The Impact of Delivery Type on Ventricular Performances of Healthy Neonates

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ABSTRACT

OBJECTIVE: The present study aims to evaluate how the mode of delivery affects the alterations in myocardial functions of healthy newborns within the first month of life.

STUDY DESIGN: This is a prospective review of 60 healthy term newborns whose cardiac functions were examined by M-mode and tissue Doppler echocardiography on the first day of their lives and subsequently at one month of age.

RESULTS: At the first visit, the tricuspid annular plane systolic excursion was significantly higher in vaginally delivered newborns. Mitral and tricuspid E velocities and E/E' ratio of the right ventricle and isovolumic relaxation time of right ventricle were also significantly higher in newborns delivered by cesarean section. Both of the groups had statistically similar M-mode and tissue Doppler echocardiography measurements at the time of the second visit. Only the increase in the tricuspid A velocity and myocardial performance index measured from septum between the first and second visits were significantly higher in the cesarean delivery group. When compared with the first visit, both isovolumic contraction time and isovolumic relaxation time were lower between the groups but myocardial performance index values were increased without significance at the second visit.

CONCLUSION: Diastolic indices were significantly elevated in newborns delivered by cesarean section than neonates delivered by vaginal route. After one-month-long follow up, an increase was observed in diastolic ventricle functions of the vaginally delivered newborns but this increase was statistically insignificant. Cesarean delivery might be associated with the impairment in ventricular functions and, thus, a delay in the improvement and maturation of cardiac functions.

Keywords: Cesarean section, M-mode echocardiography, Newborn, Tissue Doppler echocardiography, Vaginal delivery

Introduction

The transition from intrauterine life to the early postnatal period is a complicated process. During this process, hemodynamic and growth-related changes occur and these changes may influence echocardiographic parameters (1,2). With birth, neonatal circulation is established so that lungs begin to perform gas exchange, pulmonary blood flow is increased and pulmonary vascular resistance is decreased (3). Both the elimination of placental circulation and the increase in the preload of left ventricle induce systemic arterial resistance (4). On the contrary, the afterload in right ventricle decreases due to the reduction in pulmonary vascular resistance (2).

According to the data of the Organization for Economic Co-operation and Development (OECD) in 2016, the rate of cesarean delivery was reported to be as high as 512 per 1000 live births in Turkey. A rise in the cesarean delivery rate has been related to the increase in both maternal and infant morbidity. The association between Apgar scores of newborns and the mode of delivery has also been specified previously (5).

Conventional and pulsed Doppler techniques in echocardiography are commonly used to assess ventricular systolic and diastolic functions in newborns. Moreover, tissue Doppler imaging relatively allows the detailed recognition of ventricular functions (6). Hemodynamic and cardiovascular changes which would influence the echocardiographic parameters

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mainly occur during the first few weeks of life (7). It is of crucial importance to make serial echocardiographic examinations so that cardiac functions of healthy neonates can be analyzed accurately.

The present study aims to evaluate how the mode of delivery (vaginal route or cesarean section) affects the changes in the myocardial performance of healthy newborns by performing echocardiography examination on the first day of their lives and subsequently at one month of age.

Material and Method

The study was approved by the Institutional Review Board of Adana City Education and Research Hospital (Date 18.07.2018-number 238). Written informed consent was obtained from all parents and study was conducted in accordance with the Declaration of Helsinki.

Study Design

This is a prospective review of 60 healthy term newborns who were admitted to the Adana City Education and Research Hospital in Turkey between June 2018 and August 2018.

All healthy, term, singleton and appropriate for gestational age neonates who were delivered vaginally without analgesia or by cesarean section under spinal anesthesia were included. The indications for cesarean delivery consisted of malpresentation, cephalopelvic disproportion, and non-reassuring fetal heart tracings. None of the newborns enrolled in the study were exposed to antenatal corticosteroid treatment.

