Reference Values of Longitudinal Systolic Right and Left Ventricular Function Measured by M-mode Echocardiography in Healthy Preterm and Term Neonates

Yazdan Ghandi, Danial Habibi1, Elham Farahani2
Departments of Pediatric Cardiology, 1Biostatistics and 2Adult Cardiology, Faculty of Medicine, Arak University of Medical Sciences, Arak, Iran

Abstract

Background: The mitral annular plane systolic excursion (MAPSE) and tricuspid annular plane systolic excursion (TAPSE) are parameters for evaluating systolic function, which is directly affected by ventricular morphology and geometry. Materials and Methods: A cross-sectional study in term and preterm neonates calculated TAPSE and MAPSE at the lateral and septal (LAT/SEP) mitral. The study groups were divided into three classes based on birth age: two preterm groups, 30–33 weeks and 34–37 weeks, and one term group, 38–40 weeks. Results: This study included 21 term neonates and 31 preterm neonates. The mean LAT MAPSE was 0.63 ± 0.11 cm for gestational age (GA) of 30–33 weeks, 0.76 ± 0.03 cm among GA of 34–36 weeks, and 0.84 ± 0.08 cm for GA of 37–40 weeks; the mean SEP MAPSE was 0.39 ± 0.14 cm, 0.51 ± 0.06 cm, and 0.65 ± 0.09 cm, respectively; and the mean TAPSE was 0.47 ± 0.13 cm, 0.62 ± 0.07 cm and 0.88 ± 0.15 cm, respectively. The mean LAT MAPSE was 0.63 ± 0.09 cm for neonates weighing 1500–2500 g and 0.82 ± 0.06 cm for those weighing 2500–3600 g; the mean SEP MAPSE was 0.39 ± 0.11 cm and 0.61 ± 0.09 cm, respectively. The LAT MAPSE showed a positive correlation with body surface area (BSA) and body weight (BW) \((P = 0.0001)\). In addition, the SEP MAPSE indicated a positive correlation with BSA and BW \((P = 0.0001)\). The TAPSE had a positive correlation with BSA \((P = 0.0001)\) and BW \((r = 0.876, P = 0.0001)\). Conclusions: The TAPSE and MAPSE values were calculated to establish the reference values for assessing global ventricular systolic function in neonate’s health.

Keywords: Longitudinal myocardial function, mitral annular plane systolic excursion, neonates, reference values, tricuspid annular plane systolic excursion

Introduction

The longitudinal systolic right and left ventricular (LV) function is estimated through mitral annular plane systolic excursion (MAPSE) and tricuspid annular plane systolic excursion (TAPSE) using M-mode echocardiography.1 Longitudinal right and LV motion are affected by gestational age (GA) and body weight (BW) and the morphology and geometry of the ventricles. It is known that MAPSE and TAPSE are growth dependent.2

MAPSE measurement is a simple, reproducible, and relatively load-independent method to assess LV function even when the LV ejection fraction (LVEF) is still normal. Previous studies demonstrate that MAPSE is a potentially useful tool to identify patients with heart failure (HF) despite a normal EF.3 In addition, a correlation between MAPSE and LVEF has been demonstrated.1

TAPSE is a proper quantitative echocardiographic measurement to assess the longitudinal function of the right ventricular (RV) while systolic function in children.4 TAPSE can be calculated quickly and easily to evaluate the clinical setting especially in the neonatal intensive care unit (NICU). In addition, TAPSE has shown good correlation with RVEF.5 Because neonates have a relatively thin-walled LV and a functionally more hypertrophied RV, it may be very difficult to evaluate the longitudinal function of the endocardium using strain or strain rate (SR) echocardiography. Of Couse,

Address for correspondence: Dr. Yazdan Ghandi, Departments of Pediatric Cardiology, Biostatistics and Cardiology, Faculty of Medicine, Arak University of Medical Sciences, Arak, Iran. E-mail: y.ghandi@arakmu.ac.ir

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlile 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Ghandi Y, Habibi D, Farahani E. Reference values of longitudinal systolic right and left ventricular function measured by M-mode echocardiography in healthy preterm and term neonates. J Cardiovasc Echography 2018;28:177-81.
Pena et al. have been done quantification of regional left and RV deformation indices in healthy neonates using SR and strain imaging. The strain or SR echocardiography is difficult and progressive echocardiography. This method is not found in anywhere and also the cardiologist should be trained about it. At the result, the MAPSE and TAPSE may be useful alternative techniques.

