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Original Article

Construction and application of a prediction model for the delivery outcome of women with scarred uterus based on ultrasonic parameters

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Abstract: Objective: To explore the application value of the prediction model for delivery outcome of women with scarred uterus based on ultrasonic parameters. Methods: In this retrospective study, a total of 100 pregnant women with scarred uterus who delivered in Cangzhou Hospital of Integrated Traditional Chinese Medicine and Western Medicine were selected as the research subjects. Adverse pregnancy outcomes included premature delivery, low birth weight, neonatal asphyxia, postpartum hemorrhage, and uterine rupture. In line with delivery outcome, the pregnant women were segmented into good outcome group (n = 78) and poor outcome group (n = 22). We collected and compared the clinical data and the ultrasonic parameters of pregnant women of the two groups. Multivariate logistic regression analysis was conducted to explore the risk factors affecting the delivery outcome of women with scarred uterus and to establish a prediction model. Results: Multivariate logistic regression analysis showed that low hemoglobin (Hb) before delivery, high grade of uterine scar, low muscle thickness of lower uterine segment, and low blood flow index were the risk factors for poor delivery outcome of women with scarred uterus. According to the risk factors, the prediction model was obtained: Prob = 1/[1 + e^ (-5.110-2.568 * Pre-delivery Hb - 1.697 * uterine scar grade -2.895 * lower uterine muscle thickness + 19.584 * blood flow index)]. The sensitivity, specificity and area under the curve were 90.0, 91.0 and 0.959, respectively. After validation, the sensitivity and specificity were 85.71 and 87.04, respectively. Conclusion: Low Hb before delivery, low grade of uterine scar, low musculature thickness of lower uterine segment, and low blood flow index were the risk factors for poor delivery outcome of women with scarred uterus. The establishment of prediction model based on risk factors could effectively evaluate the risk of poor delivery outcome of women with scarred uterus.

Keywords: Ultrasonic parameters, scarred uterus, delivery outcome, prediction model

Introduction

Scarred uterus refers to the uterus that has undergone cesarean section or intramural myoma removal, which often has a great impact on the subsequent pregnancy outcome [1]. In recent years, with the development of the birth policy, the cesarean section rate has increased significantly, and the number of women with scar uterus has increased. In 2014, the rate of cesarean section in China was 35%. In 2016, the rate of cesarean section in general hospitals in mainland China increased to 41%, far exceeding the ideal range proposed by World Health Organization (WHO) [2]. At the same time, the probability of pregnancy in scarred uterus increases with the increase of cesarean section rate, and the incidence of adverse delivery outcomes of pregnant women with scarred uterus also increases year by year, which poses a great threat to the safety of mothers and infants, and also affects the choice of delivery mode [3]. Adverse delivery outcomes include premature delivery, neonatal asphyxia, postpartum hemorrhage, uterine rupture, etc. Scarred uterus pregnancy is an important factor leading to adverse delivery outcomes [4]. Therefore, it is necessary to strengthen the research on the related mechanisms of adverse birth outcomes in pregnant women

with scarred uterus. However, there are few prediction models for such condition. It was believed that scanning the altered morphology of the muscularis structure in the lower anterior wall of uterus and measuring its thickness and continuity could help predict the outcome of pregnancy and delivery in scarred uterus [5]. On this basis, comprehensive evaluation combined with clinical indicators can play a guiding role in improving maternal and infant outcomes and the safety of vaginal delivery. Ultrasound is the main method for clinical measurement of uterine scar thickness and observation of uterine incision healing, with advantages of simple operation, good repeatability, and high accuracy [6]. In view of the above phenomenon and the insufficiency, this study attempted to study the pregnancy outcome of scar uterus, aiming to explore influence of scarred uterus on pregnancy and delivery outcome and the risk factors of adverse birth outcomes. Based on the ultrasonic parameters, a model was built to predict the incidence, so as to monitor high-risk pregnant women and take corresponding intervention measures to improve the birth outcome of pregnant women with scarred uterus.

