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Original Article

Diagnostic value of prenatal ultrasound for detecting abnormal fetal blood flow

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Abstract: Objective: We aimed to investigate the diagnostic value of color Doppler ultrasound in detecting abnormal blood flow in the fetal umbilical artery (UA), renal artery (RA), and middle cerebral artery (MCA) in order to reduce the incidence of birth defects. Methods: The clinical records of 186 pregnant women who received color Doppler ultrasound assessment in UA, RA, and MCA were retrospectively analyzed. Of them, 95 normal pregnant women were assigned to the control group, whereas 91 high-risk pregnant women who later gave birth to babies with defects or had poor pregnancy outcomes in late-term were assigned to the study group. Color Doppler flow imaging was used to monitor the levels of the hemodynamic markers in UA, RA, and MCA of the 186 fetuses. Results: Compared with the control group, the study group had lower peak systolic velocity and end-diastolic velocity in UA and RA, higher values of pulsatility index (PI), resistance index (RI), and peak systolic velocity/end-diastolic velocity (S/D) ratio in RA, and lower values of PI, RI, and S/D ratio in UA and MCA (all $P<0.05$). Conclusion: Color Doppler ultrasound is a sensitive, easy-to-use, and safe technique in examining fetal blood flow change. It can provide a comprehensive and objective evaluation of the fetus in the uterus and help clinicians to decide on subsequent diagnosis and treatment plans.

Keywords: Color Doppler, diagnostic value, fetus, hemodynamics, prenatal examination, ultrasonography

Introduction

Gestational hypertension and prolonged pregnancy can lead to severe morbidity and mortality in the fetus [1-3]. To decrease the incidence of birth defects, prenatal ultrasound examination is often used to detect diseases in fetal systems. So far, there have been plenty of studies on the application of Doppler ultrasound in the prenatal examination. During the examination, the Doppler waveforms are generated by the change in Doppler signal frequency in the fetal umbilical artery (UA) blood circulation [4]. The flow velocity waveform (FVW) in fetoplacental circulation depends on fetal cardiac contractility, blood density, blood vessel wall elasticity, and resistance from the surrounding or downstream areas. Some scholars performed systematic reviews with meta-analysis on Doppler ultrasonography in high-risk pregnancies in 1995, and their studies verified the effect and necessity of applying UA Doppler in high-risk pregnant women [5]. Doppler ultrasound is an essential technique in clinical assessment and screening. When Doppler was not available, physicians were unable to determine the stage of labor accurately in women's delivery. It is believed that choosing a better timing for a cesarean section can be critical to reducing fetal mortality in the perinatal period [6]. The application of non-invasive Doppler ultrasound to check fetal blood flow indexes can help obstetricians and gynecologists to examine the fetus in the uterus, decrease neonatal mortality and bad outcomes in mothers and fetuses, and provide useful information for clinicians to decide on the subsequent diagnosis and treatment plans. In recent years, the diagnostic accuracy of color Doppler in detecting hemodynamic markers of UA, middle cerebral artery (MCA), and renal artery (RA) has proven to have great significance to the lowering of birth defects. Since the first report from Dublin in 1997 on applying Doppler ultrasonography for detecting the UA waveforms in pregnancy, Doppler has been widely used in this area [7, 8]. However, studies on the combined measurement of vascular dynamics in various arteries are uncommon.

Therefore, in the present study, we collected the clinical records of 186 pregnant women undergoing prenatal ultrasonography in our hospital in the past few years to investigate the application of color Doppler ultrasound in measuring hemodynamics of UA, RA, and MCA, in an effort to analyze the diagnostic value of color Doppler ultrasound in detecting abnormal fetal blood flow.

Materials and methods

Patients' characteristics

We retrospectively analyzed prenatal color Doppler ultrasound results of 186 pregnant women who gave birth in our hospital between June 2016 and June 2018. Some of them had normal labor, whereas some had fetal distress due to gestation hypertension or prolonged pregnancy. *Obstetrics and Gynecology (the 8th version)* was referred to for the classification of gestational hypertension [9]. The study was approved by the ethics committee of our hospital and informed consent was obtained from all participants.

Inclusion criteria: 1) Women who received ultrasound test at 26-28 weeks before delivery; 2) women who had no exposure to radiation or no history of medication within a half year before pregnancy; 3) fetus had no evident deformities that could affect MCA hemodynamic parameters; 4) women who had single pregnancy.

