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Original Article

The clinical value of blood flow parameters of the umbilical artery and middle cerebral artery for assessing fetal distress

Qiuping Yin, Yuying Zhang, Qinfeng Ma, Li Gao, Ping Li, Xianxia Chen

Department of Ultrasound, Qinghai Provincial People's Hospital, Xining, Qinghai, P. R. China

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Abstract: Objective: To explore the clinical value of blood flow parameters of the umbilical artery (UA) and middle cerebral artery (MCA) for gauging fetal distress. Methods: This study was conducted among 256 pregnant women who presented for routine prenatal checkups and successfully gave birth in our hospital from January 2018 to February 2020. These pregnant women were examined with the Color Doppler Ultrasound, and the color Doppler flow imaging (CDFI) showed the blood flow of the UA and MCA. In accordance with the diagnostic criteria of fetal distress, they were divided into a fetal distress group (n=67) and a control group (n=189). The receiver operator characteristic (ROC) curve analysis was performed on the diagnostic value of the flow in the UA and MCA. According to their pregnancy outcomes, they were divided into a good pregnancy outcome group (n=209) and an adverse pregnancy outcome group (n=47), and their blood flow parameters of the UA and MCA were compared. Results: The S/D, PI, and RI values of the UA in the fetal distress group exceeded those in the control group, and the S/D, PI, and RI values of the MCA were lower than those in the control group ($P<0.05$). The good pregnancy outcome group had lower S/D, PI, and RI values of the UA. The good pregnancy outcome group had higher S/D, PI, and RI values of the MCA ($P<0.05$). ROC curves revealed that the areas under curve of S/D, PI, and RI of the UA were 0.81, 0.76 and 0.74, respectively; the areas under curve of S/D, PI, and RI of the MCA were 0.82, 0.78 and 0.71, respectively. Conclusion: The hemodynamic indexes of the UA and MCA can be used as a basis for evaluating fetal distress, which shows important clinical indications for gauging pregnancy outcome.

Keywords: Umbilical artery, middle cerebral artery, blood flow parameters, fetal distress

Introduction

Fetal distress refers to a syndrome where acute or chronic hypoxia in the womb endangers the health and life of the fetus, and it severely affects the safety and quality of life of both mother and infant. It is also the main reason for an abnormal development of the neonatal nervous system, complications of other organ systems and perinatal mortality [1]. An epidemiological survey has reveal that the incidence of fetal distress in some areas of China is 13.65% [2]. It is therefore of great significance to improve the quality of perinatal medicine and eugenics to predict the early risk of fetal distress in order to rapidly take active and scientific measures in clinic practice. However, at present, there is a lack of clear quantitative indexes for the clinical judgment of fetal distress and its severity. Currently, it is mainly based on fetal heart rate monitoring and amniotic fluid status, and the condition cannot be quickly diagnosed, which means that fetuses with fetal distress are not treated with the required monitoring and intervention. Color Doppler flow imaging (CDFI) can display the vascular flow, measure its blood flow resistance indexes, and completely reflect the growth of fetuses in the womb, and its spectrum or changes of hemodynamic parameters can predict fetal diseases [3].

Studies have revealed that the blood flow parameters of the middle cerebral artery (MCA) and the umbilical artery (UA) of fetuses with fetal distress are significantly different from those of normal fetuses, and their changes well reflect the partial pressure of oxygen in the pla-

Table 1. Comparison of baseline data (X±s)

Group	Numbers	Age (years)	Gestation (week)	Body mass index before pregnancy (kg/m²)
Control group	189	27.29±3.71	39.77±4.21	22.37±3.85
Fetal distress group	67	28.32±3.83	38.68±3.73	21.63±3.61
t		1.936	1.874	1.374
P		0.054	0.063	0.741

centa and cerebral blood circulation. The changes in partial pressure of oxygen are closely associated with fetal distress [4]. CDFI uses the changes in the blood flow waveform of the fetal UA and MCA as a sensitive method to evaluate the situation of fetuses in the womb. In this study, via CDFI, we measured and compared the differences in the hemodynamic parameters of the MCA and UA between the fetal distress group and the control group, analyzed their pregnancy outcomes, and explored the clinical significance of the MCA and UA resistance indexes in predicting fetal distress and prognosis, which can help create a reasonable treatment for fetuses with fetal distress and then provides a guarantee for improving the clinical outcomes of perinatal infants. The innovation of our study lies in the application of CDFI as a detection tool. CDFI displays blood flow more intuitively, and displays the nature of blood flow and the distribution of flow velocity in the heart and blood vessels faster and more intuitively than pulsed Doppler. It has unique advantages in the display of left to right shunt blood flow and valve orifice regurgitation blood flow.

