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Abstract

Postnatal adaptations of cardiac hemodynamics in infants born vaginally or by caesarean section may be different. These cardiac functions were evaluated by Doppler echocardiography to assess adaptation differences. Cardiac output, heart rate, stroke volume, mean arterial pressure, total systemic vascular resistance, ejection fraction, and ductus arteriosus diameter were determined and compared at 1, 24 and 72 h of life in 22 infants born vaginally (group 1) and 23 born by caesarean section (group 2). One hour after delivery, heart rate, mean blood pressure, and total systemic resistance were found to be higher in group 1 infants ($P < 0.01$, $P < 0.05$, $P < 0.05$ respectively). Stroke-volume measurements were significantly higher in group 2 ($P < 0.05$). The ejection fraction and cardiac output values were similar in both groups. At 24 and 72 h, no significant differences were observed in measurements of infants born vaginally or by caesarean section. We did not find a parameter negatively affecting healthy newborns in either mode of delivery. However, under pathological conditions affecting the cardiovascular system at 1 h of life, including perinatal infections and hypoxemia, a lower stroke volume, higher heart rate, higher mean blood pressure, and higher peripheral resistance may cause additional work load to the cardiovascular system in infants born vaginally.

KEYWORDS: newborn, Doppler echocardiography, vaginal delivery, caearean section

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Original Article

Non-invasive Evaluation of the Adaptations of Cardiac Function in the Neonatal Period: A Comparison of Healthy Infants Delivered by Vaginal Route and Caesarean Section

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Postnatal adaptations of cardiac hemodynamics in infants born vaginally or by caesarean section may be different. These cardiac functions were evaluated by Doppler echocardiography to assess adaptation differences. Cardiac output, heart rate, stroke volume, mean arterial pressure, total systemic vascular resistance, ejection fraction, and ductus arteriosus diameter were determined and compared at 1, 24 and 72 h of life in 22 infants born vaginally (group 1) and 23 born by caesarean section (group 2). One hour after delivery, heart rate, mean blood pressure, and total systemic resistance were found to be higher in group 1 infants ($P < 0.01$, $P < 0.05$, $P < 0.05$ respectively). Stroke-volume measurements were significantly higher in group 2 ($P < 0.05$). The ejection fraction and cardiac output values were similar in both groups. At 24 and 72 h, no significant differences were observed in measurements of infants born vaginally or by caesarean section. We did not find a parameter negatively affecting healthy newborns in either mode of delivery. However, under pathological conditions affecting the cardiovascular system at 1 h of life, including perinatal infections and hypoxemia, a lower stroke volume, higher heart rate, higher mean blood pressure, and higher peripheral resistance may cause additional work load to the cardiovascular system in infants born vaginally.

Key words: newborn, Doppler echocardiography, vaginal delivery, caesarean section

During early neonatal adaptation, the transition from parallel fetal circulation to 2 separate neonatal circulations involves fundamental hemodynamic changes. The primary mechanism is the decrease in pulmonary resistance, which causes an increase in blood flow to the lungs and a simultaneously increased blood flow from left to right through the open ductus arteriosus (DA) [1]. The increased flow in the DA shunt plays an important role in the physiological adaptation of the newborn, causing an increase in the left ventricle (LV) end-diastolic (LVED) volume reflecting a nearly maximum Frank-Starling response [2].

In animal experiments, the interruption of placental circulation and pulmonary blood flow increased to 6 fold greater than fetal levels has been found to cause a marked increase in LV preload [3].

Alterations in the adaptation of cardiac functions after birth are affected by many factors during the perinatal period. Fetal perfusion differences related to the mode of delivery (vaginal or caesarean section) and anaesthetic agents during parturition may have possible influences on fetal hemodynamics. Previously, the cardiac function of

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healthy newborns has been evaluated using biochemical and non-invasive methods [4-9]. Umbilical arterial catecholamine concentrations have been found to differ significantly between babies born vaginally and those born by caesarean section [4, 5], suggesting that the early neonatal cardiovascular adaptations may be different between the 2 modes of delivery.

