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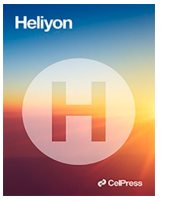

Research article

Ultrasonographic diagnosis of fetal hemodynamic parameters in pregnant women with diabetes mellitus in the third trimester of pregnancy

Dongmei Cai [a], Su Yan [b,*]

[a] Gynaecology and obstetrics, Haian City People's Hospital of Jiangsu Province, Haian, 226600, Jiangsu, China
[b] Obstetrics, Luzhou People's Hospital, Luzhou City, Sichuan Province, 646000, China

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ABSTRACT

Objective: It was to investigate the diagnosis of fetal hemodynamics in pregnant women with diabetes mellitus in the third trimester of pregnancy by color Doppler ultrasonography.
Methods: 55 women with gestational diabetes mellitus (GDM) in the third trimester of pregnancy who were clinically diagnosed and treated in Haian City People's Hospital of Jiangsu Province were selected as the observation group, and 55 pregnant women with normal prenatal examination results were selected as the controls. The hemodynamic parameters of fetal middle cerebral artery (MCA), umbilical artery (UA), and renal artery (RA) were detected, including the ratio of maximum systolic blood flow velocity to end-diastolic blood flow velocity (S/D), resistance index (RI) and arterial pulsation index (PI). Fasting serum levels of maternal patients were collected for detecting Cystain C (Cys C) and homocysteine (Hcy) to analyze the predictive value of serological indexes and target arterial hemodynamics parameters for adverse pregnancy outcome (APO).
Results: The results showed that compared with controls, in the observation group, RI, PI, and S/D of MCA and RA increased significantly, while RI, PI and S/D of UA decreased obviously ($P < 0.05$), the levels of serum Cys C and Hcy were clearly increased ($P < 0.05$). The APO rate of controls and observation group was 10.91 % and 25.45 %, respectively. It was found that the area under the curve of serum Cys C, Hcy, and the APO predicted by the hemodynamic parameters of fetal MCA, UA, and RA were all greater than 0.75 ($P < 0.05$). Multiple Logistic regression analysis showed that serum Cys C and Hcy, and the hemodynamic parameters of fetal MCA, UA and RA were correlated with APO ($P < 0.05$).
Conclusion: In summary, maternal blood glucose level can affect fetal hemodynamic parameters. In the third trimester of pregnancy, the changes of blood flow parameters of fetal MCA, UA, RA, and maternal serum Cys C and Hcy levels are helpful to understand fetal status in utero, and can be used to predict APO.

1. Introduction

GDM is a type of diabetes mellitus or decreased glycosuria that occurs during pregnancy. It is a very common complication of

* Corresponding author.
E-mail address: yansuyansu87654321@163.com (S. Yan).

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pregnancy, with an incidence of about 5 % [1]. If the maternal blood glucose level is not controlled in time, hyperglycemia will enter the fetus through the placenta, causing islet B cells to proliferate and hypertrophy and secrete a large amount of insulin, which will cause APO such as macrosomia, fetal distress, and low birth weight, and the risk of diabetes in the offspring will increase [2,3]. At present, it is believed that the occurrence of GDM is related to the secretion of various insulin antagonistic hormones by placenta [4]. GDM can reduce placental function, increase fetal-placental circulation resistance, reduce UA blood flow, and then increase fetal blood supply and cause hypoxia, as well as fetal distress [5]. When fetal intrauterine hypoxia occurs, the oxygen consumption of brain cells increases, and the compensatory expansion of cerebral artery increases blood supply and reduces blood flow resistance [6]. Studies have suggested that nutritional supplements such as inositol and α -lipoic acid, vitamin D, and metformin can reduce the risk of diabetes, while monitoring fetal hemodynamic parameters can reduce the risk of hypertension and preeclampsia [7,8]. Therefore, the use of color Doppler ultrasound to monitor the hemodynamic parameters of fetal MCA in late pregnancy can be used to predict fetal hypoxia and severity [9]. When the fetus is in intrauterine hypoxia, the blood flow RI increases after RA contraction, and the blood flow redistribution is realized. The detection of fetal hemodynamic parameters can realize the prediction of APO such as premature congenital malformation. Color Doppler ultrasound imaging can accurately detect changes in fetal hemodynamic parameters, which is very important for the prediction of perinatal prognosis [10].

