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Evaluation of Superior Mesenteric Artery (SMA) and Celiac Artery (CA) Blood Flow Pattern in Preterm Infants and Factors Influencing the Blood Flow

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Abstract

Objective: To evaluate the blood flow velocity (BFV) in superior mesenteric artery (SMA) and celiac artery (CA) in first 2 days of life in preterm (less than 32 week and less than 1 kg) and to study the influence of various factors on the blood flow velocities in the same population.

Methods: 50 preterm less than 32 week with birth weight less than 1kg was included in the prospective observation study. Assessment of SMA and CA blood flow velocities (PSV: peak systolic velocity, EDV: end diastolic velocity, TAV: time average velocity) was done twice at 24hr (20-30) and at 48hr (40-54). Blood flow indices (resistive index; RI, pulsatile index; PI) was calculated using the formula. Simultaneously data for various factors influencing the blood flow in SMA and CA was collected in the similar population.

Results: SMA BFV increases from 24hr after birth and continue to rise thereafter in first 2 days. Significant increase in SMA EDV (6.77 ± 2.38 vs 8.74 ± 4.42) and SMA PSV (37.16 ± 10.64 vs 42.72 ± 14.66) was noted postnatally. Increase in SMA TAV was also observed. CA BFV showed negative trend from 24hr after birth with reduction of all velocities (PSV, EDV and TAV). CA TAV showed significant reduction at 48hr of age compared to 24hr (28.22 ± 9.81 vs 25.00± 8.07). Significant PDA was associated with attenuated BFV in both the SMA and CA on both the occasions. Other factors associated with adverse blood flow velocities were blood transfusion and anemia. Trophic feeding was associated with increase blood flow velocities in both SMA and CA.

Conclusion: Postnatally increase in SMA BFV was noted in first 2 days of life indicating improved intestinal perfusion and opposite trend in CA BFV. Significant PDA was associated with abnormal blood flow velocities in both SMA and CA.

Keywords: Blood Flow Velocity (BFV); Superior Mesenteric Artery (SMA); Celiac Artery (CA); Hemodynamically Significant Patent Ductus Arteriosus (HSPDA)

Introduction

Significant physiological and functional changes takes place at various organ level including gastrointestinal system (GI) in preterm newborn after birth. Superior mesenteric artery (SMA) and celiac artery (CA) supplies the blood to most of the intestine and vital abdominal organs respectively. Feeding problems are common in immediate postnatal period due to various anatomical and functional reasons leading to complication in the form of necrotizing enterocolitis (NEC). Blood pressure, capillary refill time (CRT), blood lactate, metabolic acidosis has limited value to predict the regional organ perfusion. Recently bedside ultrasound performed by trained neonatologist proved to be highly beneficial and regional organ blood flow velocities (BFV) and perfusion can be assessed more accurately with pulse wave Doppler.

Increase in SMA blood flow velocities was documented from birth onwards during the first month of life in preterm infants [1,2] which implies improved intestinal perfusion and maturation. Postnatal physiological changes in intestinal BFV were reported previously by few authors in term and late preterm infants [3]. Data related to physiological changes of CA BFA is limited in preterm newborns [4,5]. Various factors like cardiovascular status, neural control, humoral substances and local control determines the regional organ blood flow [6,7].

The objective of this study is to evaluate the blood flow velocity changes in major abdominal arteries (SMA and CA) in the immediate postnatal period in high risk population of preterm less than 32 week, less than 1kg and to study the various factors influencing the velocities. This data helps the clinician to understand the pattern of BFV in two major arteries in early postnatal life, which might help to reduce the feeding related problems and GI complications.

Methods

Subjects

Infants admitted to tertiary neonatal intensive care unit with GA less than 32 week and birth weight less than 1kg were enrolled for the

prospective study to evaluate the blood flow velocity in SMA and CA with simultaneous assessment of various factors influencing the blood flow pattern. Exclusion criteria were major congenital malformations, critical congenital heart disease and evidence of perinatal asphyxia requiring significant resuscitation (need of drugs).

The demographic data of study population is shown in table 1 and 2.

This study was approved by Dubai health authority (DHA) ethical committee and written informed consent was obtained from the parents before the subject enrollment.

