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NEONATAL RENAL ARTERY BLOOD FLOW VELOCITIES USING COLOR DOPPLER ULTRASONOGRAPHY

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INDEXING WORDS

neonate; preterm; renal blood flow velocity; color Doppler; ultrasonography

SYNOPSIS

Background: It is essential to evaluate the renal function for the management of high risk neonates. Color Doppler ultrasound technique can provide a useful information to evaluate the neonatal renal artery blood flow velocities.This study was performed to obtain the normative data of renal blood flow velocities in preterm and fullterm neonates and to compare the renal blood flow velocities with the aortic blood flow velocities. The normal volumetric state of fluid balance and renal function are essential in the management of the sick neonates.
Methods: The renal peak systolic blood flow velocity (renal PSFV), the renal mean blood flow velocity (renal MFV), the renal end diastolic blood flow velocity (renal EDFV) and the renal resistance index (renal RI) and also the cardiac output, the aortic peak systolic blood flow velocity (aortic PSFV) and the aortic mean blood flow velocity (aortic MFV) were serially recorded from one to 7 days after birth in 16 preterm and one to 5 days in 23 normal fullterm neonates.
Results: The renal PSFV was significantly increased with the postnatal age, and the renal MFV was significantly increased between three and five days of age in

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the preterm neonates. In the fullterm neonates there was no significant change of the renal PSFV between one and five days of age, but the renal MFV was significantly increased between three and five days of age. There were no statistically significant differences of the renal PSFV, the renal MFV, the renal EDFV and the renal RI between the preterm and the fullterm neonates in the first five days after birth. The cardiac output in the preterm neonates was higher than that in the fullterm neonates: on day 3; 313 ± 59 vs. 254 ± 40 ml/kg/min. ($p<0.001$) and on day 5; 357 ± 95 vs. 280 ± 35 ml/kg/min. ($p<0.01$).The renal blood flow velocities were not significantly correlated with the aortic blood flow velocities in the normal fullterm neonates, whereas, in the preterm neonates the renal PSFV correlated with the cardiac output ($r= 0.35$, $p<0.01$), the aortic PSFV ($r= 0.45$, $p<0.001$) and the aortic MFV ($r= 0.39$, $p<0.01$), and the renal MFV also correlated with the aortic PSFV ($r= 0.30$, $p<0.05$) and the aortic MFV ($r=0.32$, $p<0.05$).

Conclusions: The increased renal flow velocities with the postnatal age in the preterm infants might depend on the increased cardiac output.

INTRODUCTION

The renal function plays an essential role for normal growth and development of the neonates. Hypoxia, hypoperfusion due to birth asphyxia, respiratory distress syndrome and ventilatory management are vulnerable to damage immature proximal renal tubules in preterm neonates (2,11). The renal hypoxia increases the renal artery resistance leading to hypoperfusion, resulting low urinary output and the increased renal artery resistance, causes the decreased peak systolic flow velocity until the third day of age (1). A reliable parameter of the renal artery blood flow among the normal neonates is needed to establish for an effective management of sick neonates. The normal volumetric state of fluid balance and renal function are essential in the management of the sick neonates which is not easily calculated in bed side. Renal blood flow velocities gives the knowledge on state of hydration in a sick neonate. Color Doppler ultrasonography is widely used to investigate cardiovascular hemodynamics, cerebral blood flow in the neonates, because of noninvasive, easy and less time consuming technique. However, clinically this technique is uncommon to measure renal blood flow velocities among the neonates.

The purpose of this study is to obtain the reference normative values of the renal artery blood flow velocities in the early neonatal period and to compare the renal blood flow velocities with the aortic blood flow velocities as a tool for evaluating the renal function in sick neonates.

