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Normal values of left and right ventricular function measured by M-mode, pulsed doppler and Doppler tissue imaging in healthy term neonates during a 1-year period

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ABSTRACT

Background: The measurements of left and right ventricular functions change after birth due to the influence of several hemodynamic changes upon the immature myocardium.
Aim: The aim of this study was to investigate the changes in left (LV) and right ventricular (RV) functions of healthy term newborns using conventional and Doppler echocardiography during a 1-year period.
Subjects and methods: Fifty healthy term newborns were examined prospectively on the first day, 3–4, 6–7, 9–10 and 11–12 months of their lives by M-mode, pulsed Doppler (PD) and Doppler tissue imaging techniques (DTI). PD velocities were obtained from mitral and tricuspid valves while DTI velocities were obtained from the lateral annuluses of atrioventricular valves.
Results: EF and FS did not change significantly by time. Early (E) flow velocity and early myocardial (Em) velocity were higher than late (A) flow velocity and atrial systolic (Am) velocity for LV, while A and Am velocities were higher than E and Em velocities for RV, respectively during the study period. E, A, Em, Am, Sm velocities and Em/Am ratios increased while E/Em ratios decreased significantly by time ($P<0.05$) for both ventricle. However, E/A ratios of LV and RV did not change significantly by time. Myocardial performance index (MPI), obtained by PD for RV and by DTI for LV, decreased significantly by time ($P<0.05$) and these DTI values were higher than PD values during the study period.
Conclusions: Due to hemodynamic and maturation change of myocardium PD and DTI velocity changes took place during the first year of life which reflects differences in ventricular adaptation.

1. Introduction

Several significant hemodynamic changes take place during transition from the fetal to neonatal environment. The ductus arteriosus closes and pulmonary blood flow increases in association with decreased pulmonary vascular resistance. On the other hand, the preload of the left ventricle (LV) increases, and the increased systemic arterial blood pressure caused by the closed placental circulation increases the afterload of the LV [1–3]. In the right ventricle (RV) the afterload gradually decreases due to the decrease in pulmonary hypertension. In addition to alterations in cardiac loading conditions, contractility, myocardial function and histological structure of the ventricular myocardium change after birth. These large changes in hemodynamic load occur during cardiac development and are associated with increased contractility owing to alterations in the increased expression of myofibrillar and sarcoplasmic reticulum contents. So, neonatal myocardium develops less force than the adult myocardium due to these changes after birth.

Left and right ventricular functions of children were evaluated in a number of trials, but the data related to newborn babies and infants are rather limited [1–5]. After birth, the primary changes occurring in circulation are an increase in systemic vascular resistance as a result of the removal of the very-low-resistance placenta and an increase in pulmonary blood flow due to reduction of the pulmonary vascular resistance (PVR) [6]. Normal values of left and right ventricular functions also change after birth due to the influence of these hemodynamic changes upon the immature myocardium [1,2,7].

Nowadays, echocardiographic investigations are widely used to assess changes in ventricular functions in adults and children. Especially, Doppler tissue imaging (DTI) is preferred for having the advantage of the capability to measure relaxation and contraction velocities and also time interval parameters in a single beat from a single view.

In our study, changes in left and right ventricular functions of 50 healthy mature newborn babies were evaluated during a 1-year period by conventional and DTI methods. We conducted this study because of the rarity of the reports with long follow-up periods upon this subject and we have discussed the differences between the current and previous studies.

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2. Methods

2.1. Study group

Our study group consisted of 50 healthy term newborns randomly selected from the Obstetrics Clinic of our hospital between July 2008 and 2009. Informed parental consent was obtained for each healthy term newborns and the study was approved by our institutional ethical committee. Right and left ventricular systolic and diastolic functions were determined in each newborn by M-mode, pulsed Doppler (PD) and DTI techniques in our Pediatric Cardiology Echocardiographic Laboratory. In the study group, newborns were examined on the first day and after on the first day, 3–4, 6–7, 9–10 and 11–12 months. Each DTI velocity and time intervals were measured on three consecutive cardiac cycles and subsequently averaged. Newborns with congenital or acquired heart disease, ventricular hypertrophy, rhythm abnormalities, liver, kidney or other organ diseases, syndromes, or chromosomal abnormalities were excluded. Ductus arteriosus was considered normal up to day 3.

2.2. Echocardiographic investigations

All echocardiographic examinations were performed with a Sonos 5500 (Philips, USA, 5–12 MHz transducers) using optimal gain and filter settings to minimize noise and eliminate the signals produced by the transmitral and tricuspid flows. Echocardiograms were recorded on ½-inch VHS videotape, and were subsequently analyzed by a second pediatric cardiologist directly from the stored images who was blinded for all infants.

Ejection fraction (EF) and fractional shortening (FS) of LV are investigated by M-mode echocardiography in the parasternal long-axis view. To record mitral and tricuspid early (E) and late (A) flow velocities with the PD method, sample volume was positioned at the tip of the mitral and tricuspid leaflets during diastole at an angle that was optimally parallel to flow as possible in the apical four-chamber view [8–11]. The ratio of peak E wave to peak A wave was calculated (peak E/A wave ratio). Ejection time for left and right ventricle was measured from the apical long-axis view and the parasternal short- axis view with Doppler sample volume positioned just below the aortic and the pulmonary valve [8–11].