Materials and methods

General materials

This study was conducted in 256 pregnant women who presented for routine prenatal checkups and successfully gave birth in our hospital from January 2018 to February 2020. They were aged from 21 to 35 years with an average age of 28.15±3.41. The research was conducted according to the principles of the World Medical Association Declaration of Helsinki. This study was approved by the ethical medical committee of The People's Hospital of Qinghai Province. All subjects gave written informed consent. Inclusion criteria: ① Pregnant women with single birth and the fetus was positioned with its head downwards; ② Pregnant women with regular period and clear date about the last period; ③ Pregnant women without a history of radiation exposure, drugs, smoking or drinking during pregnancy; ④ Pregnant women with complete information during pregnancy. Exclusion criteria: ① Pregnant women with fetal structural anomalies and chromosome abnormalities; ② Pregnant women with fetal damage and asphyxiation during childbirth; ③ Pregnant women with genetic diseases; ④ Pregnant women with serious internal medicine diseases, endocrine system and blood system diseases before pregnancy; ⑤ Pregnant women with poor maternal ultrasound images. According to the diagnostic criteria of fetal distress [5], they were divided into the fetal distress group (n=67) and the control group (n=189). The comparison of baseline data in the two groups was shown in **Table 1** (P<0.05).

Adverse pregnancy outcome

Their pregnancy outcomes met one or several conditions such as caesarean delivery, premature birth, neonatal disease, perinatal asphyxia, newborn jaundice and infants in the ICU.

Examination methods

Routine two-dimensional ultrasound examination of fetuses: Pregnant women underwent ultrasound examination within one week before delivery. The EPIQ7 color Doppler ultrasound system produced by Philips with a probe frequency of 2.5-5.0 MHz was used in this examination. The pregnant women were positioned on their back on the bed and received systematic examination according to the order of routine obstetric ultrasound examination. The growth data of the fetuses in the womb included biparietal diameter, head circumference, abdominal circumference, and the limbs, and spine, etc. were measured. The placental shape and grade, amniotic fluid depth and clarity were checked, and then the conditions of umbilical cord and fetal heart were recorded.

UA: Firstly, the free floating umbilical cord was found in the amniotic fluid, then we selected the umbilical artery near the placenta and the

Table 2. Comparison of the blood flow parameters of the UA (X±s)

Group	Numbers	S/D	PI	RI
Control group	189	2.26±0.28	0.79±0.23	0.50±0.12
Fetal distress group	67	3.31±0.37	1.08±0.26	0.71±0.17
t		24.138	8.564	10.958
P		0.000	0.000	0.000

Table 3. Comparison of the blood flow parameters of the MCA (X±s)

Group	Numbers	S/D	PI	RI
Control group	189	4.30±1.07	1.60±0.28	0.78±0.11
Fetal distress group	67	3.11±0.64	1.09±0.16	0.63±0.07
t		7.329	12.041	8.943
P		0.000	0.000	0.000

Table 4. ROC analysis of the UA and MCA in the fetal distress group

	UA			MAC		
	S/D	PI	RI	SD	PI	RI
Area (cm^2)	0.81	0.76	0.74	0.82	0.78	0.71
Cut-off value	3.07	1.33	0.61	3.96	1.55	0.61
Specificity (%)	91.8	77.1	90.8	85.1	86.7	51.8
Sensitivity (%)	83.1	78.0	70.7	78.2	71.8	84.0

spectrum of the artery with good blood flow signal was used as the sample. The sample volume was 0.7 mm-2 mm, and the angle between the pulse Doppler sampling line and the blood vessel was corrected to be less than 30 degrees. More than 5 continuously stable standard waveforms of the frozen images were collected, and the peak blood flow in the arterial end systole (S) and end-diastolic blood flow speed (D) were measured. Calculated S/D, pulsatility index (PI)=(SD)/M, Resistance index (RI)=(SD)/S, M is the average blood flow velocity.