Study design

50 infants fulfilling the inclusion criteria were included in this prospective observation study to evaluate the blood flow velocity in SMA and CA with simultaneous assessment of various factors influencing the blood flow pattern. The study population underwent bedside ultrasound twice at 24hr (20-30) and 48hr (40-54) to measure the blood flow velocities in SMA and CA. The measurements were done by single certified neonatologist trained in functional echocardiography and data for various factors influencing the blood flow velocities was collected simultaneously.

Factors studied which potentially influence the blood flow velocities

- Patent ductus arteriosus (PDA): Hemodynamically significant PDA (HsPDA) is defined as diameter ≥1.5mm, ratio of left atrial to aortic root dimensions ≥1.5:1, and reversal of diastolic flow in the descending aorta [8-10].
- Blood transfusion (BT): Infants receiving packed RBC transfusion as per the unit guidelines
- Anemia: Infants with hemoglobin (HB) less than 10gm%
- Presence of umbilical arterial catheter (UAC)
- Infants with proved positive blood culture sepsis
- Infants receiving trophic feeds
- Small for gestation (SGA) infants: Defined as birth weight less than 10th centile for GA

Doppler ultrasound studies

SMA and CA BFV were measured using pulsed Doppler ultrasound (vivid q GE, USA) and a 10 MHz transducer. A real-time two dimensional image and color flow mapping was used to identify the arteries. SMA was identified as the second major branch of the abdominal aorta, originating just below the CA (Figure 1). The sampling volume of the pulsed Doppler was placed 3 mm distal to the origin of the SMA and CA using a real-time two-dimensional image from a longitudinal abdominal approach. Angle correction was used when necessary.

When stable waveforms measurements were obtained, the curves were traced and the blood flow variables in each artery were calculated from at least three consecutive cardiac cycles of optimal quality .The recorded blood flow variables were: peak systolic velocity (PSV), end-diastolic velocity (EDV), time-averaged mean velocity (TAV). At least two sets of measurements were taken at each time point, and the mean of these readings was used for the final analysis. The resistive index (RI): (PSV-EDV)/PSV. The pulsatile index (PI) :(PSV-EDV)/TAV.

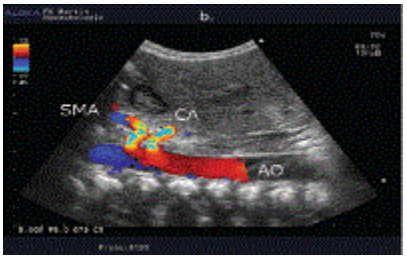

Figure 1: Doppler ultrasound view illustrating identification of the superior mesenteric artery (SMA) and celiac artery (CA) arising from the aorta (AO) in in a newborn.

Statistical analysis

Blood flow velocities – PSV, EDV and TAV and indices RI and PI for SMA and CA are shown as Mean ± SD. All the blood flow velocity variables at 24hr (20-30) and 48hr (40-54) were compared by using paired t-test. A p-value of <0.05 was considered significant. Statistical analysis were performed by using SPSS (Statistical Package for Social Sciences) version 20.0.

Results

Fifty infants were enrolled. The mean birth weight and GA of enrolled patients was 844±153gm and 27±2.1week respectively (table 1 and 2). Clinical variables that may affect the SMA and CA BFV are listed in table 1.

Variable	Value
Birth weight (gm.)	844±152
Gestational age(week)	27±2.1
Significant PDA n (%)	13(26)
Blood transfusion n (%)	8 (16)
UAC n (%)	12(24)
Trophic feeds n (%)	7/21* 14/42**
Anemia n (%)	6 (12)
Sepsis n (%)	4(8)
SGA n (%)	20(40%)
Data are the mean±s.d. unless otherwise indicated. n= number (*7 infants received trophic feeding at 24hr of age and ** 14 infants received trophic feed at 48hr of age) PDA-patent ductus arteriosus UAC-umbilical arterial catheter SGA-small for gestation	

Table 1: Demographic data and clinical variables for 50 new-born.

For each subject these variables did not change between the two scans. Postnatally, SMABFV showed rising trends with significant increase PSV (P 0.006) with simultaneous significant increase SMA EDV (P 0.001), which resulted in low RI and PI (table 3).

Variable	Distribution	Frequency
Sex	Male	26
	Female	24
GA(wk)	22-25+6	26
	26-27+6	13
	28-32	11
Birth weight(gm)	500-750	16
	751-999	34

Table 2: Demographic data.