The neonates that were born to mothers diagnosed with diabetes mellitus, gestational diabetes, preeclampsia, and chorioamnionitis were excluded from the study. The newborns with congenital heart diseases (including hemodynamically significant patent ductus arteriosus, mitral or aortic regurgitation), chromosomal abnormalities, dysrhythmias, and congenital malformations were also excluded. The neonates that required oxygen supplementation or ventilation at birth and/or intensive care admission were excluded as well.

All newborns were dried and wrapped with towels and positioned supine under the radiant heater for 10 minutes. An experienced pediatrician observed the newborns and recorded Apgar scores at 1st and 5th minutes of life. Heart rate and oxygen saturation measurements were made by a pulse oximeter (Masimo Radical, Masimo Irvine, California, USA). Blood pressure measurements were carried out by sphygmomanometer. Disposable neonatal blood pressure cuffs were applied to the right upper arms of the newborns in resting position. Vital signs were recorded at the same time with the echocardiographic assessment.

Echocardiography Examination

All newborns underwent echocardiography examination initially at a mean age of 22±2 hours (first visit, time point T1) and subsequently at a mean age of 32±2 days (second visit,

time point T2) using an S8-3 MHz probe (iE33 System, Philips Electronics, Amsterdam, Netherlands). One echocardiographer (blinded to the patients' delivery method and other data) interpreted each echocardiographic examination independently. Three values were recorded for each examination and the average of the values was used.

Parasternal long-axis views provided two-dimensional M-mode images. Interventricular septal wall thickness, left ventricular internal diameters, and posterior wall thickness were measured. Shortening fraction was determined to reflect left ventricle functions and Teichholz method was used to calculate ejection fraction (8).

Mitral and tricuspid annular plane systolic excursions (MAPSE and TAPSE respectively) were assessed by the standard M-mode technique in the apical four-chamber view during systole. Both MAPSE and TAPSE values were expressed in mm. Tissue Doppler measurements were made with the transducer from the apical 4- chamber view by aligning the beam perpendicular to the plane of the septum, lateral mitral annulus, and lateral tricuspid annulus. The left-to-right ventricle inflow pattern at the tips of the mitral and tricuspid valves provided peak early (E) and late (A) filling velocities. Peak systolic (S'), early diastolic (E'), and late diastolic (A') myocardial velocities at the septum, lateral mitral annulus, and tricuspid annulus were also specified. The isovolumic contraction time (IVCT: the interval between the end of A' wave to the beginning of the S' wave) and the isovolumic relaxation time (IVRT: the interval between the end of S' wave to the beginning of the E' wave) were measured for both sides of the mitral annulus and lateral tricuspid annulus. The following formula was used with a view to calculating the myocardial performance index (MPI).

MPI = IVRT+ IVCT / LV ejection time (defined as the duration of the S' wave) (9).

Statistical Analysis

Collected data were analyzed by Statistical Package for Social Sciences version 22.0 (SPSS, SPSS IBM, Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation. The vaginal delivery and cesarean section groups were compared by Mann Whitney U test for non-normally distributed data and Student's t-test for normally distributed data. Two-tailed p values <0.05 were considered to be statistically significant.

Results

Demographic and Clinical Characteristics

Table I summarizes the demographic and clinical characteristics of the reviewed newborns. These newborns had a mean gestational age of 38.7±0.7 weeks and a mean birth weight of 3.3±0.4 kg. There were no statistically significant differences between vaginal delivery and cesarean section groups in terms of blood pressure, heart rate, respiration rate, oxygen saturation and Apgar scores at 1st and 5th minutes.