Parameters causing alterations in the cardiovascular system may play an important role in determining the follow-up and treatment of congenital and acquired heart diseases.

Hagvenic *et al.* have noted that maternal epidural anaesthesia for elective caesarean sections with bupivacaine do not negatively influence early neonatal circulation [10].

We currently lack information regarding the differences in cardiovascular adaptations between infants born vaginally and by caesarean section and the influence on postnatal circulation in the early neonatal period. Cardiac output (CO) is the main parameter controlling organ perfusion and is determined by heart rate (HR) and stroke volume (SV) [11]. The ejection fraction (EF) is one of the main parameters for LV contractility, whereas total systemic resistance (TSR) is a determinant for afterload [12, 1].

In our study, alterations in CO, SV, HR, TSR, EF, mean blood pressure (MBP), and DA were measured and compared at 1, 24, and 72 of life in healthy newborns delivered vaginally and by caesarean section.

Materials and Methods

We studied 45 healthy newborns, 22 delivered vaginally (group 1) and 23 (group 2) by caesarean section. Gestational age was calculated from the first day of the last menstrual period. Case characteristics are shown in Table 1. None of the infants had a history of complicated pregnancy or delivery. Elective caesarean sections were performed by epidural anaesthesia using 10-12 ml of bupivacaine 5%. Apgar scores were above 8 at 1 and 5 min in all infants.

Informed parental consent was obtained in each case, and infants with congenital cardiac anomalies or any other disease requiring treatment were excluded.

The subjects included in this study were evaluated by CO, SV, HR, MBP, TSR, EF, and DA at 1, 24, and 72 h after birth. During examinations, all infants were in the supine position at standard room temperature, did not receive oxygen, and needed sedation.

Mean blood pressures (NIBP criticare monitor systems CO, 1100 3A Patient Monitor) were recorded. Heart rate was calculated from the interval time between 2 subsequent aortic waves. MBP, HR, and echocardiography measurements were carried out simultaneously.

Echocardiography. An M-mode, 2-dimensional, pulsed-wave colour Doppler echocardiography system with a 5-MHz transducer (Hewlett-Packard Co., image point, Andover, CA, USA) was used in the study. The Doppler sample volume was placed in the ascending aorta immediately distal to the aortic valve to record the aortic-flow velocity curve. A five-chamber and parasternal long-axis view of the heart was used for examination of the ascending aorta [13, 14]. The angle between the estimated direction of blood flow and the Doppler beam was 15 degrees or less in selected planes. For the diameter measurements, the ascending aorta was viewed along the long axis, with the M-mode beam being directed perpendicular to the anterior and posterior walls of the artery at the level of the aortic valve. The systolic flow velocity integral and ejection times were determined from the ascending aortic flow tracings and were calculated by planimetry. Aortic valve diameter measurements were performed at the level of the annulus from the systolic frame at the maximum diameter [15, 16]. Aortic valve area was calculated assuming that all valve orifices are circular. SV (ml) was calculated as A (aortic valve area cm^2) $\times$ VTI (velocity-time integral). CO (ml) and TSR (mmHg $\times$ min/ml) were calculated with equations SV $\times$ HR, mean blood pressure $\div$ CO respectively (1). CO and SV are expressed as milliliters per minute per kilogram and milliliters per kilogram.

The standard 2-dimensional tracings of the left ventricle volume were obtained under the guidance of a 4-chamber view. Both end-diastolic and end-systolic volumes were calculated using the bi planar Simpson's rule

Table 1 Case characteristics

	Group 1	Group 2	*P*
Number of patients	22	23	NS
Gestational age	39 ± 1.4 week	40 ± 1.7 week	NS
Female/Male	1.2	0.9	NS
Weight (kg)	3.4 ± 0.50	3.3 ± 0.35	NS

Group 1, infants born vaginally; Group 2, infant born by cesarean section.

method. LVEF was calculated using the formula: LVEF = LV end diastolic volume − LV end systolic volume ÷ LV end diastolic volume [17].