	Variable	24hr(20-30)	48hr(40-54)
SMA	PSV(cm/s)	37.16 ± 10.64	42.72 ± 14.66**
	EDV(cm/s)	6.77 ± 2.38	8.74 ± 4.42***
	TAV(cm/s)	15.90 ± 5.02	17.90 ± 7.27
	RI	0.80 ± 0.05	0.79 ± 0.06
	PI	1.84 ± 0.45	1.89 ± 0.37
CA	PSV(cm/s)	51.38 ± 14.70	49.73 ± 13.53
	EDV(cm/s)	15.37 ± 6.77	13.89 ± 6.00
	TAV(cm/s)	28.22 ± 9.81	25 ± 8.07*
	RI	0.69 ± 0.09	0.72 ± 0.08*
	PI	1.32 ± 0.47	1.46 ± 0.40*

*p<0.05, **p<0.01, ***p<0.001

Data are the mean±s.d. unless otherwise indicated.

PSV: Peak systolic velocity; EDV: End-diastolic velocity; TAV: Time-averaged mean velocity; RI: Resistive index; PI: Pulsatile index; SMA: Superior mesenteric artery; CA: Celiac artery.

Table 3: Blood flow velocity variables in superior mesenteric artery (SMA) and celiac artery(CA) in 50 ELBW newborn.

SMA TAV also showed rising trend with advancing age although not statistically significant. On the contrary, CA BFV (PSV/EDV) showed negative trend, which was associated with high RI (P 0.025) and PI (P 0.027) with advancing age. CA TAV was significantly low at 48hr (P 0.023). The graphical representation of velocities in two major arteries is represented in figure 2.

13 preterm (table 1) were diagnosed with hemodynamically significant PDA. HsPDA was associated with high SMA PSV (44.40 ± 11.51 Vs. 35.11 ± 9.58, P 0.009) and low SMA EDV resulting high RI (0.86 ± 0.06 vs. 0.78 ± 0.04, P0.000) and high PI (2.19 ± 0.52 vs. 1.75 ± 0.38, P 0.004) compared to preterm without PDA. The adverse effect of HsPDA on mesenteric circulation persisted on day 2.11 infants were diagnosed with significant PDA at 24hr of age and the number increased to 13 at 48hr of age (not shown in the table).

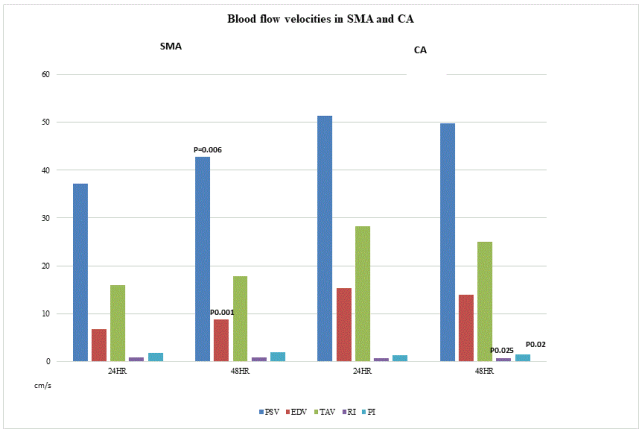

Figure 2: Blood flow velocities in SMA and CA.

Similar influence of HsPDA was observed on the CA BFV which was associated with high CA PSV (60.81 ± 13.64 Vs 48.71 ± 14.03) and low CAEDV resulting high RI (0.76 ± 0.10 vs. 0.67 ± 0.07 ,P 0.002) and high PI(1.66 ± 0.76 vs. 1.23 ± 0.30, P 0.007) on day1. This adverse effect of HsPDA on CA BFV was persisted on day 2 postnatal age.

Blood transfusion (n=8; table1) was associated with low SMA EDV (5.62 ± 2.97 vs. 6.98 ± 2.23), resulting high RI and PI in these babies. CA BFV influenced more adversely with BT compared to SMA resulting high PSV (66.18 ± 11.77 vs. 48.56 ± 13.56, P 0.001*) and high RI (0.77 ± 0.04 VS 0.71 ± 0.087, P 0.048*).