Table I: *Clinical features of study groups*

Clinical data	CD (n=30)	VD (n=30)	p
Gestational age, week	38.7±0.9	38.7±0.5	0.968
Sex, M/F	17/13	14/16	0.944
Weight, g	3400±400	3353±435	0.660
Apgar 1	7.4±0.50	7.4±0.63	0.815
Apgar 5	8.9±0.43	9.0±0.27	0.789
Heart rate, /min	137.3±11.1	131.7±11.7	0.089
SBP, mm Hg	89.8±19.9	88.8±24.2	0.863
DBP, mm Hg	47.6±12.1	49.5±15.7	0.562
Respiration rate, /min	49.5±5.8	49.7±6.0	0.914
Oxygen saturation, %	98.3±1.5	98.4±1.2	0.922

Data are presented as the mean values ± SD, CD: Cesarean delivery, DBP: Diastolic blood pressure, SBP: Systolic blood pressure, VD: Vaginal delivery, *Student t-test, Mann-Whitney U test p < 0.05 considered statistically significant

Conventional and Tissue Doppler Echocardiography at First Visit (T1)

There were no statistically significant differences between the vaginal delivery and cesarean section groups in the aspect of left ventricle diameters and functions measured by M-mode echocardiography at the first visit. Only TAPSE values at the first visit were significantly higher in the vaginal delivery group (Table II). As for tissue Doppler echocardiography parameters, mitral and tricuspid E velocities, right ventricle E/E' ratio and IVRT value at the first visit were significantly higher in the cesarean section group (Table III).

Conventional and Tissue Doppler Echocardiography at Second Visit (T2)

There were no statistically significant differences between the vaginal delivery and cesarean section groups in the aspect of left ventricle diameters and functions measured by M-mode echocardiography at the second visit. Both the vaginal delivery and cesarean section groups had statistically similar tissue Doppler echocardiography measurements.

Comparison of T1 and T2 Measurements

Left ventricle diameters and functions measured by M-mode and 'pulsed' Doppler echocardiography (including left ventricle dimensions, MAPSE and TAPSE values, E and A velocities at tricuspid and mitral annulus, E/A ratios, ejection fraction and fractional shortening) increased during the first month of life. These alterations were statistically similar between the delivery groups but only the increase in tricuspid A velocity was significantly higher in the vaginal delivery group (Table IV and V). Tissue Doppler echocardiography measurement revealed an increase in E', A', S' velocities and MPI values measured at the tricuspid annulus, mitral annulus, and septum while the mean value of IVCT, IVRT times were shortened between T1 and T2. When compared with T1, only MPI values measured from septum increased significantly at T2 (Table V).

Table II: *M-mode echocardiographic parameters of study groups on Visit 1*

Variables	CD (n=30)	VD (n=30)	p
IVSS. mm	6.1±1.3	5.9±1.1	0.572
IVSD. mm	5.8±1.5	5.5±1.2	0.766
LVEDD. mm	16.5±1.4	16.3±1.3	0.469
LVESD. mm	10.2±0.9	10.1±1.2	0.565
LVPWD. mm	3.6±0.6	3.6±0.5	0.782
LVPWS. mm	5.2±0.5	5.2±0.7	0.662
EF. %	70.8±4.3	71.0±5.7	0.898
FS. %	37.3±3.6	37.6±4.7	0.757
TAPSE. mm	9.1±1.4	10.4 ±1.2	0.033*
MAPSE. mm	6.9±0.6	7.0±0.9	0.903

Data are presented as the mean values ± SD, CD: Cesarean delivery, EF: Ejection fraction, FS: Fractional shortening, IVSS: Interventricular septum systolic thickness, IVSD: Interventricular septum diastolic thickness, LVEDD: Left ventricular end-diastolic diameter, LVESD: left ventricular end-systolic diameter, LVPWD: Left ventricle posterior wall diastolic dimension, LWPWS: Left ventricle posterior wall systolic dimension, MAPSE: Mitral annular plane systolic excursion, TAPSE: Tricuspid annular plane systolic excursion, VD: Vaginal delivery, * Mann-Whitney U, p <0.05 considered statistically significant

Table III. Conventional and tissue Doppler echocardiographic parameters of study groups on Visit 1