Materials and methods

Research object

The clinical data and ultrasound parameters of pregnant women with scarred uterus who delivered in Cangzhou Hospital of Integrated Traditional Chinese Medicine and Western Medicine from September 2019 to October 2021 were retrospectively analyzed. Inclusion criteria: (1) Second pregnancy with the first of cesarean section; (2) Single embryo by imaging examination; (3) Normal functions in pelvic, cardiac, liver, lung, and kidney. Exclusion criteria: (1) The presence of mental illness, cognitive impairment and other communication difficulties; (2) With conditions that increase uterine pressure in pregnant women, such as fetal malformation and polyhydramnios; (3) Incomplete clinical data and ultrasound parameters. In the end, 100 patients in total were included. This study was approved by the Ethics Committee of Cangzhou Hospital of Integrated Traditional Chinese Medicine and Western Medicine.

Collection of ultrasound related parameters and clinical data

Clinical data and ultrasound related parameters of all pregnant women were collected. The clinical data included age, prenatal body mass index (BMI), gestational weight gain, gestational age, number of pregnancies, number of deliveries, time between pregnancies, delivery mode, hemoglobin (Hb) before delivery, and pregnancy complication. Ultrasound related parameters included grading of uterine scar, thickness of muscular layer of lower segment of uterus, abnormal intrauterine echo, distance between pregnancy sac and incision, blood flow index, and the morphologic change of muscular layer of inferior anterior wall of uterine scar.

Detection method

Audio Video Sub System (AVSS) exploration: (1) A Siemens Acuson S2000 ABVS color ultrasound system was used to detect the thickness and continuity of the muscle layer of the lower uterine segment after 28 weeks of pregnancy, with the probe frequency of 5-14 mhz; (2) Pregnant women were guided to take supine position and were asked to hold urine to fill the bladder; (3) The lower edge of the probe was placed at the pubic symphysis, and the midline of the abdomen was used as the midpoint to carefully observe and record the fetus and placenta; (4) Images of the uterine scar on lower anterior wall were displayed, and images of its thickness and storage volume were recorded; (5) The integrity of the recursion structure of the chorionic layer, decidua layer, muscularis layer, and visceral peritoneum in the lower anterior wall of scar were observed. The thickness of the anterior lower segment of the uterine scar was measured at 33, 36, and 39 weeks of gestation, and the minimum value was taken. The vaginal delivery pregnant women underwent vaginal trial delivery under close supervision.

Grouping and criteria

Adverse pregnancy outcomes including premature delivery, low birth weight, neonatal asphyxia, postpartum hemorrhage, and uterine rupture. (1) Preterm delivery: Delivery within 28 to 37 weeks of gestation. (2) Low birth weight [7]: Low birth weight is defined as a birth weight <2500 g. (3) Neonatal asphyxia [8]: Apgar score ≤7 one minute after birth. (4) Postpartum hemorrhage [9]: The amount of bleeding within 24 hours after delivery exceeds 500 mL. (5) Uterine rupture: The rupture of the uterine body or lower segment of the uterus during pregnancy or childbirth [10]. Based on the degree, it

could be divided into complete uterine rupture and incomplete uterine rupture. Complete uterine rupture refers to the full-thickness rupture of the uterine muscle wall, and the uterine cavity was connected with the abdominal cavity. Incomplete uterine rupture refers to partial or full rupture of the myometrium, but the serous membrane layer was still intact, and the uterine cavity was not connected to the abdominal cavity. The latter often lacks symptoms of heralded rupture, and the signs are not obvious, often diagnosed in pregnancy after cesarean section. According to the different delivery outcomes, the included subjects were classified into the good outcome group and the poor outcome group.

