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*Research Article*

# Influencing Factors of Perinatal Outcomes of Pregnant Women with Diabetes under Ultrasound Guidance Guided by Multioperator Algorithm

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*Objective*. Ultrasound images based on a multioperator algorithm were used to explore the relationship between hemodynamic parameters of pregnant women and fetuses with abnormal glucose metabolism (AGM) during pregnancy and an adverse pregnancy outcome (APO). In addition, the influencing factors leading to APO were analyzed. *Methods*. 121 pregnant women with AGM during the third trimester of pregnancy were divided into poor prognosis group (group P, 80 cases) and good prognosis group (group *G*, 41 cases) according to the pregnancy outcome. Ultrasound technology based on a multioperator algorithm was used to detect the two groups of pregnant women, and the detection indexes were hemodynamic parameters of the fetus and uterus. The correlation between hemodynamic parameters and pregnancy outcome was analyzed by Logistic regression. *Results*. Compared with group *G*, the values of MCA-PI and MCA/UA in group P were dramatically decreased, while Ut-A-PI was dramatically increased ($p < 0.05$). When MCA-PI was less than 1.60, the sensitivity and specificity of MCA-PI for predicting APO reached 92.5% and 90.2%, respectively. The mean age of pregnant women, high-density lipoprotein level, family history of diabetes, and number of exercises during pregnancy in baseline data of group P were dramatically different from that of group *G* ($p < 0.05$). Advanced age and high-density lipoprotein level were risk factors for a poor prognosis, while MCA-PI, MCA-RI, and MCA/UA were protective factors for a good prognosis. *Conclusion*. The results show that color Doppler ultrasound based on the multioperator algorithm can be used to predict APO, and MCA-PI less than 1.60 was the most important predictive index and critical value.

## 1. Introduction

Pregnant women often have other complications during pregnancy, such as high blood pressure, epilepsy, and diabetes. Gestational diabetes is classified into pregnancy with diabetes and gestational diabetes, both of which are related to abnormal glucose metabolism (AGM) during pregnancy. Abnormal glucose metabolism during pregnancy is a common complication during pregnancy, which will reduce blood metabolism in the placenta and lead to the insufficient blood supply to the fetus. And the fetus's blood sugar and insulin are constantly at high levels, so the fetus's oxygen consumption is also relatively high. When the blood supply is insufficient, the growth of the fetus is restricted, or even deprived of oxygen. The health and even life of pregnant women and fetuses will be greatly affected if they are not timely treated. Studies showed that AGM during pregnancy will greatly increase the morbidity and mortality of fetuses and newborns, which is about four times that of normal pregnancy [1]. In recent years, with the application of ultrasonic dynamic monitoring in the monitoring of fetal intrauterine blood circulation, the use of ultrasound to analyze and study fetal hemodynamics has become a hot topic [2]. In this study, color Doppler ultrasound was used to detect the hemodynamics of pregnant women and their fetuses with AGM during pregnancy. The most important indicators and thresholds for predicting adverse pregnancy outcome (APO) were studied, to study the influencing factors of APO and provide evidence for the occurrence of adverse pregnancy in clinics.

## 2. Materials and Methods

*2.1. Research Object.* 121 pregnant women with AGM during pregnancy were randomly selected from June 2017 to October 2019 in the hospital. According to the pregnancy outcome, the patients were rolled into group P (80 cases) and group *G* (41 cases). The mean age of pregnant women in group P was (29.49 ± 3.88) years. The average gestation was (38.05 ± 1.03) weeks. There were 49 cases of cesarean section and 21 cases of vaginal delivery. The mean age of pregnant women in group *G* was (26.98 ± 3.40) years, and the mean gestation period was (38.09 ± 1.00) weeks.

Inclusion criteria: all pregnant women with AGM during pregnancy meet the diagnostic criteria of gestational diabetes diagnosis or pregnancy combined diabetes diagnosis and treatment guidelines (2014). Exclusion criteria: twin or multiple pregnancy, the ultrasound examination found fetal malformations and pregnant women with other diseases (heart disease, kidney disease, etc.).