Exclusion criteria: 1) Women who had eclampsia or dysfunctions in other important organs; 2) presence of fetal growth restriction; 3) presence of fetal deformities; 4) women who had abnormal placenta location.

Of the 186 patients, 95 normal pregnant women were assigned to the control group (age: 25-35 years, average 28.00±5.85 years; gestation period: 37-40 weeks, average 39±7.2 weeks), while the rest 91 women including 55 women with gestational hypertension and 36 with prolonged pregnancy were assigned to the study group (age: 24-41 years, average 30±6.78 years; gestation period of patients with gestational hypertension, 40-43 weeks, average 41±4.15 weeks; gestation period of patients with prolonged pregnancy, 42-44 weeks, average 43±2.78 weeks).

Methods

Color Doppler ultrasound (Voluson E8, GE Healthcare, USA) was used in the examination. The frequency of the probe was set at 3.5-5 MHz. The hemodynamic markers in fetal UA, RA, and MCA were measured in the study. The peak systolic velocity (PSV) and end-diastolic velocity (EDV) were detected, and pulsatility index (PI), resistance index (RI), and PSV/EDV (S/D) were calculated.

The sampling volume was 2 mm^3 when measuring UA hemodynamics. UA in the relatively static umbilical cord was chosen for the ultrasound test. Over three blood flow spectrums of regular cardiac cycles were examined, and images of good quality were measured three times to obtain the values of UA dynamic parameters (**Figure 1**).

The sampling volume was 2 mm^3 when measuring RA hemodynamics. The probe was placed near the renal hilum side of the main RA. When over three blood flow spectrums were detected, the images were captured, and values of blood flow parameters were obtained using automatic measurement (**Figure 2**).

The sampling volume was 2 mm^3 when measuring MCA hemodynamics. The MCA on the left and right sides of the cerebral arterial circle were chosen for examination. Over three continuous cardiac cycle spectrums were detected, and images of good quality were measured three times to obtain the values of MCA dynamic parameters (**Figure 3**).

Statistical analysis

SPSS 17.0 software (IBM Corp., Armonk, NY, USA) was applied for statistical analysis. The mean values of blood flow markers were calculated and are expressed as mean ± standard deviation; comparison between two groups was conducted by t-test. Count data are presented as number or percentage; comparison between groups was conducted by χ^2 test. $P<0.05$ was

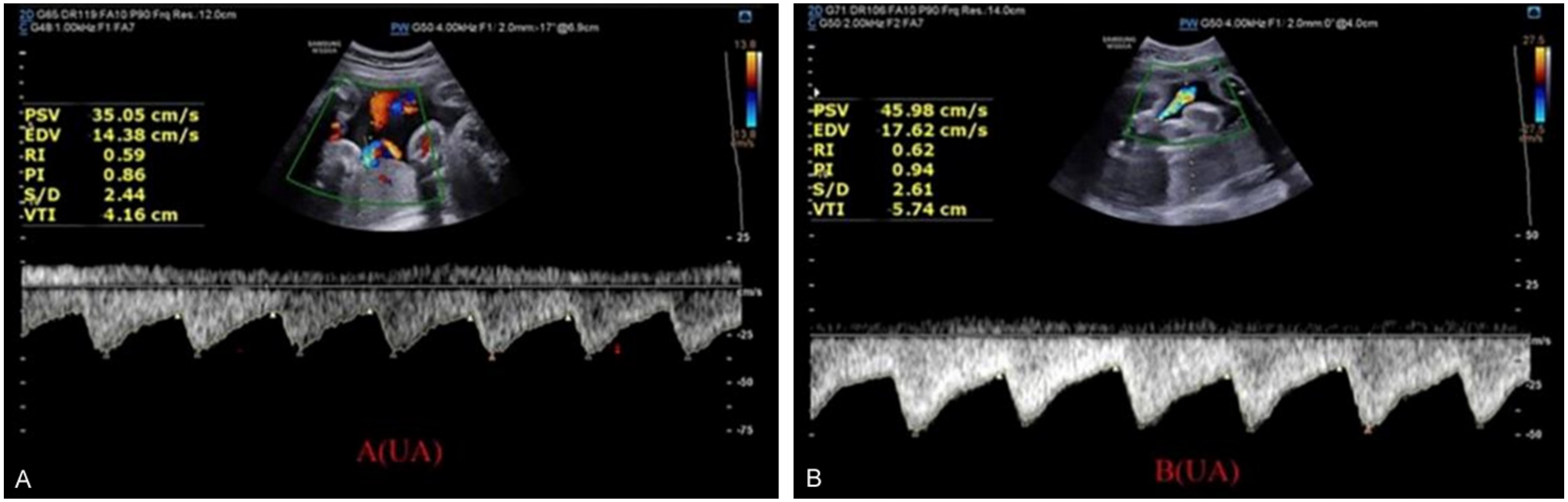

Figure 1. Color Doppler images of UA. A: UA blood flow spectrum in the study group; B: UA blood flow spectrum in the control group. UA: umbilical artery; PSV: peak systolic velocity; EDV: end-diastolic velocity; PI: pulsatility index; RI: resistance index; S/D: peak systolic velocity/end-diastolic velocity; VTI: velocity time integral.