DTI velocities were obtained at the apical 4-chamber orientation from 2 locations: the sample volume was positioned on the lateral aspect of each atrioventricular valve annulus. Care was taken to minimize the incidence angle between the Doppler beam and the direction of LV longitudinal wall motion. Peak early diastolic myocardial (Em), peak atrial systolic (Am), and peak systolic (Sm) myocardial velocities were measured by this technique, besides Em/Am and E/Em ratios were calculated. We calculated the Tei index (myocardial performance index) (MPI) using the formula $(a-b)/b$ [4,9,11,12]. In this method the “a” component is equal to the sum of isovolumic contraction time plus ejection time plus isovolumic relaxation time. The “b” component is equal to the contraction time [4,9,11,12]. Fig. 1a illustrates that in PD method, measurement of the time interval between the end and onset of mitral or tricuspid inflow is “a” interval and the ejection time of the LV or RV outflow is “b” interval (Fig. 1a). Fig. 1b illustrates that in DTI method “a” is measured as a distance between the end of (Am) and the beginning of Em and “b” is measured as a distance between the beginning and end of Sm (Fig. 1b).

2.3. Interobserver and intraobserver variability

To determine the inter- and intraobserver variability of pulsed Doppler and DTI echocardiographic measurements, variables were analyzed in 20 randomly selected newborns by two independent observers and by one observer on two different locations. For determination of inter- and intraobserver variability, the means of the absolute differences between the two observers and those between two locations were calculated and expressed as a percentage.

3. Statistics

Results are expressed as mean ± standard deviation (SD). All data analyses were performed with a commercially available statistical analysis software package (SPSS for Windows, Version 13.0). Mann–Whitney *U* test was used in order to compare the groups. Value of $P \leq 0.05$ was considered statistically significant. Correlations between groups and the repeated measurements were determined by variance analyses. If statistical significance was reached ($P \leq 0.05$) further analysis was carried out by post hoc Wilcoxon test with Bonferroni corrections. Intra- and inter-observer variability was assessed using Pearson's correlation analysis, coefficient of variance, and Bland–Altman analysis.

4. Results

Echocardiography was performed on 50 healthy term neonates (29 females and 21 males) without a history of disease. The mean birth weight and height were 3085 ± 256 g and 46.7 ± 3.4 cm respectively. Table 1 shows the demographic, clinic and anthropometric characteristics of study individuals.

EF and FS values for LV obtained by M-mode echocardiography techniques were between in normal ranges and they increased with advancing age but this increment was not statistically significant as seen in Table 2 (all, $P > 0.05$). Echocardiographic examination of mitral valve by PD echocardiography revealed that transmitral E velocity was higher than transmitral A velocity and although both E and A velocities of mitral valve increased significantly by time (all, $P < 0.05$), peak E/A wave ratio did not increase significantly (all, $P > 0.05$) (Table 2). Late transtricuspid flow velocity (A) was higher than transtricuspid E velocity and although both E and A velocities of tricuspid valve increased significantly by time (all, $P < 0.05$). However, peak E/A wave ratio of tricuspid valve did not increase significantly (Table 2). Fig. 2 shows box plots of various PD indexes determined from mitral and tricuspid valves during follow up period.

Mean value of Em velocity was higher than Am velocity during the whole examination period for LV by DTI. Also, Em, Am and Sm velocities increased significantly by time in the same ventricle. Furthermore, Em/Am ratio increased on the 9–10 months and 11–12 months of analysis which both were significantly higher than the first-day analysis result (all, $P = 0.01$). The mean value of E/Em ratio for LV decreased by time and there was a statistically significant difference between the results of first (8.09 ± 1.9) and last two analyses (7.2 ± 1.04 and 7.1 ± 0.9, respectively) (all, $P = 0.03$) (Table 2).

Em, Am and Sm velocities measured for RV by DTI increased by time. The mean value of Am velocity was significantly higher than Em velocity during whole analysis. Em/Am ratio was found to be significantly increased during the 3–4, 6–7, 9–10 and 11–12 months of analysis when compared with the result of the first-day analysis (all, $P = 0.01$). Also, E/Em ratio was found to be decreased significantly during the 5 time points ($P = 0.04$, $P = 0.01$, $P = 0.01$, $P = 0.01$, respectively) (Table 2). Fig. 3 shows box plots and various TDI indexes determined from left and right ventricles during the follow-up period.

Although MPI of LV obtained by PD did not change significantly by time (all, $P > 0.05$), MPI obtained by the same method for RV decreased significantly during 3–4, 6–7, 9–10 and 11–12 months of analysis when compared with the result of the first-day analysis ($P = 0.04$, $P = 0.01$, $P = 0.01$, and $P = 0.01$, respectively) (Fig. 2). Also, the mean value of MPI obtained by DTI for RV did not change significantly by time (all, $P > 0.05$). The mean value of MPI obtained by the same method for LV was found to be high on the first-day analysis (0.53 ± 0.1). However, it decreased significantly by time during 3–4 (0.46 ± 0.1), 6–7 (0.43 ± 0.02), 9–10 (0.41 ± 0.01) and 11–12 months (0.45 ± 0.02) of analysis