MATERIALS AND METHODS

Twenty-three normal fullterm and 16 preterm neonates admitted to the Neonatal center of Kobe University Hospital, between April 1995 and March 1996 were included for the study. The neonates who had completed 37 weeks of gestation and more than 2,499 g of birth weight without any medical as well as surgical intervention after birth were classified as the normal fullterm neonates and those who were born before completed 37 weeks of gestation and birthweight appropriate for date without any medical as well as surgical intervention and without pulmonary and circulatory problems after birth were classified as the preterm neonates. The neonates with patent ductus arteriosus by color Doppler imaging were excluded from the study. The mean and standard deviation of gestational age was 39.1 ± 1.1 weeks (range; 37 - 41 weeks) in the fullterm and 33.4 ± 1.6 weeks (range; 31 - 36 weeks) in the preterm neonates. Mean and standard deviation of the birth weight was 3,004 ± 298 g (range; 2,500 - 3,730 g) in the fullterm and 1,830 ± 297 g (range; 1,292 - 2,495 g) in the preterm neonates. Apgar score was more than 8 at one minute in fullterm neonates. The clinical data in preterm neonates showed Apgar score more than 6 and 8 at one and five minutes respectively, the serum creatinine was less than 1.2 mg/dl, urine output over 1 ml/kg/hour, and systolic blood pressure more than 50 mmHg and diastolic blood pressure more than 30 mmHg. Both the renal and aortic blood flow velocities were serially recorded on day 1 (24 hours), 3, 5 and 7 after birth in the preterm neonates and on day 1, 3 and 5 after birth in the normal fullterm neonates. An informed consent was obtained from the parents of the neonates before recording the data.

The Hewlett Packard YHP Sonos 500 with 5 MHz probe was used to record the blood flow velocities. The recordings were made on supine position one hour after feeding, when the neonates were quiet and comfort at rest. The renal artery blood flow velocities were recorded at 3 to 5 mm apart from the abdominal aorta through dorsolateral position of left and right lumber region just below the costal cartilage margin, where the renal artery was insonated at an angle of 0° insonation. The renal blood flow velocities; the renal peak systolic flow velocity (PSFV), the renal mean flow velocity (MFV), the renal end diastolic flow velocity (EDFV) were measured and the renal resistance index (RI) were calculated as follows: (PSFV - EDFV) / PSFV. At least three consecutive cardiac cycles were recorded and the median value was measured. The coefficients of variation according to the observers was within 6 % and all the recordings were performed by a single examiner to minimize the error (5). The aortic PSFV and the aortic MFV were similarly recorded and the aortic diameter was measured at the root of ascending aorta in longitudinal axis during the systolic phase within 15 -18° angle of insonation, and the cardiac output was calculated from the volumetric flow equation: $Q = \pi \times d^2/4 \times V \times 60$, where Q = volumetric flow in milliliters per minute, d = diameter of the aorta in centimeter, and V = mean velocity in centimeters per second (13). The blood flow velocities were expressed in cm/sec.

There were no statistically significant differences of the renal blood flow velocities between the left and the right renal artery in both preterm and fullterm neonates (data not shown) as mentioned by Visser et al (12), thus only the left renal artery blood flow velocities were used for data analysis. Statistical analysis was performed by t-test (two tailed) and Pearson Correlations using Macintosh SPSS 6.1 statistical package. All data are shown as mean ± 1 standard deviation, and p values less than 0.05 is considered as significant.

RESULTS

Renal blood flow velocities in fullterm neonates

There was no significant change of the renal PSFV and the renal EDFV between one and five days of age. The renal MFV was significantly increased from 17.6 ± 4.4 cm/sec on day 3 to 19.8 ± 3.5 cm/sec on day 5 ($p<0.05$), as shown in Table I and Figure 1.

Renal blood flow velocities in preterm neonates

The renal PSFV was significantly increased with the postnatal age; 41.3 ± 6.4 cm/sec on day 1, 44.2 ± 6.1 cm/sec on day 3, and 46.8 ± 4.1 cm/sec on day 5 (day 1 vs. day 3; $p<0.05$, day 3 vs. day 5; $p<0.05$) as shown in Figure 1. The renal MFV was significantly increased from 17.0 ± 2.7 cm/sec on day 3 to 19.5 ± 3.7 cm/sec on day 5 ($p<0.05$). There was no significant change in the renal EDFV and the renal RI within seven days after birth.

Comparisons of renal flow velocities between preterm and fullterm neonates

There were no statistically significant differences of the renal PSFV, the renal MFV, the renal EDFV and the renal RI between the preterm neonates and the fullterm neonates in the first five days after birth as shown in Table I.

