ORIGINAL ARTICLE

Early postnatal changes in superior mesenteric artery blood flow velocity in healthy term infants

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Abstract

OBJECTIVES: After birth, the newborn intestinal circulation undergoes physiological changes. The purpose of this work was to characterize the changes in mesenteric blood flow velocity occuring during the first three days of life in healthy term infants.
METHODS: 30 healthy term newborns were studied repeatedly at the age of 2, 24 and 70 hours. Blood flow velocity in superior mesenteric artery (SMA) was measured by Doppler ultrasound, peak systolic velocity (PSV), end-diastolic velocity (EDV) and time-averaged mean velocity (TAV) were recorded at each time point. Resistance index (RI) and pulsatility index (PI) were calculated.
RESULTS: SMA EDV increased from 2 h [−5.2±6.8 cm/s (mean ± SD)] to 24 h (12.9±3.8 cm/s, $p<0.001$) with further insignificant increase to 70 h (14.9±4.7 cm/s). At 2 h of age the mean EDV was negative in 23 of 30 cases (76.7%). PSV did not change between 2 h (58.0±21.8 cm/s) and 24 h (58.5±15.0 cm/s) but it increased to 70 h (79.6±17.7 cm/s). TAV showed a significant increase with time. RI decreased from 2 h (1.09±0.11) to 24 h (0.78±0.06, $p<0.001$) with further insignificant increase to 70 h (0.81±0.06).
CONCLUSIONS: The blood flow velocity in SMA increases during the early neonatal period in term infants. The most remarkable changes occur within the first 24 hours of life. At 2 h of age a reversed blood flow is present in majority of infants.

Abbreviations

SMA	– superior mesenteric artery
BFV	– blood flow velocity
PSV	– peak systolic velocity
EDV	– end-diastolic velocity
TAV	– time-averaged mean velocity
RI	– resistance index
PI	– pulsatility index

INTRODUCTION

The newborn intestinal circulation is unique when compared with its adult counterpart. Many of its specific features seem designed to facilitate postnatal intestinal function, as the neonate replaces the placenta with its gastrointestinal tract as the means to obtain nutrients (Reber *et al.*, 2002). The superior mesenteric artery is the major source of blood for the small intestine and to a portion of the large intestine. The dependence of intestinal blood flow on a single vessel implies that changes in SMA blood flow patterns may have significant physiologic effects on the bowel (Carver *et al.*, 2002). In preterm infants there is a significant increase in intestinal blood flow during the first week of life (Havranek *et al.*, 2006). There is increasing evidence that the rate of increase in SMA BFV may have clinical significance. Greater increases in postnatal SMA BFV in preterm infants are associated with less intestinal dysmotility (Robel-Tillig *et al.*, 2004) and with better tolerance to enteral feedings (Maruyama *et al.*, 1999, Fang *et al.*, 2001). In term newborn infants there are limited data concerning the physiological postnatal changes in intestinal circulation. The objective of this study was to characterize the changes in mesenteric circulation occuring during the first three days of life in healthy term infants.

MATERIALS AND METHODS

The study was approved by the local Institutional Review Board (IRB 0000 5636) and informed consent was obtained from the parents of each enrolled infant.

Subjects

Thirty healthy term infants (15 male and 15 female) were included in the study (mean gestational age 40 weeks, range 38–42 weeks). All infants were appropriate for gestational age (mean birth weight 3 500 g, range 2 710–4 220 g) and were born after uncomplicated pregnancies. Their postnatal course was uneventful, the infants were all breast fed. They were clinically stable in good condition without signs of cardiac or circulatory compromise. The examinantions were performed preprandially to eliminate influence of immediately proximate feedings on mesenteric blood flow. Blood flow velocity in SMA was measured with ultrasound Doppler repeatedly in each infant at the age of 2, 24 and 70 hours. No sedation was necessary, as the procedure was well tolerated by babies. The pacifier sucking was not used in this study. All infants were examined by the same investigator to avoid interobserver variability.