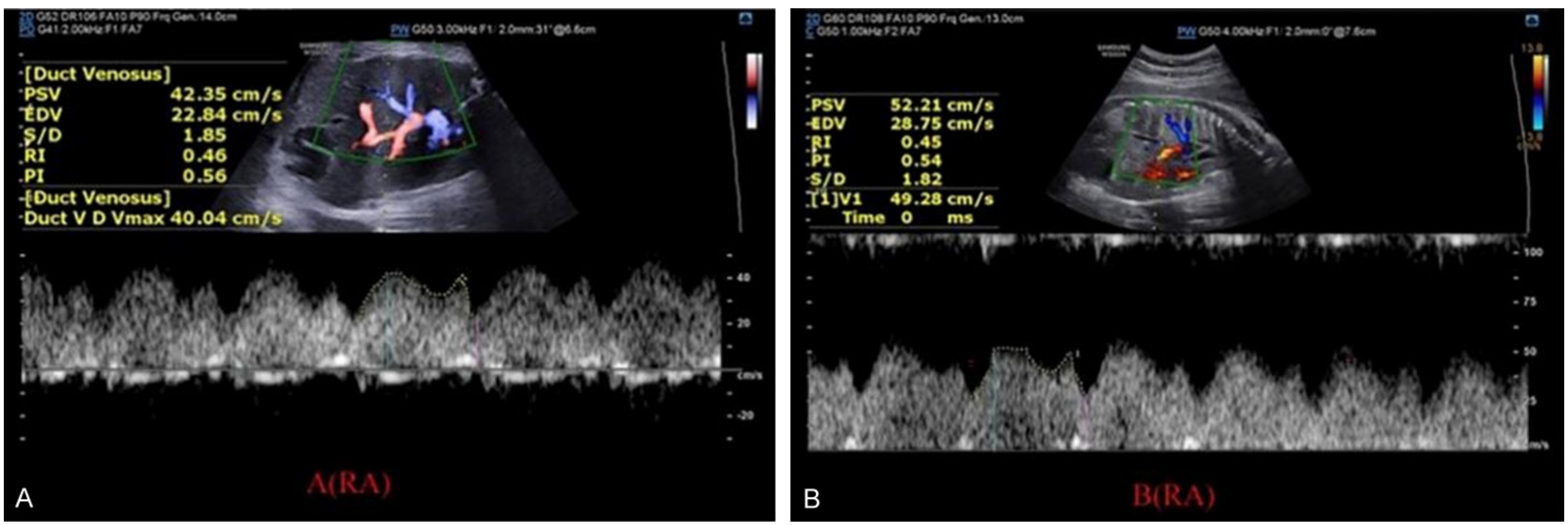

Figure 2. Color Doppler images of RA. A: RA blood flow spectrum in the study group; B: RA blood flow spectrum in the control group. PSV: peak systolic velocity; EDV: end-diastolic velocity; PI: pulsatility index; RI: resistance index; S/D: peak systolic velocity/end-diastolic velocity; RA: renal artery; V_1: renal artery blood flow velocity.