In specific patient groups, such as those dealing with congenital heart defects, sepsis, or asphyxia, a proper method for evaluating longitudinal LV/RV function is necessary. For these patients, MAPSE and TAPSE may be useful. Due to the high critical status of this study, population, practicable, usable, and available reference values of normal MAPSE and TAPSE values are needed. The aim of this study was to estimate and to calculate these reference values in healthy term and preterm neonates.

Materials and Methods

Neonatal population

Our study group comprised 51 healthy term and preterm newborns randomly selected from the NICU or those indicated to be evaluated due to the positive family history of heart disease during the first 3 days of life from July 2015 to July 2016. The study was primarily approved by the Ethics Committee University of Medical Sciences. We have acquired informed consent from newborn parents before research. Each newborn was evaluated in a resting state without a prior crying episode. None of the newborns were bottle-fed during the examination. GA was determined from the last menstrual period, and BW was measured by digital scale. Perinatal data included Apgar score at 1 min and 5 min, and the type of delivery was reported. We evaluated TAPSE and MAPSE in the lateral (LAT) and septal (SEP) mitral ring, as well as LVEF, using M-mode echocardiography for all 51 healthy term and preterm neonates. Measurements of TAPSE and MAPSE in the LAT and SEP side of the mitral ring were performed for all patients. Exclusion criteria for patients in this study were the following: EF <55%, acquired heart diseases, chromosomal syndromes, congenital heart disease (CHD), patent foramen ovale with a diameter of higher than 2 mm, infection or sepsis (positive blood culture), asphyxia (Apgar scores at 1 min and 5 min <7), pulmonary hypertension, those needing supplemental oxygen (intubation and mechanical ventilation), supplemental oxygen or nasal CPAP with FiO2 >0.3, very low birth weight (<1500), or receiving inotropic and chronotropic agents. We excluded 50 neonates in during research due to etiologies of different. We calculated the normal reference values of MAPSE and TAPSE within the first 48–72 h of life for all healthy term (38–40 weeks) and preterm (30–33 and 34–37 weeks) neonates. The aim of this division was to simplify the diagnosis and to develop a proper practice tool for the assessment of ventricular function and detection of ventricular impairment.

Echocardiographic techniques

Standard echocardiography was performed for each subject. Data were gathered by echocardiography in an average measurement of 3–5 consecutive heartbeats. The echocardiogram was performed with an echocardiographic system (Medison EKO-7) using a transducer of 3–8 MHZ. The echocardiography was performed within 48–72 h after birth by two echocardiographers.

We determined LVEF using M-mode echocardiography through parasternal long-axis view. MAPSE and TAPSE were measured using the M-mode technique in standard apical four-chamber view. To configure MAPSE SEP and MAPSE LAT measurements, the cursor was placed at the SEP and LAT side of the mitral annulus. Calculations of MAPSE and TAPSE were performed by two cardiologists, and then these data were evaluated and averaged by a third person.

The MAPSE was measured by determining the distance between the apex from the LAT and SEP annulus motion mitral ring in the systolic phase. For more accurate measurement, the sample volume was aligned as vertically as possible to the cardiac apex, and the vector was arranged to be parallel to the SEP and LAT walls. The peak MAPSE of the two walls of the left ventricle (SEP and LAT) was recorded.

TAPSE was measured from the apical 4-chamber view using M-mode echocardiography. The cursor was placed at the free wall of the tricuspid anulus, and the sample volume was aligned as parallel as possible to the free wall of RV. The maximum TAPSE was determined by the excursion of the tricuspid annulus from its highest position to lowest position during RV systole.

Statistical analysis

All data were presented as the means ± standard deviations (SD). Correlations between MAPSE/TAPSE and other variables were analyzed using the Pearson correlation coefficient. TAPSE and MAPSE were studied between male and female neonates using the t-test. For the data analysis, SPSS 23 (SPSS, Inc., Chicago, IL, USA) was used. P > 0.05 was considered statistically significant.

Results

The study group comprised 51 healthy neonates (26 females, 51%; 25 males, 49%), of which 31 were preterm (60.8%), and 20 were term (39.2%). Delivery type included 43 births (84.3%) by natural vaginal delivery and 8 births (15.7%) by cesarean section. The mean Apgar scores at 1 and 5 min were 8.24 ± 0.43 min and 9.25 ± 0.72 min, respectively. The mean birth weight (gr) and body surface area (BSA) (m2) were 2713.63 ± 628.03 gr and 0.18 ± 0.03, respectively. The mean GA was 35.18 ± 3.18 weeks.