MCA: The standard plane of the biparietal diameter was confirmed, then the probe toward the cranial base was moved, and the CDFI was employed when the pair of sphenoid wings were found. The two color pulsating blood vessels shown are the middle cerebral artery. Spectral Doppler measurement was performed at the middle 1/3 of the middle cerebral artery, and the umbilical artery measurement was the same as the above. S/D, PI and RI were calculated.

Statistical methods

All the data in this study were statistically analyzed with SPSS 20.0 software. Measurement data were represented by X±SD and analyzed using t test, when conforming to a normal distribution. The receiver operator characteristic (ROC) curve was used to analyze the blood flow parameters of the UA and MCA and then calculate the specificity and sensitivity of fetal distress. P<0.05 was considered statistically significant.

Results

Comparison of the blood flow parameters of the UA

The fetal distress group had higher S/D, PI and RI values of the UA, compared to the control group (P<0.05). See **Table 2**.

Comparison of the blood flow parameters of the MCA

The fetal distress group had lower S/D, PI and RI values of the MCA than the control group (P<0.05). See **Table 3**.

ROC analysis of the UA and MCA in the fetal distress group

A ROC curve was constructed for the diagnosis of the fetal distress. The areas under curve of S/D, PI, and RI of the UA were 0.81, 0.76 and 0.74, respectively, and when the cut-off values were 3.07, 1.33, and 0.61, their specificity and sensitivity were 91.8%, 83.1%, 77.1%, 78.0%, and 90.8%, 70.7%, respectively. The areas under curve of S/D, PI, and RI of the MCA were 0.82, 0.78 and 0.71, respectively, and when the cut-off values were 3.96, 1.55, and 0.61, their specificity and sensitivity were 85.1%, 78.2%, 86.7%, 71.8%, and 51.8%, 84.0% respectively. See **Table 4**; **Figures 1** and **2**.

Comparison of the hemodynamics of the UA and MCA between the good pregnancy outcome group and the adverse pregnancy outcome group

The good pregnancy outcome group had lower S/D, PI, and RI values of the UA, compared to

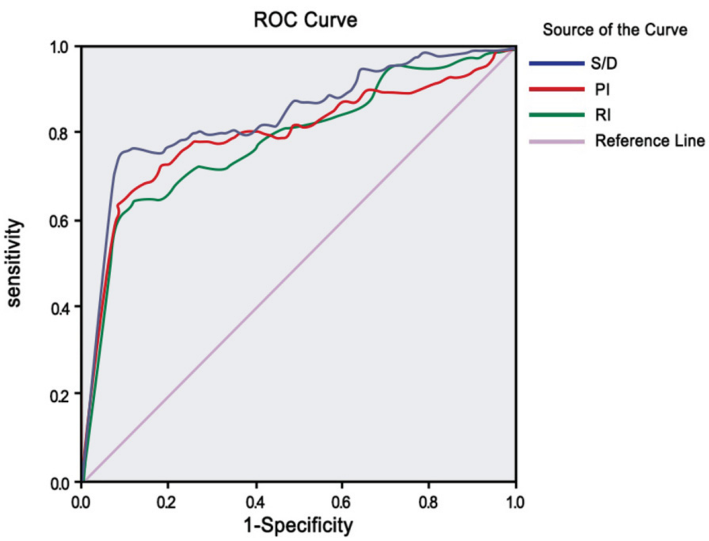

Figure 1. The predictive value of UA blood flow for fetal distress.