The shape and shunt of the ductus arteriosus were studied from the high left parasternal position. All measurements were repeated 3 times at different cardiac cycles, and mean values were used.

Statistical analysis. All data are expressed as mean ± standard deviations. The Statistical Program for Social Sciences (SPSS) ver. 10.0 was used for calculations. The Mann-Whitney *U* test was used for the comparison between characteristics of the 2 groups, and the Friedman test for the comparison of measurements at 1, 24, and 72 h were used.

Results

The HR, MBP, TSR, CO, SV, and EF measurement values are shown in Table 2.

At 1 h after birth, HR (148 ± 15 beats/min in group 1 and 129 ± 13 beats/min in group 2), MBP (50 ± 4 mmHg in group 1 and 44 ± 3 mmHg in group 2), and TSR (0.061 ± 0.01 mmHg × min/ml in group 1 and 0.042 ± 0.013 mmHg × min/ml in group 2) values were significantly higher in group 1 infants ($P < 0.01$, $P < 0.05$, $P < 0.05$ respectively) compared to group 2 infants. SV values were significantly increased in group 2 (2.7 ± 0.2) compared to group 1 (2.2 ± 0.1) ($P < 0.05$). (Fig. 1)

There were no significant differences between EF, and CO values of the 2 groups.

TSR, HR, MBP, SV, EF, and CO measurements at 24 and 72 h were similar between infants born vaginally and by caesarean section.

For both groups, changes in parameters except for HR were similar at 1, 24, and 72 h. HR decreased in group 1 from 148 ± 15 at 1 h to 130 ± 16 at 24 h ($P < 0.05$). This change was not observed in group 2, and no difference was noted at 72 h in either group. MBP increased significantly between 1, 24, and 72 h ($P < 0.05$). TSR, CO, and SV had changed significantly ($P < 0.05$) at 24 but not at 72 h in both groups. We could find no significant differences in EF values between the 2 groups.

No significant difference was observed in the length of the ductus arteriosus between infants born vaginally (3.2 ± 0.3 mm) and those by caesarean section (3.3 ± 0.4 mm). At 24 h, a left - to-right shunt pattern was observed in the ductus arteriosus in 2 infants from group 1 and in 3 from group 2. At 72 h no shunt was observed in any infants.

Discussion

In this prospective study, we observed higher HR, MAP, and TSR in infants born vaginally and lower SV in infants born by caesarean section at 1 h. At 24 and 72 h, these parameters were similar in both groups. Serial measurements of CO and EF did not reveal any difference between the 2 groups at 1, 24, and 72 h.

During the newborn period, important physiological, histochemical, and molecular adaptations occur in the cardiovascular system [18]. Quantitative hemodynamic and biochemical measurements can be used to evaluate these changes in infants born via the 2 different modes of delivery, with non invasive measurements using colour Doppler echocardiography the method of choice. In the literature, although there have been many reports investigating the evolution of adaptations in cardiac function in the newborn, there are few studies comparing cardiac adaptations between infants born vaginally and those born by caesarean section. In 2 previous studies, investigators

Table 2 The results of MBP, HR, TSR, CO, SV, and EF measures.