(1) Structural morphological changes of the inferior anterior wall muscle layer of uterine scar: Including continuous/complete hypoechoic structure of the inferior anterior wall muscle layer of uterus on any section and intermittent/disappearance on any plane. (2) Uterine scar grading [11]: Grade I: the thickness >3 mm, complete structure of each cortex, clear and uniform echo, and good continuity. Grade II: the thickness of 2-3 mm, destroyed continuity of the muscle layer in the inferior segment of the anterior wall (some disappeared), the poor continuity of the echo, and no obvious change in the pressure amniotic cavity. Grade III: the thickness <2 mm, raised anterior wall of amniotic sac, obviously damaged muscle layer, and the interrupted echo. (3) Indications for cesarean section: If the pregnant woman had fever, vaginal bleeding, cervical dilatation lasting more than 2 hours, scar pain, or fetal heart monitoring showing fetal distress or threatened uterine rupture, the vaginal trial labor was terminated in time and replaced by cesarean section.

Statistical methods

SPSS 25.0 statistical software was used for data analysis. The quantitative data conforming to normal distribution were represented by mean ± standard deviation and t-test was performed. Qualitative data were expressed by n (%), and chi-square test was performed. When 1≤ theoretical frequency <5, chi-square value should be corrected; When theoretical frequency <1, exact probability method was applied for calculation. Univariate analysis and multivariate logistic regression analysis were applied to find out the risk factors influencing the delivery outcome of scarred uterus in second pregnancy and constructed the prediction model. Hosmer-Lemeshow goodness of fit test was used. When $P>0.05$, the goodness of fit was considered to be good. Receiver operator characteristic (ROC) curve was used to determine the threshold for diagnosis and evaluate the prediction effect of the model. $P<0.05$ indicated that the difference was statistically significant.

Results

Univariate analysis of the second pregnancy delivery outcome of scarred uterus

Among 100 pregnant women with scarred uterus, 22.0% (22/100) of them had a poor outcome, and 78.0% (78/100) had a good outcome. Univariate analysis showed that there were statistically significant differences in the number of pregnancies, number of deliveries, Hb before delivery, uterine scar grade, muscle thickness of lower uterine segment, and blood flow index between the two groups (all $P<0.05$), as shown in **Table 1**.

Multivariate logistic analysis and prediction model construction of the delivery outcome of scarred uterus

The factors with statistical differences in univariate analysis were taken as independent variables, and the delivery outcome (0 = good outcome, 1 = poor outcome) was taken as dependent variables (variable values were shown in **Table 2**). The multivariate Logistic model was established, and the results showed that Hb before delivery, grading of uterine scar, thickness of muscular layer of lower segment of uterus, and blood flow index were correlated with the delivery outcome of women with scarred uterus ($P<0.05$), as shown in **Table 3**. Logistic regression coefficient and constant term were used to construct the prediction model of delivery outcome for pregnant women with scarred uterus. Prob = 1/[1 + e^(-5.110-2.568 * Hb before delivery - 1.697 * grading of uterine scar - 2.895 * thickness of muscular layer of lower segment of uterus + 19.584 * blood flow index)]. The model summary table (**Table 4**) shows that the high values of the two pseudo-R values indicate that the model had a better explanation for the variation of the origi-

Table 1. Univariate analysis of the delivery outcome of women with scarred uterus [n (%)/($\bar{x}$ ± sd)]