Recent studies have confirmed that Cys C in serum of GDM patients can promote inflammatory response and aggravate vascular damage, which can be used to predict the prognosis of GDM patients and maternal and infant outcomes [11]. The increase of Hcy level can reduce the sensitivity of the body to insulin, which in turn increases the blood sugar level and increases the risk of maternal and infant complications [12]. Maternal hyperglycemia in GDM patients can affect the formation and growth of fetal organs through the placenta, and the excessive growth of organs will lead to myocardial hypertrophy when it involves the heart [13]. Because GDM increases the risk of APO, early diagnosis of GDM and timely and reasonable treatment are important for improving maternal and infant outcomes.

110 women in late pregnancy were included. According to the fasting blood glucose and oral glucose tolerance teat (OGTT) results, the patients were divided into normal women and GDM women. Color Doppler ultrasound imaging was used to detect the changes of fetal hemodynamic parameters such as MCA, UA, and RA, and the serum Cys C and Hcy levels were detected by enzyme-related immunosorbent assay. It aimed to explore the relationship between maternal serum Cys C and Hcy levels and fetal hemodynamic parameters and APO, to provide evidence for quantifying organ damage of GDM fetus and predicting pregnancy outcome.

2. Data and methods

2.1. General information

Patients in the third trimester of pregnancy who were treated in Haian City People's Hospital of Jiangsu Province from January 2020 to June 2022 were selected as the study subjects. According to the fasting fingertip blood glucose level in the past month, the patients were grouped: controls and the observation group, with 55 cases in each group. The controls had a singleton pregnancy with normal blood glucose levels on multiple occasions, and no chromosomal abnormalities or malformations or other disorders were detected in the fetus. The observation group was GDM patients, and the specific inclusion criteria and exclusion criteria of the observation group were as follows: (1) Singleton pregnancy; (2) All women underwent OGTT and met the diagnostic criteria of GDM. (3) Women aged over 18 years old; (4) No chromosomal abnormality or malformation or other diseases were detected in the fetus. Exclusion criteria: (1) Multifetal pregnancy; (2) Fetuses with chromosomal abnormalities, malformations, or other diseases; (3) Pregestational diabetes mellitus or inflammatory diseases; (4) Women with serious damage of important organs such as heart, liver, and kidney; (5) Polycystic ovary syndrome; (6) Intrauterine infection; (7) Women taking antihypertensive, lipid-lowering, or glucose-lowering drugs within the past month that affect glucose metabolism.

The diagnostic criteria of GDM: (1) two consecutive fasting plasma glucose levels were more than 5.8 mmol/L; (2) Fasting blood glucose level over 11.2 mmol/L measured by 50 g glucose screening; (3) The fasting blood glucose was 5.6 mmol/L, 1h, 2h, 3h blood glucose was 10.3 mmol/L, 8.6 mmol/L, 6.7 mmol/L, the above two items were beyond the normal range. The trial was approved by the Ethics committee of Haian City People's Hospital of Jiangsu Province, and the enrolled patients signed the informed consent.

2.2. Fetal ultrasound image acquisition

One week before delivery, all patients were placed in the supine position for abdominal ultrasound image acquisition. After calm breathing, MCA, UA, RA, and pulmonary vein hemodynamic levels were detected by color Doppler ultrasound diagnostic system (Hitachi, HI VISION Avius, Japan) with the probe frequency set at 3–5 MHz. When more than five consistent peaks and valleys appeared in the image, the image was frozen for the measurement of blood flow parameters of the target vessel. GE Voluson 730ProV ultrasound diagnostic system (General Electric, Voluson 730ProV, USA) was adopted. The probe frequency was set at 3~5 MHz to observe the fetal growth diameter, amniotic fluid, and placenta. Each data of each fetus was tested three times, and the average value was adopted as the result. The US examination of all patients was performed by the same experienced ultrasound doctor.