The mean MAPSE LAT range was 0.63 ± 0.11 cm in preterm neonates with a GA of 30–33 weeks and 0.76 ± 0.03 cm and 0.84 ± 0.08 cm in neonates with a GA of 34–36 weeks and 37–40 weeks, respectively.

The MAPSE SEP range was 0.39 ± 0.14 cm in preterm neonates with a GA of 30–33 weeks, 0.51 ± 0.06 in neonates...
with a GA of 34–36 weeks and 0.51 ± 0.06 in neonates with GA of 37–40 weeks.

The TAPSE range was 0.47 ± 0.13 cm in preterm neonates with a GA of 30–33 weeks, 0.62 ± 0.07 in neonates with a GA of 34–36 weeks, and 0.88 ± 0.15 in those with a GA of 37–40 weeks.

Z-scores ± 2 and ± 3 SDs are shown for MAPSE (LAT/SEP) and TAPSE, based on weeks of GA [Table 1].

Tables 2-4 show the classifications based on weight in Z-scores ± 2 and ± 3 SDs for MAPSE (LAT/SEP) and TAPSE. The mean MAPSE LAT range was 0.63 ± 0.09 cm for 1500–2500 gr neonates and 0.82 ± 0.06 cm for 2500–3600 g neonates. The mean MAPSE SEP range was 0.39 ± 0.11 cm for 1500–2500 g neonates and 0.61 ± 0.09 cm for 2500–3600 g neonates. The mean TAPSE range was 0.45 ± 0.03 cm for 1500–2500 g neonates and 0.80 ± 0.16 cm for 2500–3600 g neonates.

The correlations between TAPSE/MAPSE LAT and SEP values with BW and EF were studied with the Pearson test. A positive correlation was found between MAPSE LAT/SEP and LVEF. In addition, a positive correlation was found between TAPSE and LVEF. Table 5 summarizes these correlations.

The MAPSE LAT values showed a positive correlation between BSA ($r = 0.830, P = 0.0001$) and BW ($r = 0.950, P = 0.0001$) with a linear course. The MAPSE SEP values showed a positive correlation with BSA ($r = 0.796, P = 0.0001$) and BW ($r = 0.904, P = 0.0001$) with a linear course. The TAPSE values showed a positive correlation with BSA ($r = 0.783, P = 0.0001$) and BW ($r = 0.876, P = 0.0001$) with a linear course.

We found that MAPSE LAT and SEP values, as well as TAPSE values, increase with BSA and BW in a linear manner. No significant difference in MAPSE LAT and SEP values was observed between females or males ($P = 0.644$ and $P = 0.803$, respectively). In addition, no significant difference in TAPSE values was observed between females or males ($P = 0.632$) [Table 5].

**Discussion**

The EF not only is an excellent index of global systolic function but also indicates the impairment of fiber contractility. This parameter is dependent on ventricular size and/or shape, preload and afterload. However, it has some limitations in pediatric settings, especially in the early diagnosis of systolic dysfunction. Contribution to the normal LVEF is demented by three motions: Longitudinal, spiral, and horizontal. It is shown that the motion of longitudinal myocardial fibers is important in contributing to normal LVEF. The EF is not dependent on GA and BW, but other methods such as MAPSE or TAPSE are dependent on GA, BW, or increases in the size or shape of ventricular.[7] In the current study, the TAPSE or MAPSE (LAT/SEP) values seem to be useful in early diagnosis of HF.[8]

The MAPSE is a simple method to assess the longitudinal systolic LV function and seems to be very sensitive in neonatal cardiac dysfunction. In adults, the MAPSE is correlated with LVEF. Due to these parameters can be easily measured in neonates, they may be a useful diagnostic tool for cardiac dysfunction in neonatal disease. The MAPSE may be helpful for detecting LV impairment in newborns and could differentiate patients from healthy controls. In adults, a MAPSE reduction is associated with an ominous outcome.
Ghandi, et al.: Reference values, M-mode echocardiography, neonates

