Normative Values of Doppler Parameters of Blood Flow in the Fetal Hepatic Artery of Normal Karyotype Fetuses at 11–14 Weeks Gestation

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The aim of the investigation was to develop normative (percentile) values of the peak systolic velocity (PSV) and the pulsatility index (PI) in the fetal hepatic artery in relation to the parietal-coccygeal length at 11–14 weeks gestation.

Materials and Methods. PSV in the hepatic artery and its PI were estimated in 192 normal karyotype fetuses at 11–14 weeks of gestation.

Results. The average values of PSV were 12.13±2.5 cm/s. They ranged up to 11.1 cm/s in those cases where the parietal-coccygeal length of the fetus was 45–52 mm and up to 14.6 cm/s when it was 62.1–79.0 mm. The upper limit of the norm was set as the 90th percentile. The average value of PI in the fetal hepatic artery was 1.98±0.12, standing at 1.9 in those cases where the parietal-coccygeal length was 45–52 mm and 1.7 where it was 62.1–79.0 mm. The lower limit of the norm was set as the 10th percentile.

Conclusion. As the gestation period and, therefore, the parietal-coccygeal length of the fetus increase, the PSV in the fetal hepatic artery also increases, while the PI decreases. Such specific normative values of the blood flow indicators can be used in clinical practice to determine the risk groups for unfavorable perinatal outcomes.

Key words: fetal hepatic artery; peak systolic velocity of blood flow; pulsatility index; fetal parietal-coccygeal length.

The main source of the fetal liver blood supply is the umbilical vein (70–75%). The other sources are the venous portal system which contributes 20% of the blood poorly oxygenated, and the hepatic artery (10%) [1]. The hepatic vascular system has the capacity for supporting blood supply at sufficient levels even in unfavorable conditions, for example, in hypoxia. The lumen of the hepatic artery expands when the blood supply from other sources decreases. The widening of the hepatic artery occurs due to the activation of adenosine receptors which can be found in the vessel wall. Ebbing et al. [2] studied the parameters of the blood supply in the hepatic artery: peak systolic velocity (PSV) and pulsatility index (PI) at 19–28 weeks of gestation in normal pregnancies, as well as in cases of anemia, cases of stunted fetal growth, and during acute blood loss in the mother. Blood flow in the hepatic artery was first studied at 11–14 weeks of pregnancy by Bilardo et al. [3, 4] who compared the parameters of blood flow in the hepatic artery in fetuses with normal karyotype with those in cases of chromosomal or structural anomalies. In our publications in 2013 we performed analogous comparisons [5]. As in the investigations of Bilardo et al. [4], Zvanca et al. [6] showed that if there is any widening of the nuchal translucency or there are some innate malformations, the resistance within the blood system decreases compared to the norm. As the norm we used the average values of PSV and PI at 11–14 weeks of pregnancy.

However, in clinical practice to determine the risk groups for unfavorable perinatal outcomes, the normal (percentile) values of these parameters should be available to enable quicker diagnosis and the prognoses for the perinatal outcomes. Furthermore, as the gestational age and the size of the fetus are increasing, the values of the normal blood flow parameters change as well. That is why it is of interest to determine the relationships between the parameters of blood flow in the hepatic artery and the parietal-coccygeal length.

The aim of the investigation was to develop normative (percentile) values of the peak systolic velocity and the pulsatility index in the fetal hepatic artery in relation to the parietal-coccygeal length at 11–14 weeks gestation.

Materials and Methods. 192 patients with uncomplicated pregnancies were studied at the gestational stage of 11–14 weeks. To complete the investigation we selected only those findings obtained from examinations of patients whose pregnancies ended with the delivery of healthy children at term. The study was carried out at the District Office of Prenatal Diagnostics of Nizhny Novgorod (Maternity Clinic

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No.5) in 2012–2014. We used ultrasound equipment of middle and expert class: Logiq 7, Voluson 730 Expert (GE, USA), Accuvix V10 (Medison, South Korea), and HD11XE (Phillips, the Netherlands).

The study was performed in accordance with the Declaration of Helsinki (accepted in June 1964 (Helsinki, Finland) and reviewed in October 2000 (Edinburgh, Scotland)) and approved by the Ethical Committee of the Nizhny Novgorod State Medical Academy. Each patient signed an informed consent form.