*2.2. Adverse Pregnancy Diagnosis and Outcome.* The adverse outcome of the pregnancy has many manifestations, which are divided into fetal adverse death outcome and pregnant woman's adverse outcome according to different disease objects. The specific performance is shown in Figure 1. Some of the manifestations of APO can be used as clinical diagnostic criteria for adverse pregnancy, such as macrosomia, initial cesarean section, premature delivery, fetal distress, fetal asphyxia, and amniotic fluid turbidity (degree II or above). With the addition of neonatal weight over 90th percentile gestational age, neonatal hyperinsulin/hyperbilirubinemia, oligohydramnios, and other symptoms, any one or more of these can be diagnosed as an adverse pregnancy.

*2.3. Research Methods*

*2.3.1. Collection of Clinical Data.* Before the study, relevant literature of the subject was consulted, and a reasonable questionnaire was developed according to the purpose of the study. Relevant information was collected strictly in accordance with the content of the questionnaire, and the questionnaire was filled in carefully [3].

*2.3.2. Ultrasound Examination*

(1) Preparation before operation. During the investigation, I patiently explained the inspection process and the purpose of the inspection to the research subjects and family members, obtained the consent and approval of the patient and family members, and signed the investigation informed consent with the patient or authorized immediate family members. Check the operation below.

(2) Ultrasonic examination equipment. Zone ultracolor Doppler ultrasound diagnostic equipment is used for operation inspection, a convex array probe is selected, the probe frequency 3 is 1–8.6 MHz, and obstetric conditions are selected for inspection. All the inspection operations are performed independently and skillfully under the guidance of the instructor.

(3) The fetal middle cerebral artery (MCA), umbilical artery (UA), and gestational uterine artery (UT-A) were measured in the supine position with the abdomen fully exposed, as shown in Figure 2. UA measurement: the free umbilical cord was first located (2D ultrasound), and the filled blood flow signal point was used as the sampling point for measurement. Measurement of MCA: the head of the fetus was first located (using two-dimensional ultrasound). When the standard measurement of the diameter of the fetus's two heads was displayed, the ultrasonic probe was moved parallel to the base of the skull. The sampling point of the fetal middle cerebral artery was clearly displayed by color Doppler ultrasound.

*2.4. Statistical Processing.* Using SPSS22.0 statistical software, the measurement data are indicated by the *t* test for measurement data that meets the normal distribution, and the Wilcoxon signed rank sum test is used for those that do not meet the normal distribution. The count data are expressed as a rate, and the $\chi^2$ test is performed. Receiver operating characteristic (ROC) curves of different hemodynamic parameters are drawn to predict APO, and their diagnostic efficacy is calculated. Multivariate analysis of prognosis for APO uses a binary logistic stepwise regression method. $P < 0.05$ was deemed as statistically substantial. The Sobel operator is a commonly used gradient detection operator. Let $f$ (x, y) be a grayscale digital image function, and its first-order differential is based on the approximation of various two-dimensional gradients of the image. The gradient of the image $f$ (x, y) at point (x, y) can be defined as follows:

$$\nabla f(x, y) = \begin{bmatrix} Gx \\ Gy \end{bmatrix} = \begin{bmatrix} \dfrac{\partial f}{\partial x} \\ \\ \dfrac{\partial f}{\partial y} \end{bmatrix}. \tag{1}$$

In the above equation, $\nabla f(x, y)$ is the gradient of the image, which contains the change information of gray scale, and its value can be calculated by the following formula:

$$\nabla f(x, y) = \left[\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2\right]^{1/2}. \tag{2}$$

For the convenience of calculation, in actual edge detection, formula (3) is usually used to calculate the image

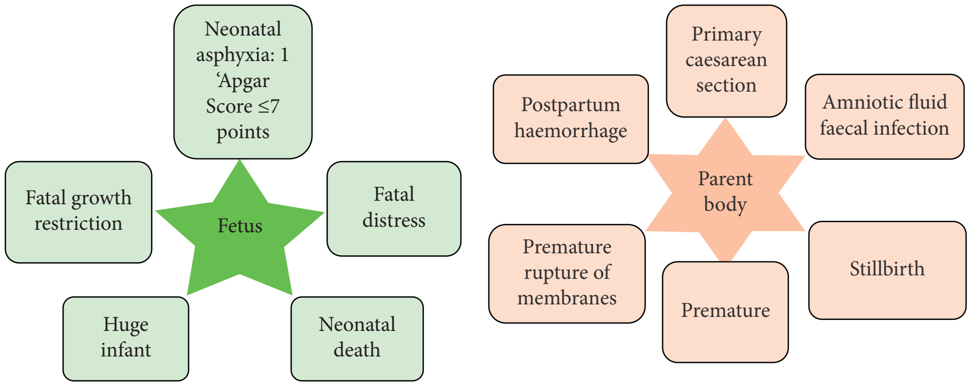



Figure 1: Adverse pregnancy outcomes: (a) fetus; (b) pregnant women.