2.3. Outcome measures

(1) The hemodynamics of pulmonary veins in the two groups were measured by Doppler ultrasound, and the S/D, RI, and PI of MCA, RA, and UA were analyzed. (2) Fetal heart examination: mitral valvular annulus (MVA) and tricuspid valvular annulus diameters

(TVA) were measured by four-chamber view; aortic valve annulus (AVA) and pulmonary valve annulus diameters (PVA) were measured on the long axis view of aorta and pulmonary artery. Left ventricular wall thickness (LVWT), right ventricular wall thickness (RVWT), and left ventricular end diastolic diameter (LVDd), right ventricular end-systolic diameter (RVDs), left ventricular fractional shortening (LVFS), left ventricular ejection fraction (LVEF), right ventricular fractional shortening (RVFS) were measured by M-mode echocardiography. (3) 3 mL venous blood in fasting state was collected in the morning. After anticoagulant treatment, the blood was centrifuged at 3000 rpm for 15 min, and the supernatant was collected. Serum Cys C and Hcy levels were measured by enzyme-linked immunosorbent assay (Diagnostic Systems Laboratories, M53019, USA). The concentration was calculated after the standard curve was drawn. (4) The incidence of complications such as premature rupture of membranes, polyhydramnios, postpartum hemorrhage, macrosomia, fetal distress, jaundice, neonatal asphyxia, and growth restriction were recorded. (5) Neonatal birth weight and neonatal intensive care unit admission rate were recorded. (6) Apgar score. The Apgar score includes muscle tone, pulse, stimulation response, skin color, and respiration, and the full score is 10 points. When the score is less than 7, the newborn is mild asphyxia. When the score is less than 4, the newborn is severely asphyxia.

2.4. Statistical processing

SPSS 19.0 statistical software was applied for data entry and statistical analysis. Mean ± standard deviation represented measurement data in accordance with normal distribution, and pairwise comparison was performed adopting one-way analysis of variance LSD method. Frequency (percentage) presented count data, and chi-square test was adopted for comparison between groups. Receiver operating characteristic curve (ROC) and multivariate Logistic regression analysis were applied to evaluate the diagnostic value of serum Cys and Hcy levels and target vascular hemodynamic parameters for APO. When $P < 0.05$, the difference between groups was statistically meaningful.

3. Results

3.1. Comparison of maternal general data

The differences in general data between the controls and the observation group were compared (Table 1). It was found that there was not clearly different in the average age, gestational age, and parity between two groups ($P > 0.05$).

3.2. Comparison of hemodynamic indexes of fetal MCA, UA, and RA

The hemodynamic parameters of MCA, UA, and RA were compared between the controls and the observation group. The Tei index of the controls and the observation group were (0.41 ± 0.05) and (0.33 ± 0.02) ($P < 0.05$). The hemodynamic parameters of fetal MCA were compared(Fig. 1A: Comparison of RI between the controls and observation group; Fig. 1B: Comparison of PI between the controls and observation group; Fig. 1C: Comparison of S/D between the controls and observation group). In contrast with the controls, the RI, PI, and S/D of fetal MCA in the observation group were decreased ($P < 0.05$). .

The differences in hemodynamic parameters of fetal UA between the two groups were compared (Fig. 2A: Comparison of RI between the controls and observation group; Fig. 2B: Comparison of PI between the controls and observation group; Fig. 2C: Comparison of S/D between the controls and observation group). In contrast with the controls, the RI, PI, and S/D indexes of fetal UA in the observation group were enhanced ($P < 0.05$).

The differences in hemodynamic parameters of fetal RA between the two groups were compared (Fig. 3A: Comparison of RI between the controls and observation group; Fig. 3B: Comparison of PI between the controls and observation group; Fig. 3C: Comparison of S/D between the controls and observation group). As against the controls, the RI, PI, and S/D indexes of fetal RA in the observation group were increased ($P < 0.05$).

3.3. Contrast of fetal cardiac structure and function

Two-dimensional echocardiography was adopted to measure the differences in the structure of the fetal cardiac annulus between the controls and observation group (Fig. 4). As against the controls, the MVA, TVA, AVA, and PVA in the observation group were enhanced ($P < 0.05$).

Echocardiography was used to measure distinction in fetal cardiac structure and function between two groups (Fig. 5A: Comparison of cardiac structural parameters; Fig. 5B: Comparison of indicators of cardiac function). Fetal LVDd and LVDs in controls were similar to those in observation group ($P > 0.05$). As against controls, the fetal RVDd, RVDs, LVWT, RVWT, LVEF, LVFS, and RVFS in

Table 1
Comparison of general data.