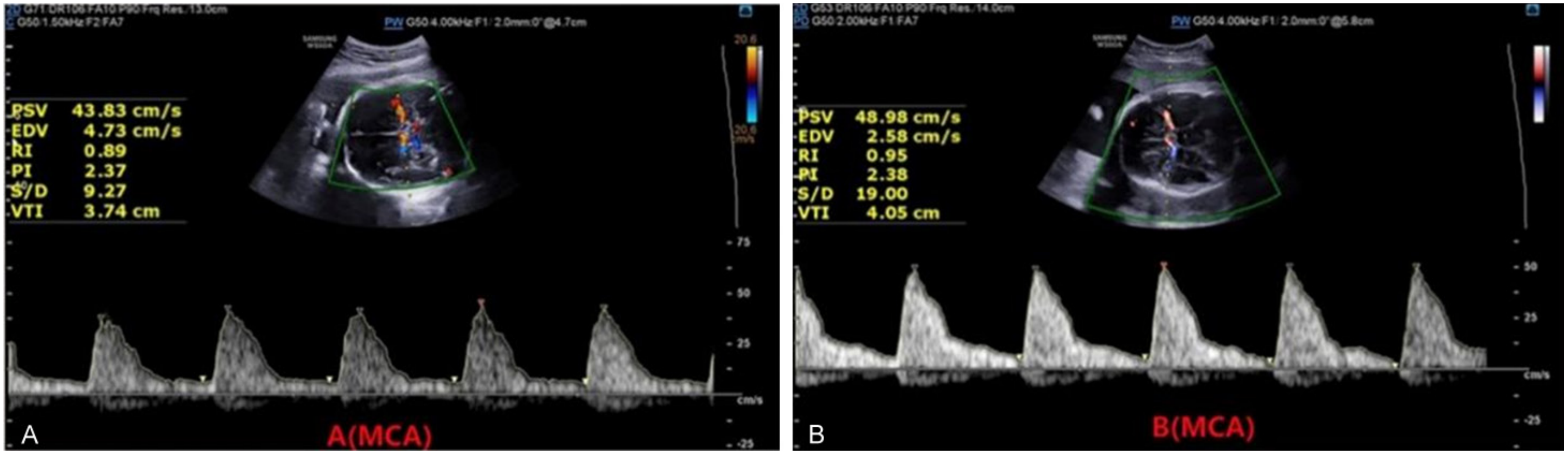

Figure 3. Color Doppler images of MCA. A: MCA blood flow spectrum in the study group; B: MCA blood flow spectrum in the control group. MCA: middle cerebral artery; PSV: peak systolic velocity; EDV: end-diastolic velocity; PI: pulsatility index; RI: resistance index; S/D: peak systolic velocity/end-diastolic velocity; VTI: velocity time integral.

Table 1. Patients' characteristics in the two groups

	Study group	Control group	X^2	P
Age			47.532	0.000
<25	26	75		
≥25	65	20		
Gestation period			28.952	0.000
<40 weeks	0	26		
≥40 weeks	91	69		
Pregnancy			186.000	0.000
Normal	0	95		
Gestation hypertension	55	0		
Prolonged pregnancy	36	0		

Table 2. UA hemodynamic markers in the fetuses of the two groups ($\overline{x}$ ± sd)

	Control group	Study group	t	P
Case	91	95		
PSV (cm/s)	49.33±9.12	45.42±10.05	17.942	0.044
EDV (cm/s)	22.21±7.57	19.73±7.05	15.681	0.012
PI	1.26±0.25	0.80±0.27	14.373	0.000
RI	0.68±0.15	0.58±0.12	11.351	0.004
S/D	2.30±0.41	2.22±0.57	9.072	0.033

Note: UA: umbilical artery; PSV: peak systolic velocity; EDV: end-diastolic velocity; PI: pulsatility index; RI: resistance index; S/D: peak systolic velocity/end-diastolic velocity.

Table 3. RA hemodynamic markers in the fetuses of the two groups ($\overline{x}$ ± sd)

	Control group	Study group	t	P
Case	91	95		
PSV (cm/s)	45.13±7.45	41.31±8.08	9.752	0.000
EDV (cm/s)	24.17±6.05	21.11±5.17	11.621	0.000
PI	1.14±0.09	1.46±0.12	8.852	0.000
RI	0.56±0.09	0.66±0.10	13.661	0.026
S/D	1.87±0.44	1.94±0.56	11.024	0.001

Note: RA: renal artery; PSV: peak systolic velocity; EDV: end-diastolic velocity; PI: pulsatility index; RI: resistance index; S/D: peak systolic velocity/end-diastolic velocity.

considered to indicate a statistically significant difference.

Results

Patients' characteristics

Intergroup differences were found in the patients' characteristics as shown in **Table 1** (all P<0.05).

UA Doppler results and levels of hemodynamic markers in the fetuses of the two groups

The Doppler images of the fetal UA in the two groups are displayed in **Figure 1**. The results exhibited that values of PSV, EDV, RI, PI, and S/D in the study group were lower than those in the control group (all P<0.05, **Table 2**).

Levels of RA hemodynamic markers in the fetuses of the two groups

The Doppler images of the fetal RA in the two groups are displayed in **Figure 2**. The results exhibited that the study group had lower values of PSV and EDV and higher values of RI, PI, and S/D than the control group (all P<0.05, **Table 3**).