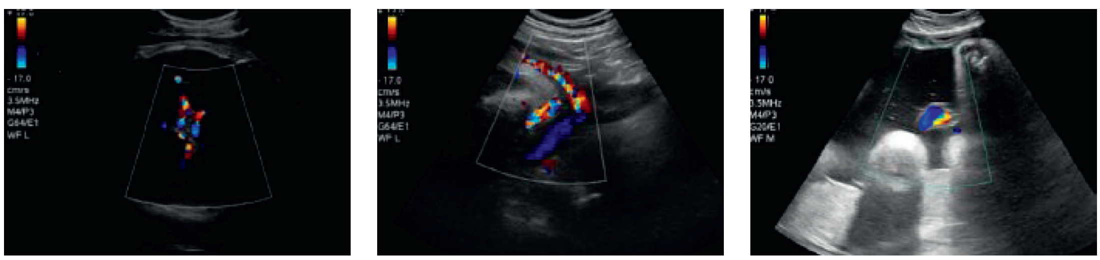



Figure 2: Ultrasound measurement section of fetal hemodynamic parameters.

gradient. Gx and Gy in formula (3) are the convolution formulas, which are used to calculate partial differentials in the horizontal and vertical directions, respectively.

$$f(x, y) = max\{|Gx|, |Gy|\}. \tag{3}$$

$$\begin{aligned} Gx &= \{f(x-1, y+1) + 2f(x, y+1) + f(x+1, y+1)\} \\ &\quad - \{f(x-1, y-1) + 2f(x, y-1) + f(x+1, y-1)\}, \\ Gy &= \{f(x+1, y-1) + 2f(x+1, y) + f(x+1, y+1)\} \\ &\quad - \{f(x-1, y-1) + 2f(x-1, y) + f(x-1, y+1)\}. \end{aligned} \tag{4}$$

The above four directional templates and formula (5) below are used to calculate the gray image point by point to get the gradient image f' 。

$$f'(x, y) = \begin{cases} \max\{|G_x|, |G_y|, |G_{45}|, |G_{135}|\}, f(x, y) > = z_1 \text{ or } f(x, y) > = z_2 \\ 0 \text{ others} \end{cases}. \tag{5}$$

In the above formula, points z1 and z2, respectively, represent the remaining two points in the same straight line direction as point (x, y) in the neighborhood of the original grayscale image 3X3. This formula shows that if the gradient of the point (x, y) in the direction is the largest and is not the minimum value in the direction, the gradient value of the point remains; otherwise, the gradient of this point is 0. This makes the positioning in the edge direction more precise and makes the edges of the gradient image thinner. In this paper, the standard deviation of the gradient image is superimposed to enhance the point with a relatively small gradient value in the gradient image f'. The standard deviation enhancement formula is shown in equation (7), where std (x, y) of the image f' represents the standard deviation of the point (x, y) in the neighborhood of 3X3.

$$g(x, y) = f'(x, y) + \mathrm{std}(x, y). \tag{6}$$

To achieve the purpose of edge refinement, this research adopts a method of fixed threshold comparison and combines with nonmaximum suppression along the gradient direction (NMS). Let $g$ be the output image and TH be the selected fixed threshold. When $x$, y> TH, if one of the conditions in formula (7) is satisfied, the value of point $g$ ‘(x, y) is 200, which is the edge point; otherwise, 0 is the nonedge point.

$$g'(x, y) = \begin{cases} g(x, y) > \ = g(x-1, y) \&\& g(x, y) \ > \ = g(x+1, y) \\ g(x, y) > \ = g(x, y+1) \&\& g(x, y) \ > \ = g(x, y-1) \\ g(x, y) > \ = g(x-1, y+1) \&\& g(x, y) > \ = g(x+1, y-1) \\ g(x, y) > \ = g(x-1, y-1) \&\& g(x, y) > \ = g(x+1, y+1) \end{cases}. \tag{7}$$

## 3. Results

*3.1. Comparison of the Hemodynamic Parameters of the Two Groups of Pregnant Women and Fetuses.* The differences of PI, RI, and S/*D* indexes in MCA, UA, and Ut-A were compared, and the results are shown in Figure 3. The MCA-PI and MCA-RI indexes in the group *G* were superior to those in the group P, and the difference was considerable ($p < 0.05$). The Ut-A-PI in the group *G* was lower than that in the group P, and the difference was substantial ($p < 0.05$). There was no remarkable difference in other indexes between group P and group *G* ($p > 0.05$).