Parameters	After birth (h)								
	1			24			72		
	Group 1	Group 2	*P*	Group 1	Group 2	*P*	Group 1	Group 2	*P*
CO (ml/min)	344 ± 52	351 ± 58	NS	260 ± 47	264 ± 45	NS	249 ± 46	254 ± 48	NS
EF (%)	0.57 ± 0.03	0.58 ± 0.04	NS	0.55 ± 0.04	0.57 ± 0.05	NS	0.57 ± 0.05	0.56 ± 0.05	NS
HR (beats/min)	148 ± 15	129 ± 13	< 0.05	130 ± 16	128 ± 14	NS	125 ± 14	126 ± 13	NS
MBP (mmHg)	50 ± 4	44 ± 3	< 0.01	58 ± 7	56 ± 7	NS	66 ± 9	67 ± 8	NS
SV (ml/kg)	2.2 ± 0.1	2.7 ± 0.2	< 0.05	2 ± 0.2	2.1 ± 0.2	NS	1.9 ± 0.1	2 ± 0.2	NS
TSR (mmHg × min/ml)	0.061 ± 0.01	0.042 ± 0.013	< 0.05	0.073 ± 0.021	0.07 ± 0.024	NS	0.08 ± 0.022	0.08 ± 0.019	NS

CO, cardiac output; EF, ejection fraction; HR, heart rate; MBP, mean blood pressure; SV, stroke volum; TSR, total systemic resistance.

found no difference in CO measurements when comparing infants delivered by the 2 different methods [4, 5].

Catecholamine levels may be important in the transition from the fetal to the postnatal period. Most studies measuring the umbilical cord catecholamine levels in the 2 modes of delivery have found increased levels in infants born vaginally [4, 19]. Other parameters such as the levels of digoxin-like immunoreactive factor and adenosine are increased in the umbilical cords of infants born vaginally [20, 21]. Adenosine is known to enhance catecholamine levels [21], and the levels of these substances may influence the regulation of cardiac function.

TSR is considered to be an important afterload parameter. In our study, TSR was higher at 1 h in the