Relevant factors		Poor outcome group (n = 22)	Good outcome group (n = 78)	t/χ^2	*P*
Clinical data					
Age (years)	<25	6 (27.27)	12 (15.38)	1.735	0.420
	25-30	11 (50.00)	48 (61.54)		
	>30	5 (22.73)	18 (23.08)		
Prenatal BMI (kg/m^2)	<18.5	2 (9.09)	9 (11.54)	0.108	0.947
	18.5-24	17 (77.27)	59 (75.64)		
	>24	3 (13.64)	10 (12.82)		
Gestational weight gain (kg)	≥12	13 (59.09)	59 (75.64)	2.331	0.127
	<12	9 (40.91)	19 (24.36)		
Gestational age (weeks)		39.12±0.62	39.03±0.45	0.759	0.450
Delivery way	vaginal delivery	9 (40.91)	34 (43.59)	0.050	0.823
	cesarean delivery	13 (59.09)	44 (56.41)		
Number of pregnancies (times)	≥3	16 (72.73)	28 (35.90)	9.447	0.002
	2-3	6 (27.27)	50 (64.10)		
Number of deliveries (times)	>2	12 (54.55)	20 (25.64)	6.589	0.010
	1-2	10 (45.45)	58 (74.36)		
Time between pregnancies (years)		3.56±1.15	3.32±1.04	0.934	0.353
Delivery mode	cesarean delivery	17 (77.27)	53 (67.95)	0.710	0.399
	vaginal delivery	5 (22.73)	25 (32.05)		
Hb before delivery (g/L)	<100	12 (54.55)	8 (10.26)	21.037	<0.001
	≥100	10 (45.45)	70 (89.74)		
Pregnancy complication	have	4 (18.18)	18 (23.08)	0.240	0.624
	not have	18 (81.82)	60 (76.92)		
Ultrasonic parameters					
Grading of uterine scar	grade III	8 (36.36)	45 (57.69)	8.879	0.012
	grade II	5 (22.73)	23 (29.49)		
	grade I	9 (40.91)	10 (12.82)		
Thickness of muscular layer of lower segment of uterus (mm)	<3	13 (59.09)	22 (28.21)	7.195	0.007
	≥3	9 (40.91)	56 (71.79)		
Abnormal intrauterine echo	have	8 (36.36)	42 (53.85)	2.098	0.148
	not have	14 (63.64)	36 (46.15)		
Distance between pregnancy sac and incision (mm)		20.15±4.32	20.59±4.16	0.435	0.665
Blood flow index		0.50±0.11	0.76±0.15	6.110	<0.001
Muscular layer of inferior anterior wall of uterine scar	continuity and integrity	13 (59.09)	40 (51.28)	0.420	0.517
	stuttering and disappearing	9 (40.91)	38 (48.72)		

BMI: body mass index; Hb: hemoglobin.

Table 2. Variable assignments

Variable	Assignment
Number of pregnancies	<3 = 0, ≥3 = 1
Number of deliveries	≤2 = 0, >2 = 1
Hb before delivery	≥100 = 0, <100 = 1
Grading of uterine scar	grade I = 1, grade II = 2, grade III = 3
Thickness of muscular layer of lower segment of uterus	≥3 = 0, <3 = 1
Blood flow index	actual value

Hb: hemoglobin.

nal variables. The statistical value of Hosmer-Lemeshow test of the model was 0.693 (*P*> 0.05), indicating that the difference between the fitting equation and the real equation was

Table 3. Multivariate logistic analysis of the delivery outcome of women with scarred uterus

	Variable	B	S.E	Wals	*P*	OR	95% CI	
							Lower limit	Upper limit
Step 1	Number of pregnancies	0.765	1.356	0.319	0.572	2.149	0.151	30.646
	Number of deliveries	-0.416	1.328	0.098	0.754	0.660	0.049	8.909
	Hb before delivery	2.465	0.941	6.864	0.009	11.761	1.860	74.352
	Grading of uterine scar	1.614	0.638	6.406	0.011	5.024	1.439	17.538
	Thickness of muscular layer of lower segment of uterus	2.802	1.037	7.308	0.007	16.481	2.161	125.696
	Blood flow index	-19.069	5.883	10.506	0.001	0	0	0.001
	Constant	4.780	2.622	3.325	0.068	119.144	-	-
Step 2	Hb before delivery	2.568	0.917	7.848	0.005	13.045	2.163	78.672
	Grading of uterine scar	1.697	0.636	7.114	0.008	5.458	1.568	18.992
	Thickness of muscular layer of lower segment of uterus	2.895	1.022	8.018	0.005	18.087	2.438	134.171
	Blood flow index	-19.584	5.759	11.565	0.001	0	0	0
	Constant	5.110	2.430	4.424	0.035	165.646	-	-

Hb: hemoglobin.