Information	Controls ($n = 55$)	Observation group ($n = 55$)	Statistic value (t)	P
Age (years)	28.13 ± 5.58	27.97 ± 6.52	0.541	0.417
Gestational weeks (weeks)	36.79 ± 3.24	36.81 ± 3.07	−0.275	0.196
Number of births (times)	1.22 ± 0.15	1.30 ± 0.21	0.433	0.250

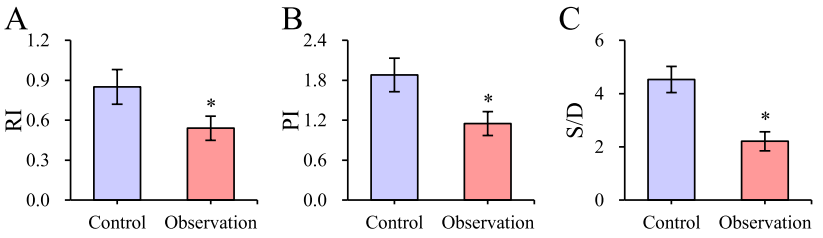

Fig. 1. Comparison of hemodynamic parameters of fetal MCA.
Note: * indicates $P < 0.05$ relative to controls.

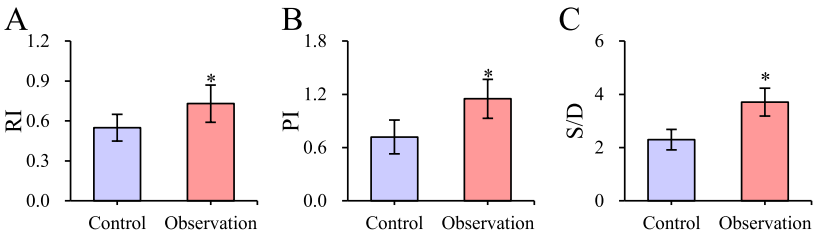

Fig. 2. Comparison of hemodynamic parameters of fetal UA.

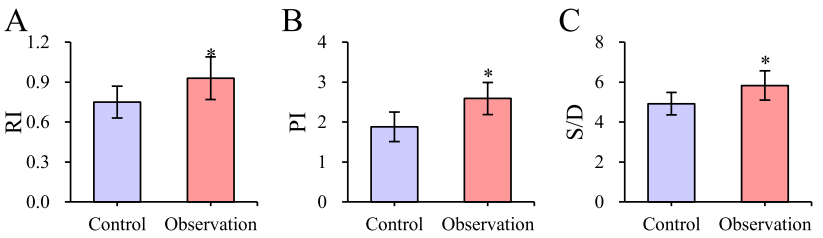

Fig. 3. Comparison of hemodynamic parameters in fetal RA.
Note:RI: resistance index; PI: arterial pulse index; S/D: the ratio of maximum systolic blood flow velocity to end-diastolic blood flow velocity.

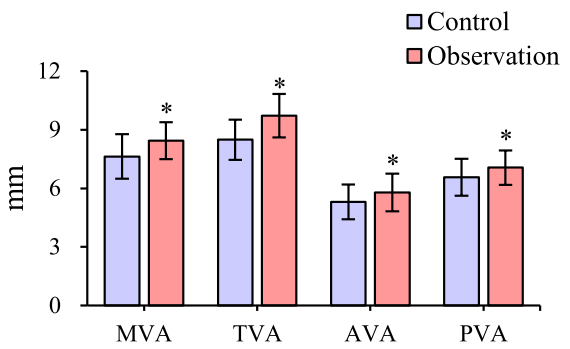

Fig. 4. Comparison of structural parameters of the fetal cardiac annulus.
Note: MVA: mitral valvular annulus; TVA: tricuspid valvular annulus; AVA: aortic valve annulus; PVA: pulmonary valve annulus.