Table 4: Classification for tricuspid annular plane systolic excursion values

| Weight | n  | -3 SD | -2 SD | Mean | +2 SD | +3 SD |
|--------|----|-------|-------|------|-------|-------|
| 1500   | 3  | 0.40  | 0.41  | 0.43 | 0.45  | 0.46  |
| 2150   | 2  | 0.44  | 0.44  | 0.44 | 0.44  | 0.44  |
| 2500   | 2  | 0.39  | 0.44  | 0.52 | 0.60  | 0.65  |
| 2750   | 3  | 0.47  | 0.52  | 0.63 | 0.73  | 0.78  |
| 2950   | 2  | 0.51  | 0.54  | 0.62 | 0.69  | 0.72  |
| 3050   | 3  | 0.46  | 0.60  | 0.86 | 1.12  | 1.26  |
| 3150   | 4  | 0.66  | 0.73  | 0.87 | 1.07  | 1.07  |
| 3200   | 2  | 0.61  | 0.63  | 0.69 | 0.75  | 0.77  |
| 3250   | 2  | 0.40  | 0.53  | 0.78 | 1.03  | 1.16  |
| 3400   | 3  | 0.42  | 0.58  | 0.92 | 1.26  | 1.42  |

SD=Standard deviation

Table 5: Correlation between left ventricular ejection fraction with mitral annular plane systolic excursion and tricuspid annular plane systolic excursion

|          | TAPSE | MAPSE lateral | MAPAES septal |
|----------|-------|---------------|---------------|
| LVEF     | 0.51  | 0.58          | 0.59          |
| P        | 0.0001| 0.0001        | 0.0001        |
| TAPSE    | -     | 0.84          | 0.88          |
| P        | -     | 0.0001        | 0.0001        |
| MAPSE lateral | 0.84 | -             | 0.93          |
| P        | 0.0001| -             | 0.0001        |

MAPSE=Mitral annular plane systolic excursion, TAPSE=Tricuspid annular plane systolic excursion, SD=Standard deviation, LVEF=Left ventricular ejection fraction

Imaging modalities, such as cardiovascular magnetic resonance, positron emission tomography and computed tomography, benefit the diagnosis of HF. They may be necessary for diagnosis in patients with acute and chronic HF. Echocardiography remains the first-line evaluation in diagnosis in patients HF and evaluation cardiac right and LV and valvular function. Faganello et al. showed strengths and limitations of cardiac imaging techniques.[9]

The TAPSE is a new index for the assessment of longitudinal RV function. Myocardial fibers in RV are either longitudinal or long axis in orientation. Systolic function in RV predominantly occurs in the long axis. The TAPSE parameter is dependent on preload volume, size or shape of the RV and BW and GA; however, this parameter differed from preterm to term.[10]

Therefore, TAPSE and MAPSE, such as longitudinal myocardial shortening, are sensitive parameters for evaluating global longitudinal LV and RV function. In comparison with EF, these parameters are more sensitive, finding the early stages of ventricular function impairment, especially in neonates with subendocardial poor imaging qualities. Therefore, despite the routine use of newly routine echocardiographic techniques, such as TDE, strain (S) and SR, measuring longitudinal myocardial shortening is useful to evaluate systolic function in patients with poor echogenicity.

Therefore, because adult and children normal reference values cannot be applied to neonatal age groups, it is important to identify normal reference values for healthy term and preterm neonates.

We performed a prospective cross-sectional study in 51 healthy term and preterm neonates without respiratory disorders to compute the normal reference values of MAPSE (LAT/SEP) and TAPSE.

Our study observed no significant differences in TAPSE and MAPSE between female and male neonates, similar to the results of Koestenberger et al.[11]

In our study, neonates were divided into three classes by GA: 30–33 weeks GA and 34–37 weeks GA were defined as preterm neonates, and the third class, 38–40 weeks GA, was defined as term neonates. We showed that TAPSE and MAPSE (LAT/SEP) values increase with increasing GA and BW among healthy neonates. In addition, the TAPSE and MAPSE (LAT/SEP) values were higher in term neonates compared to preterm neonates. It seems that these changes occur due to the developmental process and maturation of the LV and RV muscles in preterm neonates.

We showed a positive correlation between LVEF with TAPSE and MAPSE. In addition, we found a positive correlation between BSA and BW with MAPSE (LAT/SEP) and TAPSE. The MAPSE LAT range increased 1.3 times among the 30–33 weeks GA group compared to the 37–40 weeks GA group; the MAPSE SEP range increased more than 1.6 times. The TAPSE value also increased at least 1.8 times in the period from preterm to term.