Table 4. Model summary

Step	-2 logarithmic likelihood	Cox & Snell R	Nagelkerke R
1	41.815	0.470	0.722
2	41.451	0.472	0.725

not statistically significant, and the model fitting degree was good.

Analysis of model effect

In this study, ROC curve was used to evaluate the prediction model of the delivery outcome of scarred uterus. Hb before delivery, uterine scar grade, muscle thickness of lower uterine segment, blood flow index, and prob were used as test indexes. The sensitivity, specificity and area under the curve of prob were 90.0, 91.0 and 0.959, respectively. This indicates that the model has good predictive value, as shown in **Table 5** and **Figure 1**.

Validation of prediction model effect

In addition, 68 pregnant women with scarred uterus who gave birth in Cangzhou Hospital of Integrated Traditional Chinese Medicine and Western Medicine from November 2021 to May 2022 were selected as validation subjects. The prediction sensitivity and specificity of the model were 85.71 and 87.04, respectively, as shown in **Table 6**.

Discussion

Ultrasound is the most commonly used auxiliary examination in obstetrics, which can not only show the placenta position, placenta previa, uterine preamble rupture, placenta implantation and other information, but also has important value in guiding perinatal preparation, increasing maternal and infant safety, and reducing doctor-patient disputes [12]. Therefore, this study explored the influence of ultrasound related parameters on the outcome of the second pregnancy delivery of scarred uterus, and established the relevant prediction model, in order to guide clinical preventive measures and improve perinatal safety.

High resolution color Doppler ultrasound has the characteristics of rapid, safe, and high diagnostic accuracy in gynecological diagnosis [13]. Abdominal ultrasound could clearly measure the thickness of the pregnancy sac or mass to the serous membrane layer. Vaginal ultrasound was more conducive to observing the position of scar incision of pregnancy sac and uterus. Doppler imaging could show the blood flow situation and velocity around the pregnancy sac, which is of great significance to the diagnosis of the specific position of the pregnancy sac and blood supply, thus greatly improving the diagnostic effect [14]. In this study, a prediction model for the delivery outcome of women with scarred uterus was established based on ultrasound parameters. The investigation of 100 pregnant women with scarred uterus found that there were differences in pregnancy times, delivery times, Hb before delivery, uterine scar grade, muscle thickness of lower uterine segment, and blood flow index between those with poor and good delivery outcomes of women

Table 5. ROC curve analysis of each indicator and prediction model

Factors	AUC	Cut-off value	Sensitivity	Specificity	*P*	95% CI	
						Lower limit	Upper limit
Hb before delivery	0.721	0.50	54.5	89.7	0.002	0.586	0.857
Grading of uterine scar	0.652	2.50	40.9	87.2	0.030	0.513	0.792
Thickness of muscular layer of lower segment of uterus	0.654	0.50	59.1	71.8	0.027	0.521	0.788
Blood flow index	0.132	0.55	18.2	15.4	<0.001	0.058	0.205
Prob	0.959	0.330	90.9	91.0	<0.001	0.919	1.000

Hb: hemoglobin.