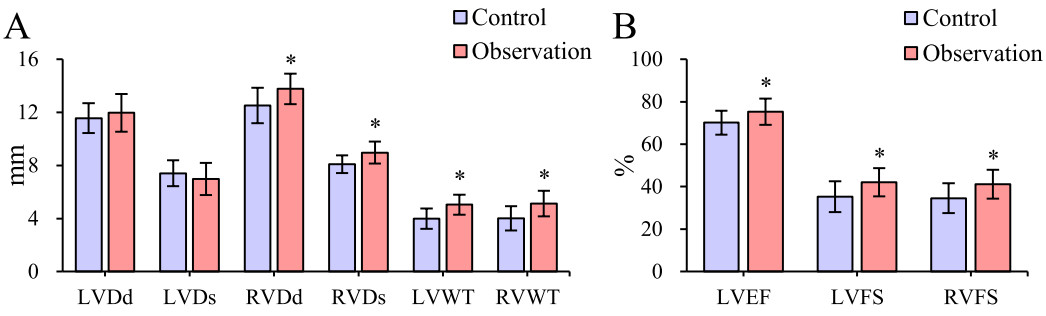

Fig. 5. Contrast of indexes of fetal cardiac structure and function.
Notes: LVDd: left ventricular end diastolic diameter; LVDs: left ventricular end-systolic diameter; RVDd: right ventricular end diastolic diameter; RVDs: right ventricular end-systolic diameter; LVWT; left ventricular wall thickness; RVWT: right ventricular wall thickness; LVEF: left ventricular ejection fraction; LVFS: left ventricular fractional shortening; RVFS: right ventricular fractional shortening.

observation group increased ($P < 0.05$).

3.4. Comparison of maternal serum Cys C and Hcy levels

The levels of Cys C and Hcy in the controls were (0.69 ± 0.07) mg/L and (10.17 ± 1.28) μmol/L, respectively. Those in the observation group were (1.35 ± 0.14) mg/L and (19.88 ± 1.34) μmol/L, respectively. Compared with the controls, the prenatal serum Cys C and Hcy levels of the observation group were enhanced ($P < 0.05$) (Fig. 6A: Comparison of serum Cys C between the observation group and the control group; Fig. 6B: Comparison of serum Hcy between the observation group and the control group).

3.5. Contrast of maternal pregnancy outcomes

As against the controls, the incidence of abnormal amniotic fluid (too much or too little), premature rupture of membranes, macrosomia, preeclampsia, hypertension, postpartum hemorrhage, fetal distress, premature delivery, fetal growth restriction, low birth weight, and neonatal asphyxia were evidently increased in the observation group. There were 6 cases (10.91 %) of APO in the controls and 14 cases (25.45 %) of APO in the observation group. Therefore, the incidence of APO was increased in the observation group ($P < 0.05$) (Fig. 7).

3.6. ROC curve analysis of maternal serum indexes and fetal hemodynamic indexes in predicting pregnancy outcomes

The area under the ROC curve (AUC) of prenatal serum Cys C level for predicting pregnancy outcome was 0.753, and the cut-off value (COV) was set as 1.032. The AUC of prenatal serum Hcy level in predicting pregnancy outcome was 0.640, and the COV was set as 12.419. In MCA, the AUC of RI in prediction was 0.859, COV as 0.547; the AUC predicted by PI was 0.781, COV as 1.158; the AUC of S/D in prediction was 0.875, COV as 2.290. In UA, the AUC of RI in prediction was 0.863, COV as 0.728; the AUC predicted by PI was 0.779, COV as 1.152; the AUC of S/D in prediction was 0.871, COV as 3.774. In RA, the AUC of RI in prediction was 0.877, COV as 0.940; the AUC predicted by PI was 0.762, COV as 2.613; the AUC of S/D in prediction was 0.850, COV as 5.832. Prenatal serum Cys C and Hcy levels and fetal MCA, UA, and RA hemodynamic parameters could be adopted to predict pregnancy outcomes ($P < 0.05$) (Table 2). Fig. 8A: ROC curve of maternal serum Cys C and Hcy to predict pregnancy outcome; Fig. 8B: ROC curve of RI, PI, and S/D of fetal MCA prediction; Fig. 8C: ROC curve of, RI, PI, and S/D of fetal UA prediction; Fig. 8D: ROC curve of, RI, PI, and S/D of fetal RA prediction.