The normal blood flow spectrum of fetal MCA in the second trimester was a high-speed and high-resistance type, and it was “Li Jianfeng;” the abnormal blood flow spectrum was a low-speed and a low-resistance type (Figure 4). The normal blood flow spectrum of Ut-A is a low-speed and low-resistance type; the abnormal blood flow spectrum is of a high-resistance spectrum, and there is a systolic notch (Figure 5). The normal blood flow spectrum of UA is of a low-speed and low-resistance type; the abnormal blood flow spectrum is of a high-speed and high-resistance type, showing a “peak shape” (Figure 6).

*3.2. ROC Curve Analysis*

*3.2.1. ROC Curve Analysis of MCA, UA, and Ut-A Hemodynamic Parameters to Predict APO.* The APO is taken as positive and the negative pregnancy outcome as negative. *D*, Ut-A-PI, RI, and S/D ROC curve analysis where the area under the ROC curve of MCA-PI, MCA-RI, and Ut-A-PI is 0.803, 0.771, and 0.639, respectively. Therefore, it can be used to predict the APO of AGM in late pregnancy. The parameter is selected with the largest area under the ROC curve: MCA-PI the area under the ROC curve of MCA-PI is 0.803; the ROC curve is drawn, and the critical value of the abnormal pregnancy outcome of AGM is analyzed and predicted in late pregnancy (see Figure 7). It can be seen that the maximum Youden index of different vascular blood flow parameters to predict the abnormal outcome of AGM in late pregnancy is 0.709. At this time, the value of MCA-PI is 1.60, and the sensitivity for predicting the abnormal pregnancy outcome of AGM in late pregnancy is 92.5%. The specificity is 90.2%. It can be seen from the ROC curves of different vascular blood flow parameters that predict the abnormal pregnancy outcome of AGM in late pregnancy. Using MCA-PI as a reference index to predict the abnormal pregnancy outcome of AGM in late pregnancy has high sensitivity and specificity. MCA-PI can be used as a single vascular hemodynamic indicator to predict the abnormal pregnancy outcome of late glucose metabolism.

*3.2.2. ROC Curve Analysis of MCA, UA, and Ut-A Combined Hemodynamic Parameters to Predict the Occurrence of APO.* Taking the APO as positive and the negative pregnancy outcome as negative, the combined hemodynamic parameters of MCA, UA, Ut-A (PI ratio (MCA/UA, UA/Ut-A, and MCA/Ut- A), RI ratio (MCA/UA, UA/Ut-A, and MCA/Ut-A), S/*D* ratio (MCA/UA, UA/Ut-A, and MCA/Ut-A) for ROC curve analysis where the area under the ROC curve for the PI ratio (MCA/Ut-A), RI ratio (MCA/UA), and RI ratio (MCA/Ut-A) is 0.747, 0.881, and 0.797. The parameter is selected with the largest area under the ROC curve: The area under the ROC curve of RI ratio (MCA/UA) is 0.881, the ROC curve is drawn, and the critical value is analyzed for predicting APO (see Figure 8).

*3.3. Analysis of Prognostic Factors*

*3.3.1. Single Factor Analysis.* The differences between the basic data and laboratory examination results of patients in the group *G* and the group P are compared in Table 1. There were no great differences in pregnancy, family history of hypertension, serum total cholesterol, triglyceride, and low-density lipoprotein between the two groups ($p < 0.05$). Compared with the group *G*, the mean age and family history of diabetes in the group P were dramatically older. Serum high-density lipoprotein level and the number of exercises during pregnancy were dramatically lower ($p < 0.05$).