Table I. Aortic blood flow and renal blood flow velocities in preterm and fullterm neonates.

	Day 1		Day 3		Day 5		Day 7
	Preterm	Fullterm	Preterm	Fullterm	Preterm	Fullterm	Preterm
	n= 16	n=23	n= 16	n=23	n= 16	n=21	n= 15
Aortic blood flow							
Cardiac output, ml/kg/min	305 ± 111	279 ± 38	313 ± 59 ***	254 ± 40	357 ± 95 **	280 ± 35	341 ± 60
PSFV, cm/sec	77.4 ± 11.7	80.6 ± 6.6	76.9 ± 7.8	78.0 ± 8.9	79.9 ± 6.6	82.2 ± 6.1	77.0 ± 5.7
MFV, cm/sec	22.7 ± 4.8 **	26.9 ± 2.0	23.8 ± 7.4	24.5 ± 2.9	23.9 ± 3.4 **	27.2 ± 2.2	22.8 ± 3.2
Renal artery blood flow							
PSFV, cm/sec	41.3 ± 6.4	43.6 ± 6.5	44.2 ± 6.1	44.0 ± 6.3	46.8 ± 4.1	44.4 ± 6.3	46.7 ± 4.0
MFV, cm/sec	16.7 ± 2.6	16.9 ± 3.4	17.0 ± 2.7	17.6 ± 4.4	19.5 ± 3.7	19.8 ± 3.5	18.0 ± 3.8
EDFV, cm/sec	7.09 ± 2.13	6.58 ± 2.65	6.58 ± 2.52	6.96 ± 3.08	7.69 ± 2.71	7.72 ± 2.81	6.52 ± 2.09
Resistance index	0.82 ± 0.06	0.84 ± 0.07	0.85 ± 0.06	0.84 ± 0.07	0.84 ± 0.05	0.82 ± 0.07	0.86 ± 0.04

PSFV; Peak systolic blood flow velocity, MFV; Mean blood flow velocity, EDFV; End diastolic blood flow velocity

Values are mean ± SD.

** $p<0.01$, *** $p<0.001$, preterm versus fullterm neonates (unpaired t-test).

Table II. Correlation coefficients of renal blood flow and aortic blood flow in normal preterm and fullterm neonates.

a) Preterm neonates.

Aortic blood flow	Renal blood flow PSFV	MFV	EDFV	RI
Cardiac output	0.3463 **	0.1357	0.0030	0.1503
PSFV	0.4508 ***	0.3032 *	0.3480 **	-0.1373
MFV	0.3780 **	0.3216 *	0.3001 *	-0.1071

b) Fullterm neonates.

Aortic blood flow	Renal blood flow PSFV	MFV	EDFV	RI
Cardiac output	0.1815	-0.0061	-0.0021	0.0519
PSFV	0.2120	-0.0564	-0.1863	0.2450 *
MFV	0.0234	-0.0025	-0.0539	0.0411

PSFV; Peak systolic blood flow velocity, MFV; Mean blood flow velocity.

EDFV; End diastolic blood flow velocity, RI; Resistance index.

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

Aortic blood flow velocities in fullterm neonates

The cardiac output on day 3 was significantly lower than that on day 1 ($p<0.01$) and on day 5 ($p<0.001$) (Figure 2). The aortic PSFV on day 3 was significantly lower than that on day 5 ($p<0.01$), and the aortic MFV on day 3 was also significantly lower than that on day 1 ($p<0.01$) and day 5 ($p<0.01$) (Figure 3).

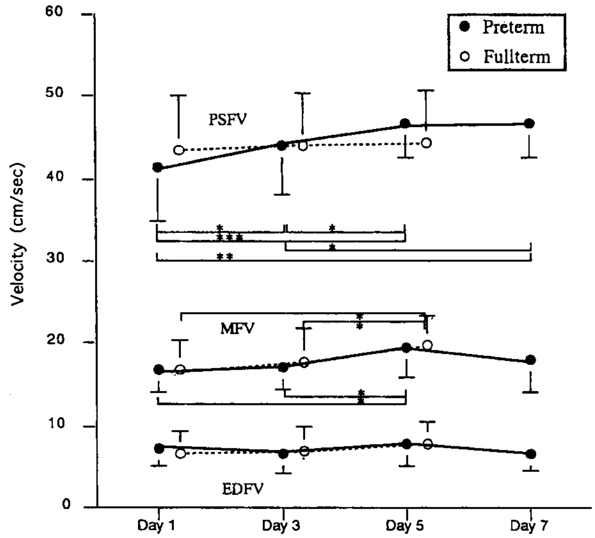

Fig. 1. Renal artery blood flow velocities in normal preterm and fullterm neonates.
* $p<0.05$, ** $p<0.01$, and *** $p<0.001$