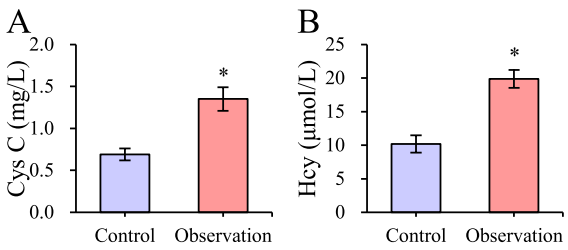

Fig. 6. Comparison of prenatal serum Cys C and Hcy levels.

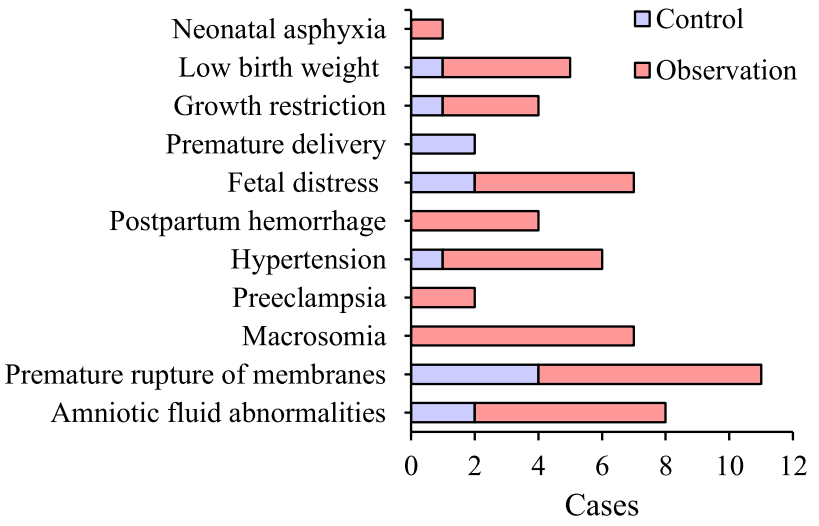

Fig. 7. Comparison of the number of postpartum APO cases.

Table 2
Predictive value of maternal serologic and fetal hemodynamic measures for pregnancy outcomes.

Indicators		AUC	Standard error	95 % confidence interval	*P*
Maternal serology	Cys C	0.753	0.016	0.681–0.862	<0.05
	Hcy	0.640	0.028	0.514–0.778	<0.05
Fetal MCA	RI	0.859	0.035	0.805–0.911	<0.05
	PI	0.781	0.011	0.676–0.895	<0.05
	S/D	0.875	0.020	0.794–0.952	<0.05
Fetal UA	RI	0.863	0.017	0.813–0.920	<0.05
	PI	0.779	0.025	0.689–0.863	<0.05
	S/D	0.871	0.019	0.802–0.948	<0.05
Fetal RA	RI	0.877	0.032	0.821–0.950	<0.05
	PI	0.762	0.026	0.664–0.875	<0.05
	S/D	0.850	0.014	0.816–0.921	<0.05

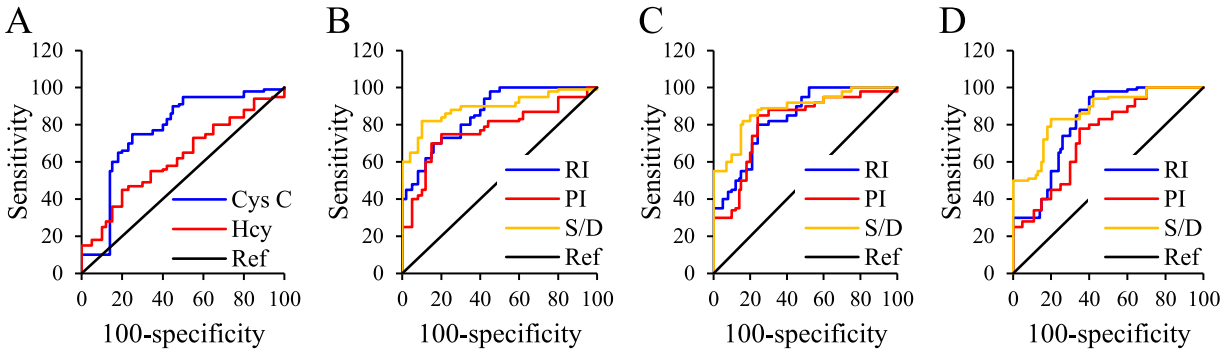

Fig. 8. ROC curves for maternal serologic and fetal hemodynamic measures in predicting pregnancy outcomes.
Note: (A) ROC curve of maternal serum Cys C and Hcy to predict pregnancy outcome; (B) ROC curve of RI, PI, and S/D of fetal MCA prediction; (C) ROC curve of, RI, PI, and S/D of fetal UA prediction; (D) ROC curve of, RI, PI, and S/D of fetal RA prediction.