*3.3.2. Multifactor Analysis.* Taking the occurrence of APO as a dependent variable, the results of preliminary univariate analysis showed that there were differences in age, high-density lipoprotein, family history of diabetes, exercise

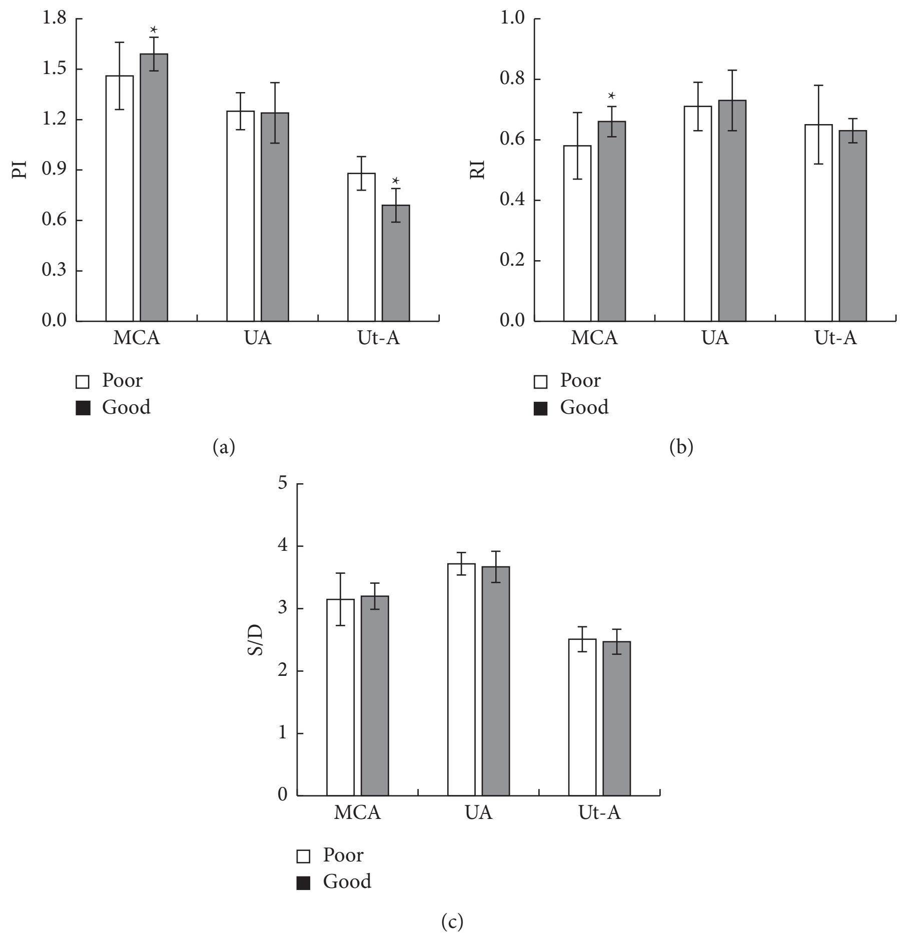



FIGURE 3: Hemodynamic parameters of pregnant women and fetuses (the difference between groups was considerable, * $((p) < 0.05)$).