Variables	CD (n=30)	VD (n=30)	p
Mitral E (cm/s)	0.66±0.11	0.58±0.1	0.038*
Mitral A (cm/s)	0.59±0.11	0.57±0.1	0.639
Mitral E/A	1.15±0.29	1.06±0.31	0.183
Tricuspid E (cm/s)	0.61±0.15	0.54±0.1	0.043*
Tricuspid A (cm/s)	0.62±0.16	0.58±0.1	0.495
Tricuspid E/A	1.03±0.34	0.96±0.29	0.523
S'm (cm/s)	0.58±0.05	0.59±0.09	0.823
E'm (cm/s)	0.75±0.14	0.71±0.11	0.382
A'm (cm/s)	0.70±0.15	0.67±0.12	0.856
ETm (ms)	199±13.8	196.7±12.9	0.579
IVCTm (ms)	38.4±4.2	37.4±3.2	0.264
IVRTm (ms)	39.4±4.4	38.1±3.3	0.152
MPIm (ms)	0.39±0.02	0.38±0.02	0.397
E/E'm	0.08±0.02	0.08±0.01	0.333
S's (cm/s)	0.52±0.06	0.51±0.06	0.701
E's (cm/s)	0.59±0.10	0.64±0.12	0.144
A's (cm/s)	0.64±0.12	0.62±0.12	0.544
ETs (ms)	195±14.7	196±11.8	0.647
İVCTs (ms)	36.3±3.8	36.0±3.5	0.859
İVRTs (ms)	38.5±2.9	38.7±2.8	0.793
MPIs (ms)	0.38±0.02	0.37±0.02	0.368
E/E's	0.07±0.18	0.07±0.02	0.573
S'r (cm/s)	0.70±0.12	0.67±0.08	0.701
E'r (cm/s)	0.86±0.23	0.81±0.26	0.145
A'r (cm/s)	0.86±0.25	0.89±0.23	0.594
ETr (ms)	203±15.8	204±18.1	0.859
IVCTr (ms)	37.0±4.6	38.5±6.8	0.527
IVRTr (ms)	40.4±5.1	37.7±3.6	0.041*
MPIr (ms)	0.36±0.03	0.38±0.04	0.102
E/E'r	0.11±0.02	0.09±0.02	0.018*

*Data are presented as the mean values ± SD, A': Late diastolic myocardial velocity, CD: Cesarean delivery, E': Early systolic myocardial velocity, ET: Ejection time. IVCT: Isovolumetric contraction time. IVRT: Isovolumetric relaxation time, MPI: Myocardial performance index, m: lateral mitral annulus, S': Peak systolic myocardial velocity, s: septal mitral annulus.. r: lateral tricuspid annulus, VD: Vaginal delivery, * Mann-Whitney U test p < 0.05 considered statistically significant*

Table IV: M-mode echocardiographic parameter changes of study groups between T1 and T2

Variables (delta change)	CD (n=30)	VD (n=30)	p
IVSS. mm	0.06±0.11	0.04±0.08	0.620
IVSD. mm	0.02±0.15	0.07±0.11	0.467
LVEDD. mm	0.17±0.18	0.17±0.11	0.886
LVESD. mm	0.10±0.15	0.11±0.11	0.956
LVPWD. mm	0.09±0.11	0.06±0.07	0.783
LVPWS. mm	0.12±0.09	0.09±0.09	0.239
EF. %	-0.40±7.2	-0.41±6.2	0.834
FS. %	0.11±6.3	-0.33±5.1	0.930
TAPSE, cm	1.71±2.70	2.24±3.97	0.249
MAPSE. cm	1.08±1.18	1.02±1.12	0.988