Aortic blood flow velocities in preterm neonates

Both the cardiac output and the aortic PSFV were increased between day 3 and day 5 in the preterm neonates ($p<0.01$, respectively). There was no postnatal change of the aortic MFV in the preterm neonates.

Comparisons of aortic flow velocities between preterm and fullterm neonates

The cardiac output in the preterm neonates was higher than that in the fullterm neonates: on day 3; 313 ± 59 vs. 254 ± 40 ml/kg/min. ($p<0.001$) and on day 5; 357 ± 95 vs. 280 ± 35 ml/kg/min. ($p<0.01$). There were no differences of the aortic PSFV between the preterm and the fullterm neonates, however the aortic MFV in the preterm neonates was significantly lower than

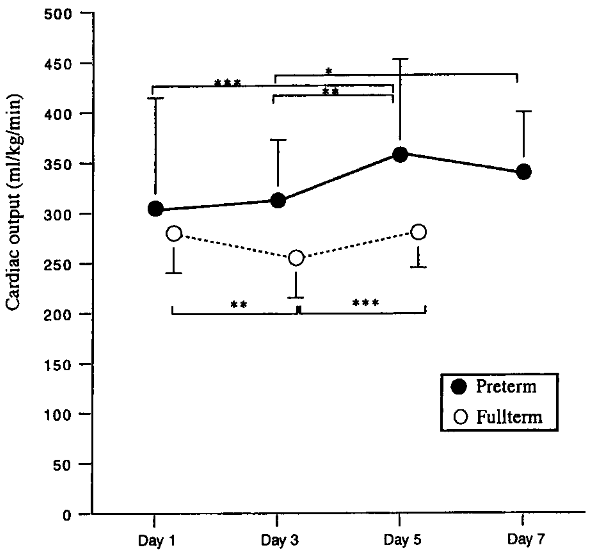

Fig. 2. Cardiac output in normal preterm and fullterm neonates.
* p<0.05, ** p<0.01, and *** p<0.001

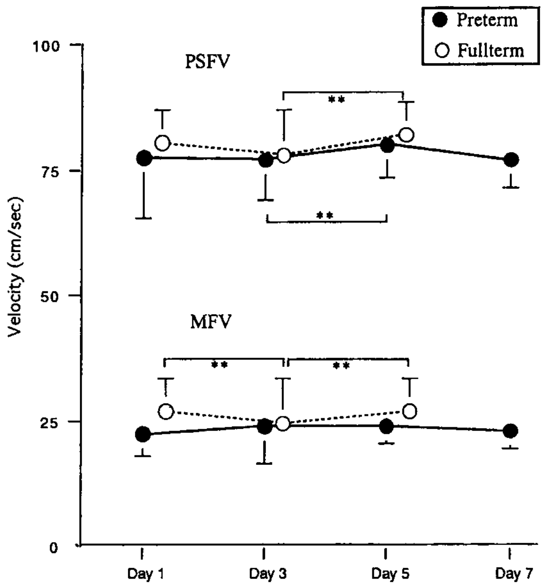

Fig. 3. Cardiac output velocities in normal preterm and fullterm neonates.
** p<0.01

that in the fullterm neonates: on day 1; 22.7 ± 4.8 vs. 26.9 ± 2.0 cm/sec ($p<0.01$) and on day 5; 23.9 ± 3.4 vs. 27.2 ± 2.2 cm/sec ($p<0.01$).

Correlations between renal blood flow velocities and aortic blood flow velocities.