The gestation age was determined according to the first day of the last menstruation, and was, on average, 12 weeks 3 days. The age of the patients varied from 19 to 40, on average, 28.0±4.6. Twenty of the pregnant women were older than 35 (10.4%). There were 134 primiparous (69.8%) and 58 (30.2%) multiparous women. 192 children with normal karyotype and without malformations were delivered, including 110 (57.3%) girls and 82 (42.7%) boys. The average weight of each child at birth was 3,220±311 g (from 2,700 to 4,350 g). 30 children (15.6%) had a weight of more than 4,000 g. The average height was 51.2±2.2 cm (from 47 to 56 cm), which corresponds to the average data for the population.

The measurement of blood flow parameters in the fetal hepatic artery was performed by triplex scanning using color Doppler imaging and Doppler pulsed wave modes. The evaluation of blood flow in the fetal hepatic artery in the living fetuses was performed with adherence to the ALARA principle of safety (as low as reasonably achievable), that is with minimisation of radiation exposure, and at all times within reasonable limits. The following quantitative parameters of the arterial blood flow were evaluated: PSV and PI in the fetal hepatic artery. The selection of these blood flow parameters was based on the fact that in some instances during the investigation the curves of blood flow velocity in the hepatic artery had a zero diastolic component, therefore measurement of the resistance index was impossible. That is why we decided to measure the PI as an angle-independent parameter.

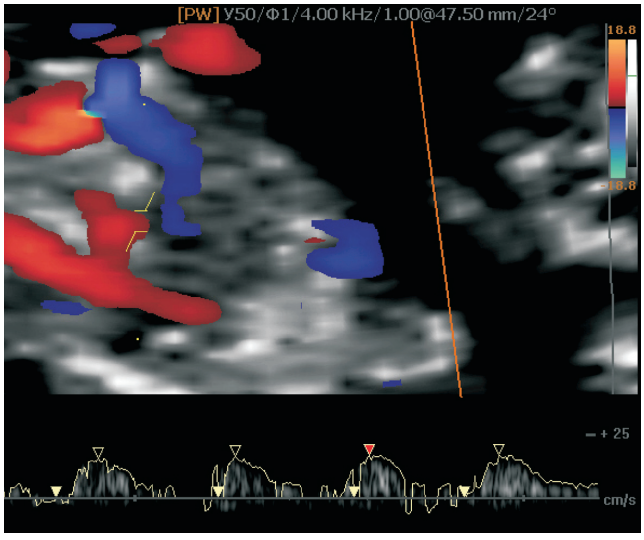

Figure 1. Transabdominal investigation of Doppler parameters of blood flow in the hepatic artery of a fetus with normal karyotype at 12–13 weeks gestation (peak systolic velocity of blood flow is 12.6 cm/s, with a pulsatility index of 1.82)

Blood flow in the fetal hepatic artery was evaluated by transvaginal and transabdominal investigation according to the methods suggested by Zvanca et al. [1, 6]. We obtained the sagittal section of the fetus body using color Doppler imaging, took an image of the ductus venosus, then decreased the control volume of scanning to 1 mm and shifted downwards in the direction of the descending aorta on a small vessel extending from the aorta (Figure 1).

Results and Discussion. All the patients taking part in the investigation were evaluated for the presence of markers of chromosome anomalies and for the anatomy of the fetus according to the guidelines of the International Fetal Medical Foundation. None of the fetuses from the group under investigation had any ultrasound markers of chromosome anomalies or malformations. The values of nuchal translucency thickness fluctuated from 0.9 to 2.3 mm, an average of 1.63±0.32 mm. This thickness increased in line with increased parietal-coccygeal length.

During the investigation there were some difficulties in finding the hepatic artery: malposition of the fetus, its small size, periods of active fetal movement, and anomalous topographic anatomy of the hepatic artery. The time spent on searching for the vessel and on the examination of the blood flow in each fetus was, on average, 3–5 min.

PSV values in the fetal hepatic artery at 11–14 weeks of gestation varied from 5.7 to 17.8 cm/s, while the PI values ranged from 1.62 to 2.6 (Table 1).

It was determined that the PSV and PI values depended on the parietal-coccygeal length: the greater this length the greater the PSV, while the PI, by contrast, decreased (Figure 2).