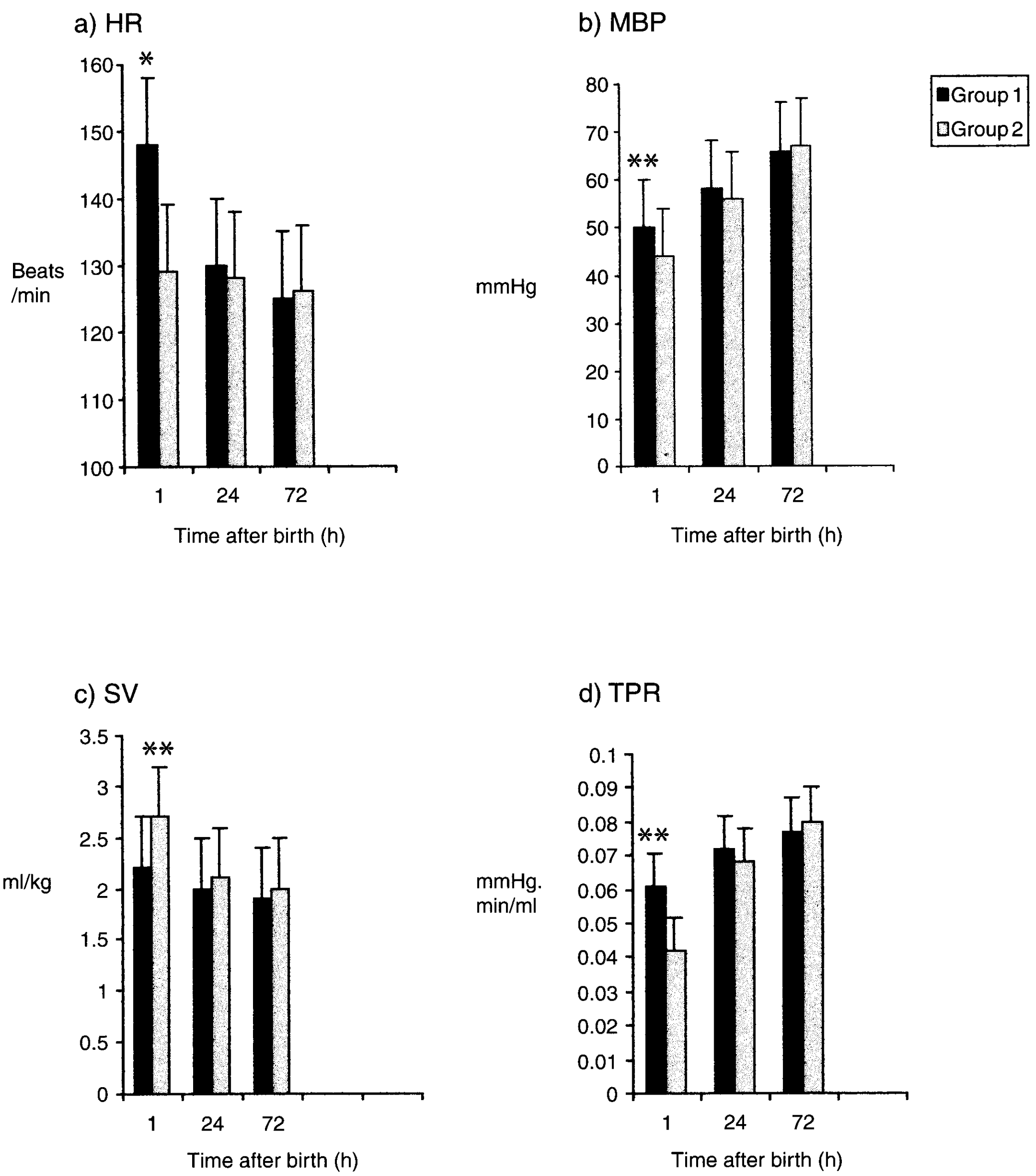

Fig. 1 Heart rate (HR) (**a**), mean blood pressure MBP (**b**), stroke volume (SV) (**c**), total peripheral resistance (TPR) (**d**) of newborn delivered by vaginally (Group 1) and by cesarean section (Group 2).
*The differences between the values of Group 1 and Group 2 are significant ($P < 0.01$).
**The differences between the values of Group 1 and Group 2 are significant ($P < 0.05$).

group 1 infants than in group 2, as was MBP. We could not measure the cord catecholamine levels, but it appears likely that these higher levels of TSR and MBP might be correlated with the levels of catecholamines in the umbilical cords of group 1 infants, based on previous literature reports [4, 19, 21]. SV was found to be lower at 1 h in group 1 than in group 2, and this finding is in accordance with the increased TSR and afterload. However, the higher HR in group 2 maintained the CO at similar levels to group 1 by compensating for the lower SV. Although the EF values were expected to increase due to the alterations described above, we found that they were similar in the 2 groups. A possible explanation may be the effect of increased levels of catecholamines on the immature heart of the newborn, which increases the heart rate but not the contractility. Important parameters of cardiovascular evaluation, EF and CO, were comparable in both groups at 1 h.

Since we measured the DA diameter in both groups at 1 h, we speculated that there were no differences in the adaptation mechanism affecting preload between the 2 groups [2, 3]. Doppler echocardiography is a useful non invasive method for evaluating the dynamic cardiac function of the newborn. In our study, we found no parameter that negatively affected the healthy newborns in either mode of delivery. However, with regard to the pathological conditions affecting the cardiovascular system such as perinatal infections and hypoxemia, it is important to consider the lower stroke volume and higher peripheral resistance associated with vaginal deliveries. These differences occurring in the cardiovascular system during the adaptation period are not important in healthy newborns during the early neonatal period. Nevertheless, we consider that these differences may lead to a decrease in inadequate tissue perfusion when the heart is exposed to pathological stress such as perinatal infection, hypoxemia, or congenital heart disease. Our findings suggest that further studies are necessary to further delineate the differences between the 2 modes of labor when the heart is exposed to pathological stress. In these high - risk patients, it may be necessary to select caesarean section to prevent cardiovascular problems.

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