In SMA, Preterm with UAC (n=12; table 1) showed almost similar velocity pattern at 24hr (PSV: 35.83 ± 9.84 vs. 37.58 ± 10.98, EDV 6.75 ± 1.97 vs. 6.77 ± 2.53, TAV 15.12 ± 4.09 vs. 16.14 ± 5.30) and 48hr (PSV: 38.29 ± 9.18 vs. 44.11 ± 15.86, EDV 8.79 ± 3.55 vs. 8.72 ± 4.70, TAV 15.89 ± 5.69 vs. 18.53 ± 7.65) compared to preterm without UAC. CA BFV were also comparable in preterm with UAC and without UAC.

Anemia (n=6; table1) was associated with high SMA PSV (24hr: 43.41 ± 14.34 vs.36.30 ± 9.95, 48hr:44.50 ± 8.24 vs. 42.47 ± 15.38) and low EDV(24hr:6.41 ± 4.24 vs. 6.81 ± 2.09,48hr:8.66 ± 3.77 vs. 8.75 ± 4.54) on both the occasions, leading to high RI (0.83 ± 0.11 vs. 0.799± 0.05) and PI (1.82 ± 0.77 vs. 1.85 ± 0.40) compared to preterm with normal hemoglobin. This negative effect of anemia on SMA BFV was significant on day 2, resulting high PI (2.21 ± 0.26 vs. 1.84 ± 0.36*) and high RI (0.84 ± 0.02 vs. 0.78 ± 0.06).Similar influence of anemia was observed in CA, high PSV (24hr: 68.91 ± 9.89 vs. 48.98 ± 13.65 *) and low EDV.

Sepsis (n=4; table1) was associated with high CA BFV (PSV: 61.25 ± 12.33 vs. 50.52 ± 14.69, EDV: 22.82 ± 5.44 vs. 14.72 ± 6.53, P 0.02, TAV: 39.50 ± 11.79 vs. 27.23 ± 9.13, P 0.01) on day 1 and similar influence on mesenteric circulation was noted, which was not statistically significant.

Trophic feeding (n=7 at 24hr/21 at 48hr; table1) was associated with positive influence on SMA and CA velocities. SMA TAV (20.31 ± 9.16 Vs. 16.15 ± 4.99, P 0.044) was higher in trophic fed infants on day 2.

SGA preterm (n=20; table1) had low SMA velocities compared to AGA (n=30), whereas CA BFV were comparable in both the groups.

Discussion

Pulse wave Doppler has been used as a non-invasive parameter to assess the intestinal BFV in human newborns by measuring the blood flow in SMA and CA. Although there are some reports of physiological changes in intestinal blood-flow velocity after birth in healthy term infants [11,12] little is known about these changes in immature high risk preterm. To understand the maturation of intestinal circulation and pathophysiology of intestinal diseases in this population, we studied postnatal blood-flow velocity pattern in SMA, CA and factors influencing the blood flow by means of pulse Doppler ultrasound. Values at 24hr (20-30) were used as baseline reference values for the comparison.

Pappci et al. [1] and Coombs et al. [11], reported significant increase in SMA PSV and other velocities postnatally during the first month although velocities directly proportional to GA. Matsova et al. [3] and Kocvaroval et al. [13] showed significant increase in all SMA BFV resulting in low RI and PI in term and late preterm respectively. Agata et al. [12] and Martinussen [14] reported significant increase in SMA EDV compared to PSV in term infants during first 96hr of life, which predicts the improved intestinal perfusion compared to RI and other velocities. We also report that progressive increase in SMA BFV postnatally with significant increase in EDV and PSV-a finding in agreement with other investigators, which reflects improved intestinal perfusion. RI reflects vascular resistance, thus the index is inversely related to blood flow. A change in vascular resistance is presumed to influence diastolic BFV more than peak systolic BFV [14]. Under normovolemic conditions, the increase in PSV, EDV and TAV in the SMA are caused by a redistribution of abdominal systemic blood flow, because of the progressive opening of vascular beds due to a decrease in peripheral resistance under the influence of physiological factors like increasing blood pressure, increasing stroke volume and closure of the ductus arteriosus [2].

Pappci et al. [1] and Matsova et al. [3] in their studies showed positive trend in CA PSV, whereas CA EDV and TAV showed reducing trend resulting high RI and PI in preterm and term newborn. We reported negative trend in all CA velocities in first 48hr after birth resulting significantly high RI and PI – a finding in agreement with other reports possibly because of complex tributary system of celiac circulation [1].