The findings allowed us to determine normative values for the PSV and PI of the fetal hepatic artery depending on its parietal-coccygeal length in the first trimester of

Table 1

The values of peak systolic velocity of blood flow and pulsatility index in the fetal hepatic artery at 11–14 weeks gestation

Parameters	Peak systolic velocity of blood flow (cm/s)	Pulsatility index
Maximal value	17.8	2.6
Minimal value	5.7	1.62
Average value	12.13	1.98
Standard deviation	2.25	0.22

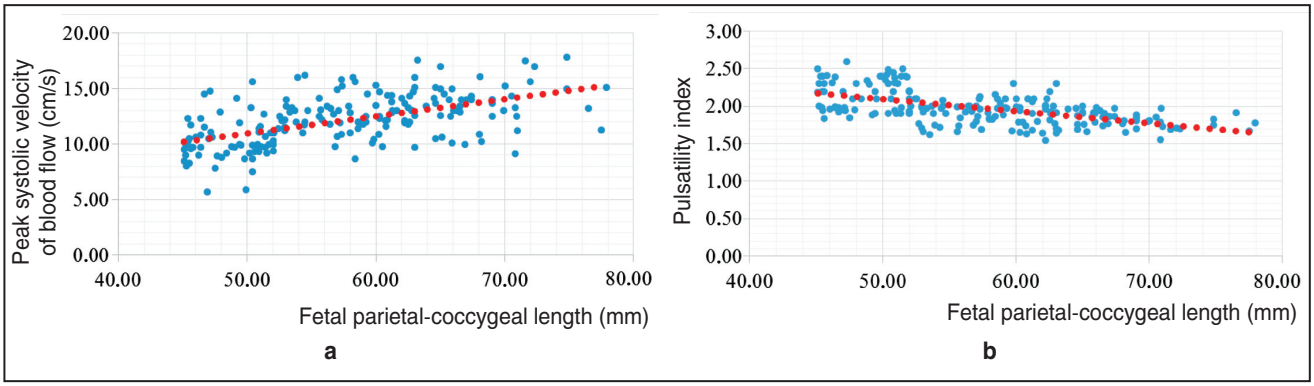

Figure 2. Blood flow parameters in the fetal hepatic artery in relation to its parietal-coccygeal length at 11–14 weeks gestation: (a) peak systolic velocity of blood flow; (b) pulsatility index. The average value of the parameter is marked in red

Table 2

Normative values of peak systolic velocity of blood flow and pulsatility index in the fetal hepatic artery in the first trimester of pregnancy

Fetal parietal-coccygeal length (mm)	Peak systolic velocity of blood flow (cm/s)			Pulsatility index		
	Percentile					
	10th	50th	90th	10th	50th	90th
45.0–52.0	6.2	11.1	17.1	1.45	1.9	2.2
52.1–62.0	9.5	12.7	18.8	1.4	1.8	2.1
62.1–79.0	10.2	14.6	21	1.35	1.7	2.0

pregnancy. The results are represented as a normative percentile table (Table 2).

Thus, studying the blood flow parameters in the fetal hepatic artery we obtained the percentile values of PSV and PI depending on the parietal-coccygeal length of the fetus. The values of the average PSV ranged from 11.1 cm/s when the parietal-coccygeal length of the fetus was 45–52 mm, up to 14.6 cm/s when the parietal-coccygeal length was 62.1–79.0 mm. On average they were 12.13±2.50 cm/s. The upper limit of the norm was defined as the 90th percentile. The average value of PI in the fetal hepatic artery was 1.9 in the case of the parietal-coccygeal length being 45–52 mm but stood at 1.7 in those cases where the parietal-coccygeal length was 62.1–79.0 mm. The average PI value was 1.98±0.12. The lower limit of the norm was defined as the 10th percentile.

In the investigations of Zvanca et al [6] the average PSV of the hepatic artery at 11–13 weeks gestation for a normal karyotype fetus was 10 cm/s, and the average PI was 2.0. In a study by Bilardo et al [4] the average PI values were equal to 2.03±0.46. In our study the average parameters of blood flow do not contradict the findings of these foreign authors, but they do demonstrate the changes in these parameters depending on the parietal-coccygeal length.

Conclusion. The normative values which we have established for the blood flow parameters in the fetal hepatic artery can be used in clinical practice to determine the risk groups for some types of unfavorable perinatal outcomes. They offer to play a major role in diagnostics if the markers of chromosome anomalies are determined (especially if the nuchal translucency is widened), as, in fetal chromosome anomalies, especially in Down's syndrome, there is a decrease in the resistance index and an increase in the peak systolic velocity of the blood flow.

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