BFV measurements

A duplex scanner with pulsed Doppler and color flow mapping was used (Hawk 2102 EXL, B-K Medical). The studies were performed with the least ultrasound intensity necessary to obtain clinically readable waveforms using 7.5 MHz transducer. For imaging of SMA, the transducer was placed on the midabdomen above the umbilicus in the sagittal plane. Color flow mapping was used to identify the artery where it originated from the aorta. The sample volume of the pulsed Doppler was placed a few millimeters distal to the origin of the SMA. Angle correction was used when necessary. When stable waveforms were obtained, the curve was traced and the BFV was calculated. From the recorded Doppler tracings, PSV, EDV and time-averaged mean velocity TAV were obtained from the peak velocity envelope of five consecutive cardiac cycles. At each time point, at least two sets of measurements were recorded and the final measurements were the mean of these readings. The pulsatility index (PI) for SMA was calculated as: (PSV–EDV)/TAV. The PSV refers to the maximum systolic velocity, and the EDV refers to the minimum, end diastolic velocity. If diastolic flow is absent, minimum velocity equals zero. If the diastolic flow is reversed, minimum velocity equals maximum reversed diastolic flow and is recorded as a negative number. TAV is the average velocity under the waveform, which includes both systolic and diastolic flows. The resistance index (RI) was calculated as: (PSV–EDV)/PSV.

Statistical analyses

Comparisons of the measurement results at the particular time points were statistically analysed using a one-way ANOVA test and Bonferroni comparisons of means. $p<0.05$ was considered significant.

RESULTS

Data are shown as the mean ± SD and the confidence interval 95% in Table 1. The changes in splanchnic circulation over time are demonstrated by comparing the results from particular measurements at 2, 24 and 70 hours of life. PSV did not change from 2 to 24 hours, but there was a significant increase in PSV from 24 to 70 hours ($p<0.001$). EDV (Figure 1) started out rather low. The mean EDV showed negative values in 23 of 30 infants (76.7%) at the age of 2 hours. Until 24 hours the EDV reversed and increased up to 12.85 cm/s ($p<0.001$). At 24 and 70 hours EDV was positive in all infants. Further increase of EDV from 24 to 70 hours was not significant. TAV increased with time significantly ($p<0.001$). PI and RI (Figure 2) decreased from 2 to 24 hours, the differences were significant ($p<0.001$). Until 70 hours PI and RI increased again, they were insignificantly higher at 70 h than at 24 hours. Despite the increase they did not reach the values of PI and RI at 2 hours of age.

DISCUSSION

Blood flow and oxygen delivery into newborn intestine is greater than during fetal life. The rise in intestinal blood flow that occurs between fetal and newborn life should not be surprising. From a functional standpoint, the fetal intestine is a relatively dormant organ engaged in minimal activity so that a relative paucity of blood flow and oxygen delivery is adequate to meet its limited oxygen demand. After birth, the intestine is a site of intense metabolic activity as it becomes the sole site for nutrient absorption. This activity necessitates abundant intestinal perfusion and oxygen delivery (Reber *et al.*, 2002).

Doppler ultrasound technique permits noninvasive studies of the circulatory adaptive changes during the

Table 1. Superior mesenteric artery – Doppler ultrasound measurement results in healthy term infants at the age of 2, 24 and 70 hours.

	2 hours	24 hours	70 hours
PSV (cm/s)	58.0 (49.86–66.14) ± 21.81	58.54 (52.95–64.13) ± 14.96	79.61 (72.98–86.23) ± 17.74 *
EDV (cm/s)	–5.22 (–7.76 to –2.68) ± 6.81*	12.85 (11.44–14.25) ± 3.76	14.89 (13.14–16.64) ± 4.68
TAV (cm/s)	13.23 (10.63–15.84) ± 6.98 *	24.51(22.20–26.81) ± 6.17 *	30.33 (27.66–32.99) ± 7.13 *
PI	5.68 (4.67–6.70) ± 2.71 *	1.89 (1.73–2.05) ± 0.43	2.18 (2.0–2.37) ± 0.49
RI	1.09 (1.05–1.13) ± 0.11 *	0.78 (0.76–0.80) ± 0.06	0.81 (0.79–0.83) ± 0.06

values are mean (CI 95%) ± SD; *p<0.001.

early postnatal period. It is suitable for clinical practice and is well tolerated, even by the small sick newborn infants. Doppler ultrasound method can be used to study intestinal circulation. EDV follows the qualitative changes in blood flow very closely and it seems to predict the changes in blood flow better than TAV and RI. PSV did not correlate with SMA blood flow (Martinussen *et al*., 1996).