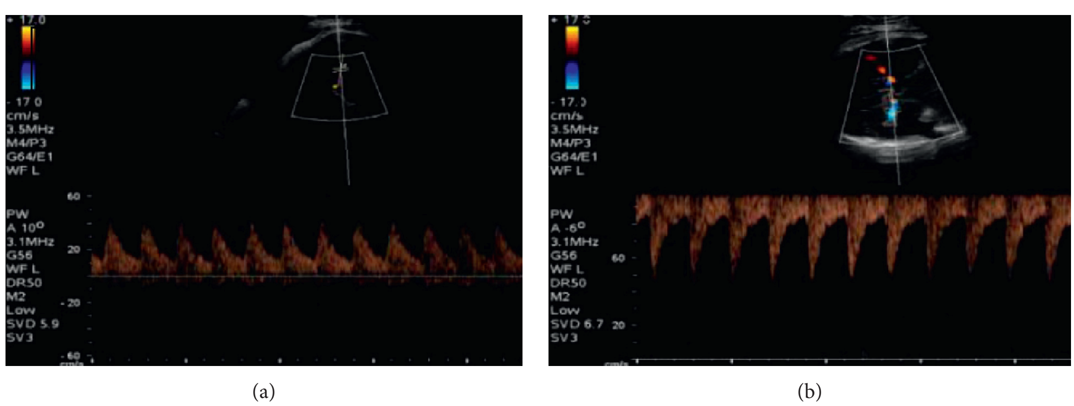
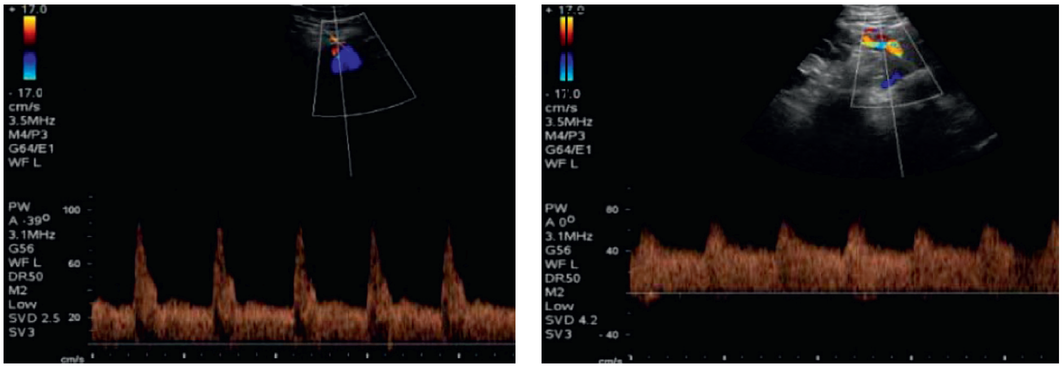



FIGURE 4: Spectral diagram of arterial blood flow in the brains of two groups of fetuses: (a) group P; (b)group G.

during pregnancy, MCA- PI, MCA-RI, and Ut-A-PI. Therefore, the above indicators were selected as independent variables for binary logistic stepwise regression analysis. The results are shown in Table 2. The protective factors of APO were exercise during pregnancy, MCA- PI $\geq 1.60$, MCA-RI $\geq 0.65$, and Ut-A-PI $\geq 0.82$. The risk factors for APO were advanced age, family history of diabetes mellitus, and high-density lipoprotein level $\leq 1.2$ mmol/$L$.

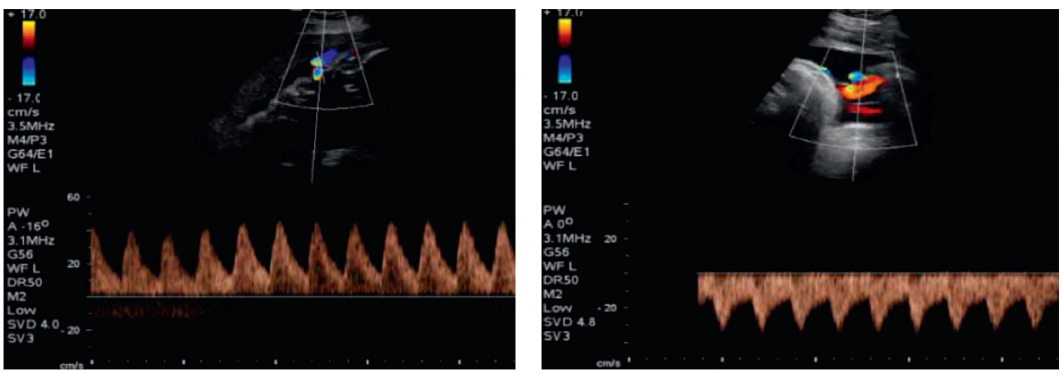
## 4. Discussion

In recent years, with the improvement of living standards, changes in lifestyle, and the opening of the national second-child policy, the incidence of AGM during pregnancy has increased from 3% to 8%, increasing the incidence of APO. In this study, two-dimensional ultrasound and color ultrasound Doppler technology were used to measure the



(a) (b)

Figure 5: Spectra of uterine artery blood flow in two groups of pregnant women: (a) group P; (b) group G.



(a) (b)

Figure 6: Spectra of umbilical artery blood flow of two groups of fetuses: (a) group P; (b) group G.

