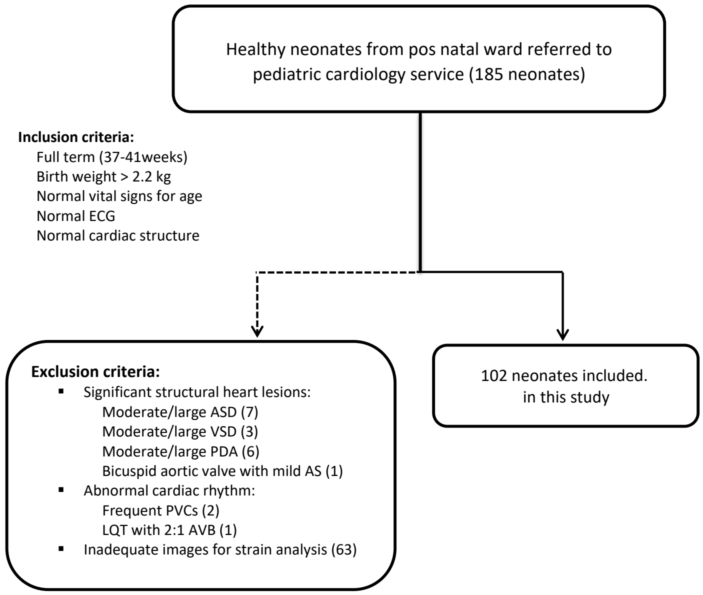

R² Linear = 0.087
p=0.003
.70
.65
.60
.55
.50
EF strain
.50
.55
.60
.65
.70
.75
EF biplane

FIGURE 1: Cohort flowchart of neonates assessed in the study.



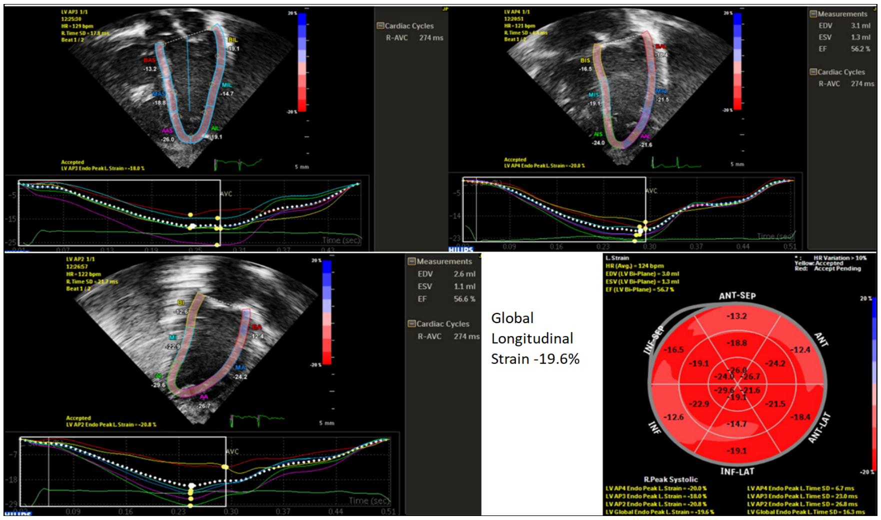


Figure 4: Relationship between average EF by strain and by biplane method among all patients included in the study.