In our study, the EDV was in the early postnatal period negative in 76.7% of all infants. It is in contrary to study of Martinussen *et al*., (1994) that included fewer infants comparing with our study. Authors reported negative EDV at 1 h of age in two of ten infants. When measured at 2 h of age, one of eight infants had negative and seven had zero EDV. The reversed blood flow in SMA was probably due to left-to-right shunt through the ductus arteriosus, resulting in ductal steal. Ductus arteriosus was not evaluated in the current study, it was presumed to be physiologically opened at 2 hours and closed at 3 days of age in all infants (Martinussen *et al*., 1994). The SMA may be affected also by a steal effect from the coeliac axis, as it originates from the aorta only a few millimeters away from the SMA (Kempley and Murdoch, 2000). Interestingly, in the coeliac axis there were not observed negative values of EDV at any point in time (RI<1) (Matasova *et al*., 2006). Negative EDV may be also related to increased end organ vascular resistance documented by high RI. The clinical significance of the reversed blood flow in SMA in the early postnatal period is unclear. From h 24 onward, all measurements of EDV were positive. These results are in agreement with those of Martinussen and his coworkers (1994). Okada *et al*.,

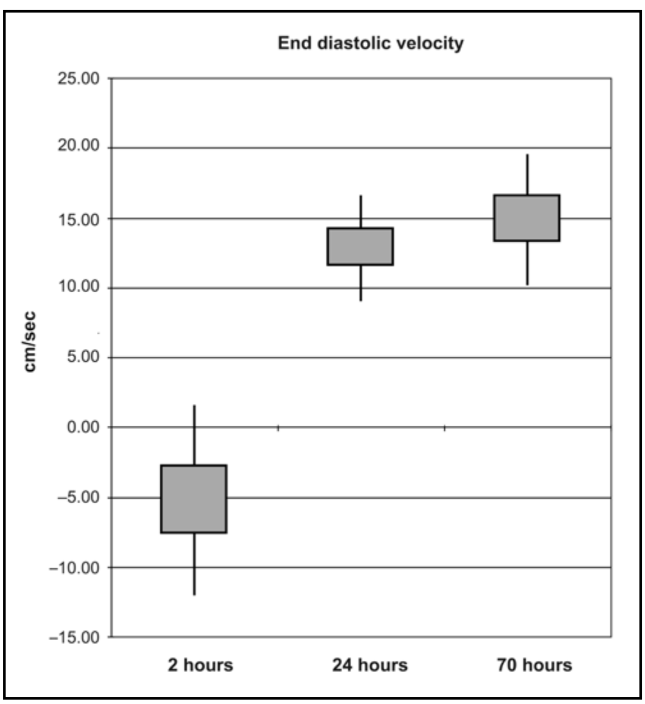

Figure 1. Changes in superior mesenteric artery EDV in connection with postnatal age. Mean EDV measured at 2, 24 and 70 hours after birth. Boxes represent 95% confidence limits, whiskers show standard deviation.