*Data are presented as the mean values ± SD, CD: Cesarean delivery, EF: Ejection fraction, FS: Fractional shortening, IVSS: Interventricular septum systolic thickness, IVSD: Interventricular septum diastolic thickness, LVEDD: Left ventricular end-diastolic diameter, LVESD: left ventricular end-systolic diameter, LVPWD: Left ventricle posterior wall diastolic dimension, LWPWS: Left ventricle posterior wall systolic dimension, MAPSE: Mitral annular plane systolic excursion, TAPSE: Tricuspid annular plane systolic excursion, VD: Vaginal delivery, * Mann-Whitney U p < 0.05 considered statistically significant*

Table V: Conventional and tissue Doppler echocardiographic parameter changes of study groups between T1 and T2

Variables	CD (n=30)	VD (n=30)	p
Mitral E (cm/s)	0.69±1.96	0.26±0.19	0.874
Mitral A (cm/s)	0.14±0.22	0.16±0.18	0.910
Mitral E/A	0.12±0.55	0.08±0.45	0.710
Tricuspid E (cm/s)	0.49±1.78	0.22±0.20	0.166
Tricuspid A (cm/s)	0.30±1.69	0.10±0.21	0.014*
Tricuspid E/A	0.24±0.63	0.18±0.45	0.292
S'm (cm/s)	0.72±1.37	0.95±1.30	0.409
E'm (cm/s)	2.18±2.27	2.85±1.84	0.176
A'm (cm/s)	1.18±3.04	0.66±2.27	0.904
ETm (ms)	-10.3±14.7	-5.45±13.8	0.096
IVCTm (ms)	-1.31±4.94	-0.45±4.08	0.371
IVRTm (ms)	-1.54±5.14	-0.50±4.60	0.262
MPIm (ms)	0.007±0.02	0.0075±0.031	0.799
S's (cm/n)	0.92±0.81	0.89±0.88	0.947
E's (cm/s)	3.5±3.2	2.83±2.40	0.339
A's (cm/s)	1.9±2.5	1.00±2.30	0.231
ETs (ms)	-4.5±18.9	-11.8±16.5	0.276
İVCTs (ms)	-0.86±6.2	-0.54±4.88	0.748
İVRTs (ms)	-1.8±5.5	-1.87±4.71	0.965
MPIs (ms)	-0.005±0.03	0.012±0.03	0.030*
S'r (cm/s)	1.95±2.18	2.37±2.16	0.552
E'r (cm/s)	3.00±5.13	3.61±5.56	0.886
A'r (cm/s)	1.88±3.89	3.12±2.77	0.075
ETr (ms)	-14.7±16.5	-17.3±18.6	0.741
IVCTr (ms)	-1.04±6.12	-2.41±7.79	0.699
IVRTr (ms)	-4.12±6.00	-1.50±4.82	0.085
MPIr (ms)	0.015±0.04	0.025±0.04	0.499

*Data are presented as the mean values ±SD, CD: Cesarean delivery, ET: Ejection time. IVCT: Isovolumetric contraction time. IVRT: Isovolumetric relaxation time. MPI: Myocardial performance index. s: septal mitral annulus. m: lateral mitral annulus. r: lateral tricuspid annulus, VD: Vaginal delivery. *Mann-Whitney U test p < 0.05 considered statistically significant*

Discussion

Significant alterations occur in vital signs, oxygen saturation, and umbilical cord blood pH values of the newborns according to the mode of delivery. Hagnevik et al. reported some differences in left ventricular dynamics in relation to general anesthesia, and there were no negative effects of maternal epidural anesthesia on early neonatal circulation of a healthy term infant (10,11). A study comparing epidural and general anesthesia for cesarean delivery in preeclampsia patients demonstrated an association with a lower neonatal umbilical arterial pH (12).

There are only a few studies in the literature that specifically assess the cardiac functions of the vaginally and abdominally delivered newborns by echocardiography. This prospective study has been designed to investigate the cardiac functions of the newborns delivered vaginally and abdominally under spinal anesthesia within a period of one month.