Table 3
Multiple logistic regression analysis of pregnancy outcomes.

Indicators		Coefficient of regression	Standard error	Wald value	OR value	95 % confidence interval	*P*
Maternal serology	Cys C	0.315	0.104	5.980	1.321	1.250–1.426	<0.05
	Hcy	0.169	0.218	3.452	1.937	1.458–2.343	<0.05
Fetal MCA	RI	0.347	0.083	7.633	1.210	1.007–1.504	<0.05
	PI	0.442	0.116	0.925	2.336	1.459–3.327	<0.05
	S/D	0.569	0.221	2.044	1.897	1.424–2.470	<0.05
Fetal UA	RI	0.387	0.187	10.938	1.350	1.016–1.735	<0.05
	PI	0.305	0.214	0.971	1.196	0.895–1.567	<0.05
	S/D	0.671	0.265	1.315	2.049	1.559–2.731	<0.05
Fetal RA	RI	0.426	0.144	6.272	0.998	0.614–1.275	<0.05
	PI	0.502	0.275	1.468	1.157	0.930–1.346	<0.05
	S/D	0.511	0.308	2.150	2.243	1.672–3.250	<0.05

3.7. Multiple Logistic regression analysis of influencing factors of pregnancy outcome

The relationship between maternal prenatal serum Cys C and Hcy levels and fetal hemodynamic parameters of MCA, UA, and RA and pregnancy outcomes was analyzed (Table 3). It can be found that the levels of prenatal serum Cys C and Hcy, and the RI, PI, and S/D of fetal MCA, UA, and RA were related to APO ($P < 0.05$).

4. Discussion

At present, the pathogenesis of GDM is not very clear, but it is believed that it is related to insulin resistance caused by placental prolactin, progesterone, and glucocorticoids reversing the increase of insulin and the decrease of adiponectin [14]. With the deepening of research, it is found that GDM patients have more APO, such as premature delivery, fetal distress, neonatal asphyxia, and low birth weight [15,16]. With the gradual maturity of radiomics technology, color Doppler ultrasound technology has been able to be used in the examination of fetal MCA, UA, and RA hemodynamic indicators, which is very important for improving maternal and infant outcomes and perinatal prognosis. Color Doppler ultrasound is the preferred method for the detection of fetal hemodynamic parameters. It has the non-invasive and repeatable characteristics. It can directly and timely reflect the changes of fetal hemodynamics, which is conducive to the monitoring of perinatal prognosis [17]. The differences of MCA, UA, and RA hemodynamic indexes between normal healthy and GDM pregnant women were detected by color Doppler ultrasound imaging.

Hyperglycemia can destroy the balance between vasoactive substances NO and endothelin in patients, induce vascular damage, and even increase the risk of abnormal vasodilation and contraction function [16]. Relative to normal pregnant women, GDM women will have a compensatory phenomenon of hypoxia, and then the placental tissue will increase [18]. As a direct continuation of the internal carotid artery, MCA is also the most abundant blood vessel in the fetal brain, which can display the blood circulation status of the fetal brain and is very important for evaluating the dynamic changes of fetal cerebral circulation [19,20]. It suggested that the RI, PI, and S/D levels of fetal MCA in GDM patients were clearly decreased. With the development of the fetus, the brain volume gradually increases, so the oxygen demand and blood supply of cerebral blood also increase. RI will decrease because of the increase of MCA blood perfusion, and then the cerebral blood flow will increase [21]. UA is the only link connecting the fetus and placenta, and monitoring the changes of UA blood flow levels can evaluate the changes of blood flow circulation between the fetus and placenta [22]. It revealed that the RI, PI, and S/D levels of fetal UA in GDM patients were clearly enhanced. With the development of the villi, the area of the placental vascular bed also gradually increases. In order to ensure the blood supply level during the growth and development of the fetus, the blood circulation resistance decreases, the end-diastolic blood flow velocity increases, and the S/D and RI levels decrease [23]. Relative to UA, RA is more related to fetal growth and development, because the kidney is one of the organs with the most abundant blood perfusion in the fetal body. When pregnancy is complicated by diabetes, renal blood perfusion levels increase. When end-diastolic blood flow is blocked in RA, the S/D level enhances, which indicates the level of fetal renal blood flow, leading to the reduction of urine volume and amniotic fluid volume, then forming intrauterine hypoxia [24,25]. The results suggested that the RI, PI, and S/D levels of fetal UA in GDM patients were evidently enhanced. The above results indicate that the hemodynamic levels of MCA, UA, and RA are abnormal in GDM patients, and maternal hyperglycemia may affect fetal cerebral circulation, fetus-placental circulation, and renal blood perfusion, thereby increasing the risk of APO.