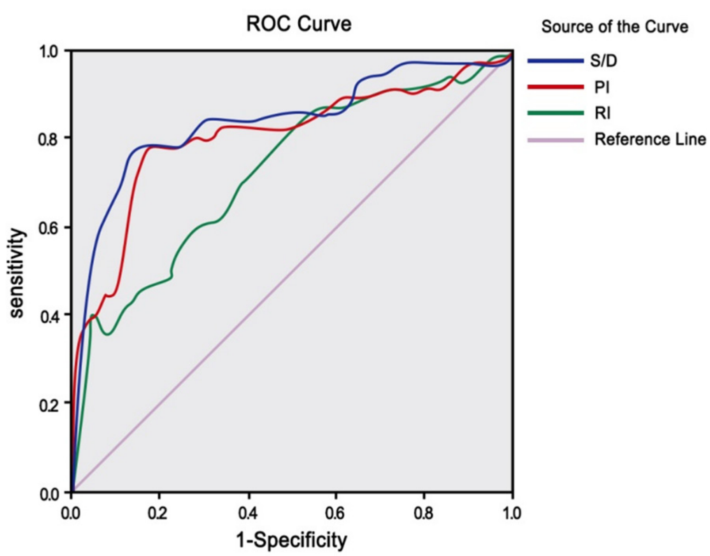

Figure 2. The predictive value of MCA blood flow for fetal distress.

the adverse pregnancy outcome group. The good pregnancy outcome group had higher S/D, PI, and RI values of the MCA, compared to the adverse pregnancy outcome group. See **Table 5**.

Discussion

Fetal distress is caused by maternal diseases such as placental factors, high blood pressure during pregnancy, anemia, umbilical cord factors, fetal factors, anesthetics and anesthesia techniques, etc. If the fetal distress cannot be found and treated in time, it will cause newborn asphyxia, premature birth, neurological diseases and other developmental disorders. In severe cases, fetal death and stillbirth occurs. Fetal distress severely endangers the health and life of fetuses. Early and accurate diagnosis of fetal distress and timely appropriate intervention have an important clinical value for reducing neonatal organ damage, reducing perinatal mortality, improving perinatal health care, predicting pregnancy outcome, etc.

The fetal UA is the link between the fetus and the placenta, and it controls the exchange of oxygen and nutrition. The changes of UA hemodynamics accurately reflect the hemodynamic status of the fetus-placental cycle and the physiological changes of the fetus, and the evaluation of the UA hemodynamics changes provides references for the diagnosis, prediction and disease evaluation of fetal distress. The MCA is the main branch of the internal carotid artery, and it completes its development as the gestational age increases and directly reflects the various dynamic changes of fetal cerebral circulation. With the increase of gestational age, blood flow resistance decreases [6]. The S/D, RI and PI values directly demonstrate the resistance of blood vessels during blood circulation. With the progress of pregnancy, blood flow increases, placental circulation resistance decreases, and UA S/D, PI, and RI values gradually decrease [7]. When hypoxia in the womb happens, the fetal body ensures the supply of oxygen to important organs such as the brain and heart, which leads to significant changes in the hemodynamic, increase in the cerebral blood flow speed, and decrease in the MAC resistance index, thus resulting in a "brain protection effect". The decrease in blood supply of the UA causes a significant increase in RI and PI of UA, and the activation in the fetal stress mechanism aims to alleviate hypoxia. When the S/D, PI, RI values of the MCA blood flow have a gradual decrease, and the UA resistance index shows a gradual

Table 5. Comparison of the hemodynamics of the UA and MCA (X±s)

	UA			MCA		
	S/D	PI	RI	S/D	PI	RI
Good pregnancy outcome group (n=209)	2.83±0.62	0.52±0.21	0.82±0.38	4.31±1.15	0.80±0.29	1.62±0.43
Adverse pregnancy outcome group (n=47)	3.42±0.73	0.74±0.25	1.11±0.52	3.04±0.73	0.57±0.16	1.05±0.38
t	5.699	6.257	4.393	7.244	5.255	8.379
P	0.000	0.000	0.000	0.000	0.000	0.000

upward trend, especially when there is a waveform of end-diastolic blood flow loss, this can predict the occurrence of a high-risk pregnancy situation like fetal distress [8].