Despite the prominent advances in cardiac imaging, ejection fraction and fractional shortening are still the most com-

monly used parameters for assessing systolic functions. Serial echocardiographic measurements revealed postnatal changes in left ventricular diastolic filling and systolic cardiac performance in healthy term newborns (13). The neonates delivered via vaginal route and the cesarean section had statistically similar ejection fraction and fractional shortening values at their first visit and these values did not change significantly at the time of their second visit.

Barany and colleagues showed that atrial diastolic values remained stable despite the increase in early mitral velocities during the postnatal period and they suggested cardiac maturation leading to left ventricular relaxation was the cause (14). Eidem et al. revealed that mitral and tricuspid E velocities increased significantly over the first month of life while mitral and tricuspid A velocities decreased during childhood, and both mitral and tricuspid E/A ratio increased as a result (15). Hiarada et al. demonstrated a significant increase in tricuspid E and A velocities in healthy newborns during the first day of life (6).

In the present study, mitral and tricuspid E velocities were

higher than A velocity and increased by the time because ventricular preload is increased due to both higher pulmonary vascular resistance and persistence of ductus arteriosus. While the myocardium of neonatal heart is stiffer, cardiac maturation during the first days of life increases the compliance of ventricles resulting in their relaxation. Our findings of increased mitral and tricuspid E velocity in the cesarean newborns may indicate the impaired relaxation of both ventricles in cesarean delivery.

It is well known that the right ventricle E/E' ratio correlates with the right atrium pressure (16). In this study, newborns delivered by cesarean section had significantly higher right ventricle E/E' ratios. This finding can be attributed to the immature diastolic functions in relation to the relatively higher right ventricle filling pressure. However, both the vaginal delivery and cesarean section groups had statistically similar right ventricle E/E' ratios at their second visit and the alterations in these ratios were statistically insignificant within a period of one month.

Right ventricle contractions have a primary longitudinal component while left ventricle contractions have both circumferential and longitudinal components (17). As expected, diastolic and systolic velocities at the tricuspid annulus have their peak values in healthy newborns. Although IVRT was significantly prolonged, MPI did not change significantly in the cesarean delivery group at the time of the first visit. This finding implicates abnormal right ventricle relaxation in newborns delivered by cesarean section.

Systolic and diastolic velocities measured at the septum, tricuspid annulus and mitral annulus significantly correlate with age. That is, diastolic filling patterns are altered in healthy term neonates following delivery and these alterations do not depend on the mode of delivery (4). Similarly, this study demonstrated that E', A' and S' velocities measured by tissue Doppler echocardiography for both ventricles increased during the first month of life but this increase was statistically insignificant in both the vaginal delivery and cesarean section groups. These findings suggest that cesarean delivery is somehow associated with the impairment in right ventricle functions at birth but this impairment becomes insignificant after one month. It can be hypothesized that thoracic compression during vaginal delivery triggers the clearance of pulmonary secretions which may help to establish neonatal circulation more efficiently (18).

Study Limitations

The power of the present study was limited by the relatively small cohort size, inclusion of newborns with hemodynamically insignificant patent ductus arteriosus and lack of data related to inter-observer variability in echocardiographic measurements.

Conclusions

It is well known that elective cesarean section is associated with a higher risk of maternal and fetal morbidity than vaginal delivery. It has been recommended that health care providers should be aware of these potential risks and their decisions about the mode of delivery should be based on maternal and fetal benefits (19).

The present study has indicated that diastolic indices were significantly elevated in the newborns delivered by cesarean section than the neonates delivered vaginally. After one-month-long follow up, an increase was observed in diastolic ventricle functions of the vaginally delivered newborns but this increase was statistically insignificant. Therefore, it may be speculated that cesarean delivery is associated with the impairment in ventricular functions and, thus, a delay in the improvement and maturation of cardiac functions. Further research is warranted to clarify how the cardiac functions of the newborns are altered by the mode of delivery.

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