Cys C can induce inflammatory response and also participate in vascular damage in GDM [26]. Studies have shown that serum Cys C level is clearly raised in GDM patients, and is closely related to insulin sensitivity and insulin resistance [27]. Hcy is a kind of hydrophobic amino acid, and the increase of serum Hcy level can cause lipid metabolism disorders, and then hinder the growth of vascular endothelial cells [28]. The high blood glucose level of GDM patients will stimulate the generation and urination of urine, which will reduce the levels of vitamin B and folate, and then enhance the level of Hcy [29]. Studies have confirmed that elevated serum Hcy level can reduce insulin sensitivity, which can be used as a predictor of GDM and APO [30]. Prenatal serum Cys C and Hcy levels are evidently raised in GDM patients. It suggests that pregnant women with GDM may have problems such as microvascular lesions or microcirculation disorders.

The changes of fetal heart structure and function in GDM patients were examined by two-dimensional ultrasound and M-mode echocardiography. It was found that the indexes of fetal heart MVA, TVA, AVA, PVA, RVDd, RVDs, LVWT, RVWT, LVEF, LVFS, and

RVFS in GDM patients were obviously raised. It indicates that fetal cardiac hypertrophy occurs in GDM patients, and the inner diameters of each annulus and the right heart chamber are clearly augmented. Maternal high blood glucose level can affect the configuration of the fetal heart, and then change the fetal cardiac function [31]. The incidence of APO such as abnormal amniotic fluid (too much or too little), premature rupture of membranes, macrosomia, preeclampsia, hypertension, postpartum hemorrhage, fetal distress, premature delivery, fetal growth restriction, low birth weight, and neonatal asphyxia enhanced obviously in GDM patients. The incidence of neonatal complications and mortality will augment with the placental classification of GDM patients [32]. High blood glucose level stimulates the oxidation reaction of the placenta, leading to the weakened ability of the placenta to store oxygen, causing damage to the structure and function of the placenta, and eventually leading to APO [33,34]. The results of ROC curve and multiple Logistic regression analysis showed that prenatal serum Cys C and Hcy levels and fetal MCA, UA, RA hemodynamic indexes were related to APO.

5. Conclusion

Color Doppler ultrasound technology can reflect the changes of perinatal hemodynamic level, which is beneficial to the monitoring of perinatal infants. GDM enhances the risk of APO. Serum Cys C and Hcy levels in GDM patients and fetal MCA, UA, and RA hemodynamic parameters are related to APO. However, the sample size is small, and the maternal and neonatal prognosis was not monitored. In the future, it is necessary to expand the sample size and include more indicators to analyze the risk factors affecting the maternal and neonatal outcomes and prognosis of GDM patients. It can provide reference for the prevention of APO in GDM patients.

Statement

Ethics approval

All methods were performed in accordance with the ethical standards as laid down in the Declaration of Helsinki and its later amendments or comparable ethical standards.This study were approved by Ethics Committee of Haian City People's Hospital of Jiangsu Province (approval number: 2019-H-K10).

Informed consent

The study was informed consent from all subjects and/or their legal guardian(s) for publication of identified information/images in an online open-access publication.

Availability of data and materials

No additional unpublished data are available. The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Not Received.

CRediT authorship contribution statement

Dongmei Cai: Writing – review & editing, Data curation. **Su Yan:** Writing – original draft, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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