The authors used CDFI to analyze the hemodynamics of the UA and MAC of pregnant women in the two study groups. The results revealed that the S/D, PI, and RI values of the UA in the fetal distress group exceeded those in the control group, and the S/D, PI, and RI values of the MCA were lower than those in the control group, which was consistent with the study of Zhang Xinrong, etc. [9]. When hypoxia in the womb occurres, the UA and MCA have obvious hemodynamic changes and their blood flow resistance indexes change significantly. The UA ultrasound features of fetal distress manifested as the increase in resistance and decrease in blood flow, associated with the fetal hypoxia and the oxidative stress [10]. Cerebral blood vessels maintain oxygen delivery during hypoxia. Animal experiments have discovered that long-term exposure to hypoxia visualized using Doppler ultrasound measurements show an increase in the average cerebral blood flow velocity by (15±8)% [11]. CDFI has a good effect in testing MCA and UA hemodynamics, and accurately displays the dynamic value of blood flow resistance indexes. These values have evaluation significance for the degree of hypoxia and the oxidative stress damage, and can be used as an important basis for the judgment of fetal distress in the third trimester of pregnancy.

In this study, we analyzed the sensitivity and specificity of S/D, RI, and PI of the UA blood flow in the diagnosis of fetal distress were 83.1%, 91.8%, 70.7%, 90.8%, 78.0%, and 77.1%, respectively. The sensitivity and specificity of S/D, RI and PI of the MAC blood flow were 78.2%, 85.1%, 71.8%, 86.7%, 84.0%, 51.8%, respectively. From the above research data, the flow in the UA and MAC were able to predict the fetal hypoxia accurately, simply and quickly. Normal fetuses were compared with fetuses with an umbilical cord around the neck, and there was a significant difference in the MCA and UA resistance index ratios between the two groups (P<0.01). The sensitivity and specificity of the MCA and UA resistance index and resistance index ratio in predicting the hypoxia of fetuses with an umbilical cord around the neck were 43%, 85%, 92%, 83%, 89% and 100%, which might help early discovery of hypoxia, thus the diagnosis can be made before fetal distress [12]. The sensitivity and specificity of S/D, PI and RI of the MCA and UA in diagnosing hypoxia in the womb were 80.8%/85.9%, 75.4%/99.0%, and 80.8%/81.7% [13]. Li Fengyi, et al. [14] employed ultrasound of the UA and MCA for quantitative examination to predict fetal distress. The sensitivity of S/D, RI and PI of the UA to predict fetal distress was 0.986, 0.958 and 0.944, with the specificity of 0.614, 0.625 and 0.534. The sensitivity of S/D, RI and PI of the MCA to predict fetal distress in the womb was 0.997, 0.924 and 0.992, with the specificity of 0.712, 0.657 and 0.684.

The results of this study revealed that the hemodynamic values of UA and MCA were associated with the adverse pregnancy outcomes of pregnant women. Compared with the Doppler blood flow of normal artery, the Doppler waveform abnormality of the umbilical artery was associated with caesarean delivery, newborns in ICU, respiratory distress syndrome, neonatal sepsis, neonatal jaundice and early neonatal death [15]. There was a significant increase in the fetal distress, caesarean delivery rate, amniotic fluid contamination and APgar score <7 in the abnormal umbilical artery blood flow group. Using Ultrasound to check the UA blood flow in late pregnancy served an important clinical significance in evaluating fetal distress and the methods of delivery [16-18]. Previously, scholars accurately and timely diagnosed the cause and degree of fetal distress [17-22], with a coincidence rate of 98.0%

through analyzing the S/D, RI values of the UA and the RI, PI values of the MCA, combined with three-dimensional ultrasound reconstruction images.

In conclusion, when fetal distress occurs, the hemodynamics of the MCA and UA will change significantly. Measuring the dynamic values of S/D, RI, and P reflects the oxygen supply in the womb, and better evaluates the condition of hypoxia, which shows a high clinical significance in the observation of labor and the timing and method of delivery.

Disclosure of conflict of interest

None.

Address correspondence to: Xianxia Chen, Department of Ultrasound, Qinghai Provincial People's Hospital, No. 2, Gonghe Rd, Xining, Qinghai, P. R. China. Tel: +86-18997217582; E-mail: mengyi11280@126.com

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