In conclusion, we demonstrated the normal reference values of TAPSE and MAPSE (LAT/SEP) in healthy preterm and term neonates within the first 48–72 h of life. These findings may serve as a reference for evaluating cardiac systolic function in preterm and term neonates for the early diagnosis of LV and RV systolic dysfunction. These parameters may be useful for diagnosing poor prognosis and very ill neonates. In addition, they may help assess ventricular dysfunction in term and preterm neonates. The MAPSE and TAPSE are simple, noninvasive methods to assess cardiac dysfunction, especially during the neonatal period when the endocardium is not able to be optimally traced.

Conclusions

The evaluation of longitudinal LV and RV contraction using MAPSE and TAPSE reference values may be useful to assess global LV and RV systolic functions during the neonatal period with various parameters, including GA and BW. Moreover, the use of MAPSE and TAPSE reference data is a noninvasive, reproducible method for evaluating cardiac function, and a
simple method for the early diagnosis of ventricular systolic dysfunction in neonates with CHD, acquired cardiac disease or HF.

**Study limitations**
The small size of the study population was a limitation of this study. The second limitation was showing no effects on LV/RV diastolic function by measuring MAPSE or TAPSE. The third limitation was that we did not index MAPSE or TAPSE based on GA or BW for each group. We did not evaluate the interobserver variability of the measures. We also did not evaluate the effects of preload variations related to respiration. In addition, we did not measure RV and LV length in M-mode, which had been used to evaluate the correlation between ventricular geometry and TAPSE/MAPSE.

**Acknowledgment**
We would like to thank all neonatology personnel for their kind cooperation in collecting the data used in our analysis.

**Financial support and sponsorship**
This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

**Conflicts of interest**
There are no conflicts of interest.

**References**

1. Elnoamany MF, Abdelhameed AK. Mitral annular motion as a surrogate for left ventricular function: Correlation with brain natriuretic peptide levels. Eur J Echocardiogr 2006;7:187-98.
2. Carlhäll C, Wigström L, Heiberg E, Karlsson M, Bolger AF, Nylander E, et al. Contribution of mitral annular excusion and shape dynamics to total left ventricular volume change. Am J Physiol Heart Circ Physiol 2004;287:H1836-41.
3. Yuda S, Inaba Y, Fujii S, Kokubu N, Yoshioka T, Sakurai S, et al. Assessment of left ventricular ejection fraction using long-axis systolic function is independent of image quality: A study of tissue Doppler imaging and m-mode echocardiography. Echocardiography 2006;23:846-52.
4. Miller D, Farah MG, Liner A, Fox K, Schluchter M, Hoit BD, et al. The relation between quantitative right ventricular ejection fraction and indices of tricuspid annular motion and myocardial performance. J Am Soc Echocardiogr 2004;17:443-7.
5. Roberson DA, Cui W, Chen Z, Madronero LF, Cuneo BF. Annular and septal Doppler tissue imaging in children: Normal z-score tables and effects of age, heart rate, and body surface area. J Am Soc Echocardiogr 2007;20:1276-84.
6. Pena JL, da Silva MG, Faria SC, Salemi VM, Mady C, Baltabaeva A, et al. Quantification of regional left and right ventricular deformation indices in healthy neonates by using strain rate and strain imaging. J Am Soc Echocardiogr 2009;22:369-75.
7. Wandt B, Bojö L, Hatle L, Wranne B. Left ventricular contraction pattern changes with age in normal adults. J Am Soc Echocardiogr 1998;11:857-63.
8. Sveälv BG, Olofsson EL, Andersson B. Ventricular long-axis function is of major importance for long-term survival in patients with heart failure. Heart 2008;94:284-9.
9. Faganello G, Doimo S, DI Nora C, DI Lenarda A. Cardiac imaging in patients with acute or chronic heart failure. Minerva Cardioangiol 2017;65:589-600.
10. Koestenberger M, Nagel B, Ravekes W, Urlesberger B, Raith W, Avian A, et al. Systolic right ventricular function in preterm and term neonates: Reference values of the tricuspid annular plane systolic excursion (TAPSE) in 258 patients and calculation of Z-score values. Neonatology 2011;100:85-92.
11. Koestenberger M, Nagel B, Ravekes W, Avian A, Heinzl B, Frithsch P, et al. Left ventricular long-axis function: Reference values of the mitral annular plane systolic excursion in 558 healthy children and calculation of Z-score values. Am Heart J 2012;164:125-31.