Levels of MCA hemodynamic markers in the fetuses of the two groups

The images of the MCA Doppler assessment in both groups can be seen in **Figure 3**. The results exhibited that the study group had lower values of PSV, RI, PI, and S/D and higher value of EDV than the control group (all P<0.05, **Table 4**).

Discussion

Incidences of gestational hypertension and prolonged pregnancy account for 5-12% and 1-10% of the pregnancies, respectively, depending on the demographic characteristics, methods for determining gestational age, and whether labor is induced [10]. Since gestational hypertension and prolonged pregnancy can harm health and even be life-threatening to mother and fetus, women with these conditions are considered to have high-risk pregnancies [11, 12]. Color Doppler ultrasound has been widely used clinically due to its real-time capability and non-invasiveness [13]. Currently, studies on the color Doppler technique for examining hemodynamic markers of normal fetuses and fetuses in high-risk pregnancies have been well conducted. However, the diagnostic value of color Doppler in

Table 4. MCA hemodynamic markers in the fetuses of the two groups ($\bar{x}$ ± sd)

	Control group	Study group	t	P
Case	91	95		
PSV (cm/s)	53.08±17.66	45.60±10.09	11.089	0.032
EDV (cm/s)	9.09±6.02	10.15±7.03	11.232	0.001
PI	1.61±0.25	1.33±0.14	10.340	0.003
RI	0.81±0.17	0.77±0.12	6.125	0.001
S/D	5.22±1.64	5.03±1.56	7.624	0.019

Note: MCA: middle cerebral artery; PSV: peak systolic velocity; EDV: end-diastolic velocity; PI: pulsatility index; RI: resistance index; S/D: peak systolic velocity/end-diastolic velocity.

the combined assessment of UA, MCA, and RA markers are yet to be investigated.

UA, a link between the placenta and the fetus, is different from other arteries in the body, as vessels in the umbilical cord are not dominated by nerves. During the early stage of pregnancy, the placenta is newly formed, and resistance to blood flow can be increased by small and thin arteries. As gestation progresses, the placenta gets mature. The blood flow volume rises due to the increases of placental villi in number and thickness, and values of PI, RI, and S/D decrease, so that there can be normal growth and development of the fetus [4, 14, 15]. In the present study, the results showed that PSV, EDV, PI, RI, and S/D values in UA of the study group were all lower than those in the control group. This may be due to the placenta function damage in the high-risk pregnancy. A high-risk pregnancy can increase the blood flow resistance in the placenta and reduce the blood flow perfusion in different organs, leading to more poor outcomes in the perinatal period, such as difficult labor, perineal injury induced by macrosomia, and fetal death [16]. In the present study, the RA, PSV and EDV values were both lower, while PI, RI, and S/D values were higher in the study group than those in the control group (all P<0.05). Hypoxemia may be a possible reason for the increase in PI of fetal RA, and the clinical manifestations include reduced renal blood flow percentage in cardiac output, decreased fetal RA and renal function, and decreased renal perfusion [17]. The decreased renal perfusion in the fetus with intrauterine growth restriction may damage the kidney and decrease kidney volume. Furthermore, in prolonged pregnancy with oligohydramnios, the resistibility in fetal renal vascular bed increases, and RA blood flow decreases [18]. Some scholars believe that Doppler ultrasound measurement of fetal RA should be considered as a routine test item for women with oligohydramnios in late pregnancy [19].

Reduction in the resistance of fetal MCA is regarded as a brain-sparing effect, a manifestation of redistribution of fetal blood circulation. The results of our study are aligned with this pattern: the PSV, PI, RI, and S/D values were lower and EDV value was higher in the study group than those in the control group (all P<0.05). Some researchers have reported that the MCA Doppler test can be an adjunct to UA Doppler assessment since the calculation of cerebroplacental ratio using MCA can enhance the UA evaluation and help to predict poor prenatal outcomes in single-pregnancy [20].

In conclusion, color Doppler ultrasound is an easy and safe way to measure changes in fetal blood flow and can evaluate fetal development comprehensively and objectively. The combined assessment of UA, RA, and MCA makers can provide critical information for clinicians to decide on a subsequent diagnosis and treatment plans. However, since monitoring fetal blood flow need to be carried out in a quiet environment to achieve accurate results, and the fetal blood flow changes in our study may be affected by the noises during an ultrasound test, more studies are required in the future for further verification.

Disclosure of conflict of interest

None.

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