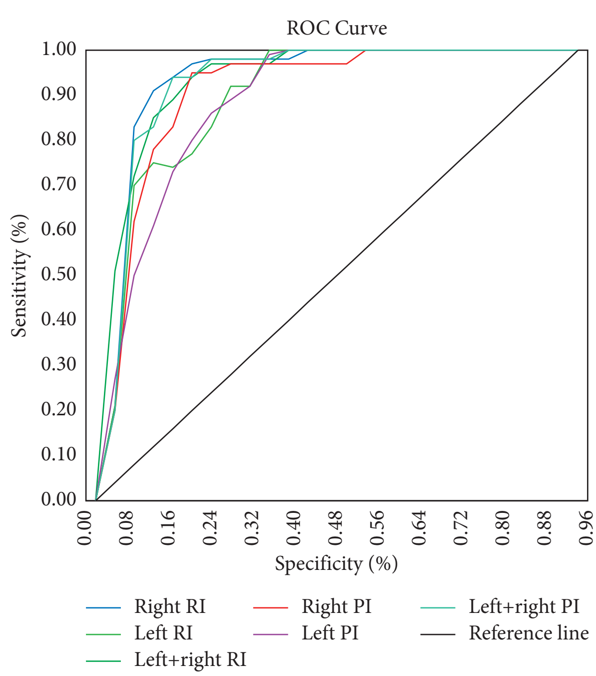



Figure 7: MCA-PI ROC curve predicting the occurrence of abnormal pregnancy outcomes.

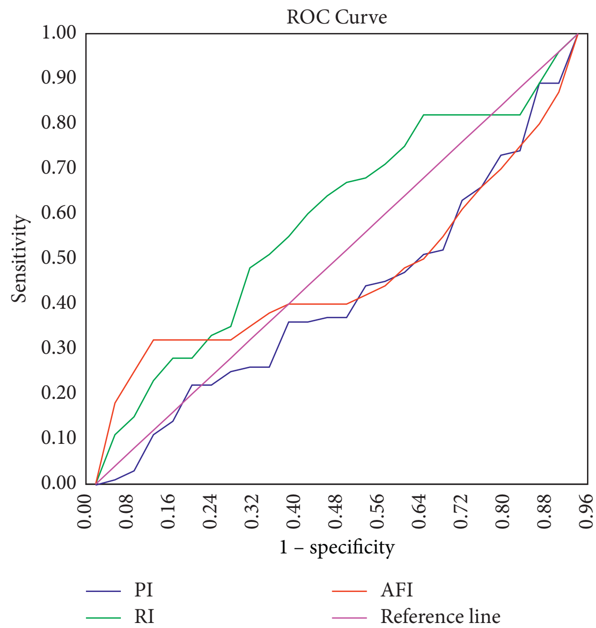



Figure 8: ROC curve of RI ratio (MCA/UA) predicting the occurrence of APO.

Table 1: One-way ANOVA of basic data of patients in the two groups.

| Item | Group $G$ ($n = 41$) | Group P ($n = 80$) | Statistics | $P$ |
|---|---|---|---|---|
| Age (years old) | 26.98 ± 3.40 | 29.49 ± 3.88 | 2.037 | 0.031 |
| Pregnancy (weeks) | 38.09 ± 1.00 | 38.05 ± 1.03 | 0.148 | 0.527 |
| Total cholesterol (mmol/L) | 5.45 ± 1.43 | 5.91 ± 1.20 | 0.629 | 0.322 |
| Triglycerides (mmol/L) | 3.84 ± 1.15 | 4.03 ± 1.07 | 0.228 | 0.493 |
| High-density lipoprotein (mmol/L) | 1.81 ± 0.22 | 1.47 ± 0.34 | 5.297 | 0.000 |
| Low-density lipoprotein (mmol/L) | 2.85 ± 0.66 | 2.87 ± 0.45 | 1.418 | 0.161 |
| Family history of diabetes (n/%) | 4/9.8 | 27/33.8 | 8.326 | 0.000 |
| Family history of hypertension (n/%) | 10/24.4 | 24/30.0 | 0.051 | 0.629 |
| Exercise during pregnancy (n/%) | 31/75.6 | 29/36.3 | 9.117 | 0.000 |

general ultrasound measurement indexes of fetal AGM and MCA, UA, and Ut-A three vessels, and comprehensively evaluate the glucose metabolism during pregnancy. The survival status of abnormal fetuses is to predict the APO, to find the best indicators and cut-off values to predict the APO of AGM during pregnancy, and to explore its influencing factors.