In the preterm neonates, the renal PSFV correlated with the cardiac output ($r= 0.35$, $p<0.01$), the aortic PSFV ($r= 0.45$, $p<0.001$) and the aortic MFV ($r= 0.39$, $p<0.01$). The renal MFV correlated with the aortic PSFV ($r= 0.3032$, $p<0.05$) and the aortic MFV ($r=0.32$, $p<0.05$), and the renal EDFV correlated with both the aortic PSFV ($r= 0.35$, $p<0.01$) and the aortic MFV ($r=0.30$, $p<0.05$) (Table II).

There were no statistically significant correlations between the renal blood flow velocities and the aortic blood flow velocities in the fullterm neonates.

DISCUSSION

Color and pulsed Doppler ultrasonography provides non invasive estimate of the blood flow velocities in the renal artery under a very sharp wave (3). A reliable identification of the renal arteries is possible because they are the only two arteries to branch off pairs in the upper abdominal aorta and to have a characteristic flow velocity waveform with a prominent flow velocity throughout the diastolic phase. The actual renal blood flow volume cannot be determined with this technique, which is not sensitive enough to measure the internal diameter of the renal artery accurately; even though several previous reports showed that the renal blood flow velocity measurement may be indicative of the renal blood flow (6,9,10). In the preterm lambs, the blood flow to various organs (kidneys, liver, spleen, gastrointestinal tract and adrenal glands) is reduced during patency of the ductus arteriosus, mainly because of a reduced perfusion pressure (4). Thus, the infants with patent ductus arteriosus by color Doppler flow imaging were excluded from the study to obtain normative data for the renal artery blood flow, because left-to-right ductal shunt may develop absolutely or relatively reduced the renal blood flow.

Bomelburg et al.(3) showed that the maximum renal blood flow velocity significantly increased with the body weight from 17 cm/sec below 1,000 g to 29 cm/sec above 3,000 g of body weight, and the pulsatility indices were dependent on body weight. Otherwise, Visser et al. (12) have demonstrated that the renal blood flow increased significantly with advancing birth weight and gestational age, because of increased vessel diameter but the blood flow velocity did not. In this study there were no differences of the renal peak systolic blood flow velocity, the renal mean blood flow velocity, the renal end diastolic blood flow velocity and the renal resistance index between the preterm and the fullterm neonates in the first five days after birth. The renal peak systolic blood flow velocity increased with age in the first five days in the preterm neonates, and the renal mean flow velocity increased significantly on day 5 both in the preterm and the fullterm neonates. Koons et al. (7) has mentioned that the pulsatility index represents the vascular resistance, which is only one parameter to influence the blood flow, however the measurement of pulsatility index of cerebral artery can be used to follow the trends in the cerebral circulation. In this study there was no difference of the resistance index of renal blood flow between the preterm and the fullterm neonates in the first five days after birth. These results suggest that there is no difference of the renal blood flow between these two groups and also no change with advancing age.

The redistribution of organ blood flow occurs after a decrease in the cardiac output: usually decreased blood flow to the kidneys and gastrointestinal tract and an relatively increased blood flow to the brain, adrenal glands and diaphragm (3). It has been reported that a reduction in the renal mean blood flow velocity was found in small preterm infants with severe respiratory distress syndrome (3,12) and a reduction of the renal blood flow velocity was associated with a reduction in the cardiac output, which may occur in infant undergoing mechanical ventilation, because high intrathoracic pressure can obstruct the venous return to the heart (8). This study revealed that the aortic peak systolic flow velocity and the cardiac output were significantly increased on day 5 in both the preterm and the fullterm neonates: in particular, the cardiac output in the preterm neonates was higher than that in the fullterm neonates. This phenomena is thought to be due to the extrauterine physiological adaptation in the early neonatal period. The renal blood flow velocities were independent from the cardiac output in the fullterm neonates, whereas, in preterm neonates both the peak systolic and the mean blood flow velocity of renal artery were correlated with the aortic peak systolic blood flow velocity and with the aortic mean blood flow velocity. These results suggest that the increase of the renal blood flow velocity in preterm neonates might depend on the increased cardiac output by age.

This study revealed the normative data of the renal blood flow velocities in the preterm and the fullterm neonates with an adequate urine output and with an adequate blood pressure according to their age advancement. The further studies should be performed to obtain the renal blood flow velocities influencing the urine output in critically sick neonates.

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