Effect of significant PDA is not widely reported in CA, as it was studied in SMA. SMA EDV has been reported to decrease with symptomatic PDA [11,15,16]. Frank et al. [17] reported high SMA PSV and negative EDV with significant PDA with normalization to reference values after PDA closure. SMA diastolic BFV and TAV increases after closure of the ductus arteriosus with indomethacin was reported by Jakob et al. [18] and Shimada et al. [19]. El-Khuffash et al. [20] reported lower CA BFV in presence of PDA in his recent study. Consistent with these reports, our study also showed abnormal SMA (high PSV and low EDV) and abnormal CA BFV in presence of significant PDA.

Banerjee et al. [21] reported no significant change in SMA velocities after blood transfusion in ELBW preterm in agreement with other studies in term and old preterm infants. Pitzele et al. [22], demonstrated attenuated BFV response (low PSV) immediately post-transfusion in VLBW preterm. Nelle et al. [23] reported post-transfusion decrease CA BFV in stable preterm. Our study showed compromised intestinal blood flow after transfusion in study population although effect was significant in CA (high PSV).

In the present study, the presence of UAC did not have any adverse effect on the SMA and CA BFV – a finding that is in agreement with other investigators [24,25]. Position of UAC was confirmed with a follow up x-ray done after the insertion (all the infants in the study population had high position UAC). We observed slightly low PSV in both major arteries with UAC in situ without compromising the perfusion. Roll et al. [24] and Shah et al. [25] demonstrated that there was no difference in blood-flow velocities in the SMA and celiac axis before and after removal of a UAC in the high position. On the contrary, Rand et al. [26] showed low PSV with the UAC in situ. Havranek et al. [27] concluded that Pre-prandial and postprandial SMA BFV responses to minimal enteral feedings were not affected by the presence of a UAC.

Delay in the introduction of enteral feed is major cause for postnatal growth restriction adding to the morbidity in preterm infants [28-30]. Enteral feeding is essential for the promotion of intestinal maturation and growth, as it increases the intestinal blood flow, stimulates intestinal motility and induces release of trophic factors. Leidig et al. [31] and Fang et al. [32] reported significant increase in PSV after feeding in preterm infants hence concluded positive correlation between increase SMA velocities and feed tolerance. Other investigators, Martinussen et al. [4] and Thompson et al. [33], reported increase pre-prandial SMA EDV and increase SMA PSV after trophic feed respectively. In agreement with these reports, our study showed higher velocities in both major arteries after trophic feeding indicating improved perfusion.

Animal models demonstrate that anemia can impair gut blood flow and increase oxygen extraction as a compensatory mechanism [34,35]. Dani et al. [36] and Grisen et al. [37] showed no change in SMA BFV in anemic preterm secondary to autoregulation, which was in agreement with two other studies, which showed that SMA BFV parameters were not altered by anaemia [2,38]. Effect of anemia on CA BFV not studied previously in preterm infants. Our study concluded that anemia is associated with compromised intestinal blood flow (more in SMA) in high risk preterm, which needs to be studied in larger trial.

Kempley et al. [39] reported a similar effect to adult systemic inflammatory response in preterm with sepsis in both SMA and CA, although significant effect in later vessel.In agreement with this report-our study reported increased velocities in culture positive septic preterm infants with significant hyperemia in celiac circulation, which may result in increased cardiovascular demands in sepsis. Consistent with previous report [40], our study demonstrated low SMA BFV in SGA preterm compared to AGA; whereas CA BFV in both the groups were comparable.

This is clinically relevant study, which gives us a basic idea of baseline blood velocity pattern in two major arteries in high risk preterm infants. This study contributes to understand the physiological changes at the major viscera during the postnatal period. This study not only identifies the various factors influencing the intestinal blood flow pattern, but also describes the rate at which blood flow is affected .The main strengths of this study were, it's prospective and adequately subjects size population. The other advantages were the strict inclusion and exclusion criteria. On the other hand, the study

had some limitations. Firstly, it was not a randomized trial and was conducted at single centre.

Conclusion

High risk preterm infants showed improved intestinal perfusion associated with increased SMA velocities after birth.CA BFV showed opposite trend in the same period. Preterm with significant PDA have attenuated blood velocities in both arteries.

Conflict of Interest

The authors declare no conflict of interest

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