The normal MCA blood flow spectrum in the second trimester is a high-speed and high-resistance type due to the physiological reasons of the fatal brain structure, and it is a "Li Jian Feng." The UA and Ut-A in the second trimester are low-speed and low-resistance type blood flow spectrum. When intrauterine hypoxia occurs in the fetus, due to the "blood flow redistribution phenomenon" (brain protection effect), the blood in the fetus is redistributed, the blood supply to the more important organs such as the brain and heart increases, the blood vessels dilate, and the resistance to blood flow decreases. "Little butterfly wings" like a low-resistance spectrum, and peripheral blood vessels such as UA contract to ensure blood supply to important organs, the diameter of the tube becomes narrower, and blood flow resistance increases, making UA and Ut-A show a high-resistance spectrum. Studies suggested that there is a link between fetal hypoxia and reduced RI ratio (MCA/UA) [3]. Compared with neonates with RI ratio greater than 1, neonates with RI ratio less than 1 had lower Apgar score and umbilical arterial blood gas acid-base status 5 min after birth. Studies [4] also show that the RI ratio (MCA/UA) < 1 can predict the adverse outcome of the fetus at labor. The results of this study and the above studies are basically the same. Compared with UA and Ut-A, MCA can more fully reflect the change of the fetal physiological state. The reason for the analysis may be that Ut-A is mainly affected by the pregnant woman's own hemodynamics. UA, as a channel connecting the mother and the fetus, is affected by both the mother and the fetus, and the fetal MCA is only affected by the fetal hemodynamics, so it can directly and accurately reflect the fetal survival status in the mother.

In this study, the analysis of the factors affecting the prognosis of AGM in late pregnancy found that older age, overweight or obesity, and a family history of diabetes are risk factors for pregnancy prognosis because the older the age, the higher the prepregnancy body mass index and the family history of diabetes. Decreased regulatory ability,

Table 2: Logistic multivariate analysis results of factors affecting the prognosis of AGM during pregnancy.

| Variable | Beta | Se | Wald $\chi^2$ | $P$ | OR | 95% confidence interval |
|---|---|---|---|---|---|---|
| Age | 0.255 | 0.091 | 9.562 | 0.000 | 1.286 | 1.101–1.603 |
| Family history of diabetes | 3.567 | 1.643 | 4.847 | 0.027 | 42.165 | 2.063–1069.331 |
| Exercise during pregnancy | 2.731 | 1.055 | 6.599 | 0.000 | 0.059 | 0.010–0.367 |
| High-density lipoprotein | 1.889 | 1.027 | 4.321 | 0.020 | 0.443 | 0.128–0.980 |
| MCA-PI | 2.073 | 0.926 | 7.027 | 0.006 | 0.121 | 0.035–0.461 |
| MCA-RI | 2.526 | 1.051 | 6.114 | 0.017 | 0.069 | 0.010–0.596 |
| Ut-A-PI | 3.434 | 1.208 | 8.321 | 0.005 | 0.043 | 0.005–0.328 |

stronger insulin resistance, poor blood sugar control during pregnancy, and obesity can easily induce complications such as hypertension in pregnancy, making the condition worse. Through Logistic regression analysis, this study concluded that the protective factors of APO were exercise during pregnancy, MCA- PI $\geq$ 1.60, MCA-RI $\geq$0.65, and Ut-A-PI $\geq$0.82. When the blood circulation of the fetus in the mother conforms to the fetal physiological state, MCA hemodynamics is also in a high impedance state, and peripheral vascular UA and Ut-A are in a low impedance state. If the above indicators are abnormal, the fetus may have hypoxia, leading to fetal distress, early meconium discharge, and amniotic fluid contamination [5]. Therefore, exercise before pregnancy can reduce the incidence of insulin resistance before pregnancy.

## 5. Conclusion

Through the analysis of the above research results, it is understood that color Doppler ultrasound images based on the multioperator algorithm can be used to predict APO and evaluate the condition of the fetus. MCA-PI <1.60 is the most important predictor and critical value. It is also found that advanced age, family history of diabetes, high-density lipoprotein level, exercise during pregnancy, MCA-PI, MCA-RI, and Ut-A-PI can affect the adverse outcomes of pregnant women. They are helpful for the early detection of clinical adverse pregnancy and prevention of APO.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare no conflicts of interest.

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