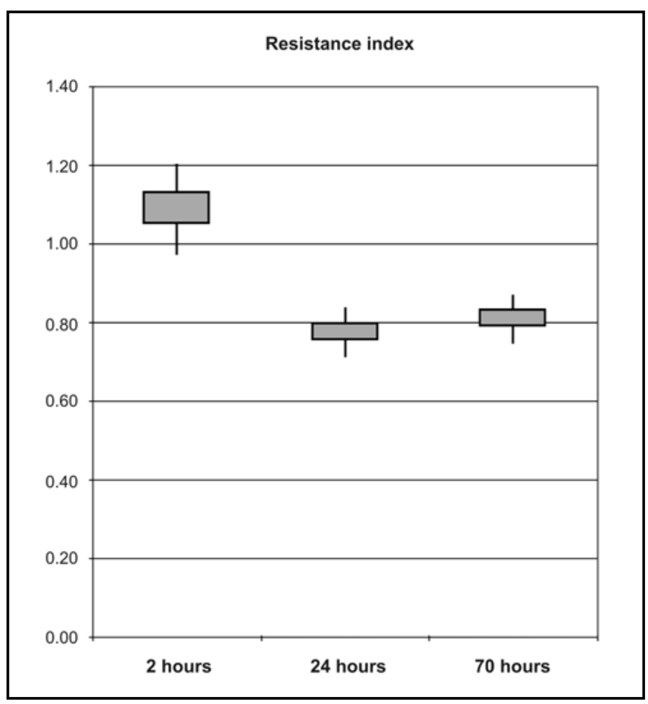

Figure 2. Changes in superior mesenteric artery RI in connection with postnatal age. Mean RI measured at 2, 24 and 70 hours after birth. Boxes represent 95% confidence limits, whiskers show standard deviation.

(2001) reported positive EDV (21.8±2.8 cm/s) in all of 22 infants at 10.0±1.6 days of age.

The superior mesenteric artery TAV should be directly proportional to blood flow provided the angle between the ultrasound beam and the blood flow vector, and the diameter of the vessel remained constant. Since local regulation of organ blood flow has been reported to take place in the small arterioles while the diameter of the larger arteries does not change, it has been suggested that Doppler studies of blood flow could be carried out in larger arteries without taking into consideration changes in the cross-sectional area of the vessels (Martinussen *et al.*,1996). During a cardiac cycle the diameter of SMA did not vary significantly, its mean value was reported 3.2 mm (range 2.7–3.7 mm) (Leidig, 1989). In our study, the low TAV in SMA at 2 h of age were a result of negative or very low EDV. TAV increased from hour 2 to hour 70 corresponding with previously reported data (Martinussen *et al.*, 1994). Leidig (1989) found the correlation of TAV with postnatal age as well.

The use of resistance index as a reflection of blood flow was based on the assumption that the index reflected vascular resistance, thus the resistance index was inversely related to blood flow (Martinussen *et al.*, 1996). Basal vascular resistance substantially decreases following birth (Nankervis *et al.*, 2001). A change in vascular resistance was presumed to influence diastolic blood flow velocity more than peak systolic blood flow velocity (Martinussen *et al.*, 1996). In our study RI decreased during the first 24 hours of life. At the same time the increase in the EDV was observed while the PSV remained unchanged. Thus, the decrease in RI was due to the increased EDV. This suggests that a decrease in local vascular resistance contributes to the increase in SMA blood flow velocity. The peak in the vascular resistance documented by the high values of RI at 2 h of age suggests, that intestinal vasoconstriction may play a role in the regulation of the systemic circulation in the presence of a ductal shunt. The reduction of intestinal vascular resistance occuring in the early postnatal period is probably the consequence of the increased endothelial production of the potent vasodilator nitric oxide (Reber *et al.*, 2002).

Changes in mesenteric EDV, TAV and RI in term infants reflect the increase in intestinal perfusion during the early neonatal period. The increase in EDV and TAV and decrease in RI from 2 h onward may be explained partly by the closure of the ductus arteriosus and the fall in basal intestinal vascular resistance, although the effect of enteral feeding may also have contributed. BFV in SMA increases after enteral feeding. Factors reported to influence the postprandial increase in SMA blood flow velocity in infants include feeding volume (Martinussen *et al.*, 1994; Leidig 1989), interval (Lane *et al.*, 1998) and meal composition (Carver *et al.*, 2002; Hsu *et al.*, 1994; Carver *et al.*, 2004). The pacifier sucking was also reported to influence mesenteric blood flow in newborn infants. PSV and EDV were significantly increased after pacifier sucking in the preprandial stage (Huang *et al.*, 2003).

In conclusion, the blood flow velocity in superior mesenteric artery increases during the early neonatal period in healthy term infants. A reversed blood flow was observed in majority of infants at 2 hours of age. The most remarkable changes in intestinal perfusion occur within the first 24 hours of life.

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