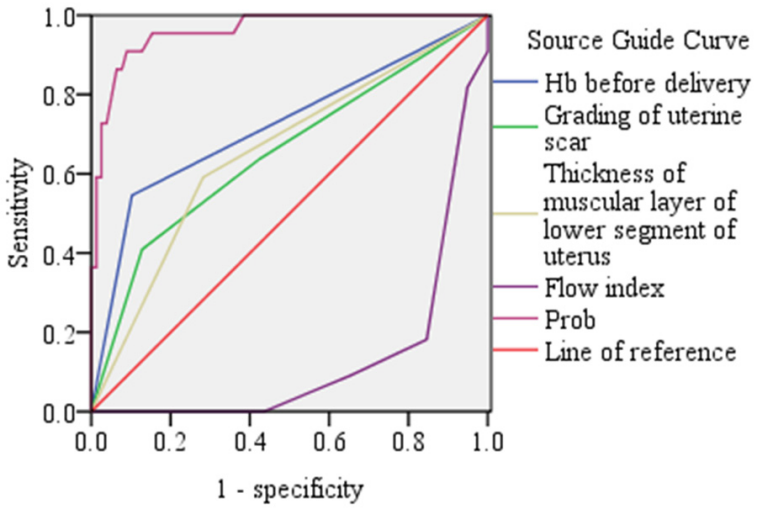

Figure 1. ROC curve of the prediction model for the delivery outcome of women with scarred uterus. Hb: hemoglobin.

Table 6. Validation of prediction model

Actual result	Model prediction results		Total
	Poor outcome	Good outcome	
Poor outcome	12	2	14
Good outcome	7	47	54
Total	19	49	68

with scarred uterus. Multivariate logistic regression analysis showed that low Hb before delivery, high grade of uterine scar, low muscle thickness of lower uterine segment, and low blood flow index were the risk factors for poor delivery outcome of women with scarred uterus, which findings were similar to previous research results [15-17]. At present, the clinical pathogenesis of the poor delivery outcome in women with scarred uterus is not clear, and the occurrence of uterine rupture is believed to be caused by scarred uterus. Hb is a special protein that carries oxygen in red blood cells. The decrease of Hb indicates the decreased oxygen supply to the fetus which hinders the normal growth and development of the fetus. Studies have shown that low Hb level of pregnant women before delivery increases the incidence of preterm delivery [18]. Another study found that daily prenatal iron supplementation significantly improved birth weight and reduced the risk of low birth weight. The improvement of prenatal Hb concentration was associated with a linear increase in birth weight [19]. Therefore, vigilance should be raised for pregnant women with scarred uterus with low Hb level before delivery. The thinner the scar thickness, the less ability of the scar to withstand external pressure, so it was more likely to lead to scar rupture and postpartum bleeding [20]. The lower uterine segment in the third trimester forms a clear boundary and the thickness which can be measured. If the full thickness of the lower uterine segment is less than 3 mm, the scar elasticity is insufficient and the original tissue structure is lost, which affects the overall regular uterine contractions [21]. In this study, there were 13 pregnant women in the adverse outcome group with the full thickness of the lower uterine segment less than 3 mm, suggesting that the low thickness of the muscular layer of the lower uterine segment was not conducive to the safety of childbirth. It may be because the poor elasticity of scar uterine muscle layer, due to decreased thickness of the lower uterine segment, can lead to an increase in the incidence of incomplete uterine rupture, poor healing of uterine incision, weakness of uterine contraction, and neonatal as-

phyxia in pregnant women, ultimately leading to an increase in the risk of adverse delivery outcomes. Therefore, full attention to women with lower uterine full-thickness less than 3 mm during the perinatal period is necessary. In addition, pregnant women at high-risk should be closely monitored about ECG and fetal heartbeat, and termination of trial labor is recommended for the occurrence of fetal heart abnormalities to avoid adverse delivery outcomes. The uterine artery is located in the uterine neck of the upper vagina of the female. It passes through the myometrium to the midline and branches off radial artery into the endometrium at right angles [22]. The radial artery branched inside the endometrium into the endometrial basilar artery and the spiral artery. The basilar artery feeds the basal layer of the endometrium which is unaffected by hormones. Spiral arteries enter the functional layer of the endometrium and vary in diameter depending on ovarian hormone levels. After pregnancy, the spiral artery undergoes a series of physiological changes to adapt to embryo growth and development. Therefore, the blood flow dynamics of uterine artery is relatively stable, so the blood flow index of this study was derived from uterine arterial blood. The small blood flow index indicated less uterine artery perfusion of pregnant women, resulting in insufficient supply of blood, blood oxygen, and nutrients in utero [23]. On the one hand, it would be difficult to ensure adequate nutrition for the fetus, and on the other hand, it would harm the placental function (material exchange, defense, synthesis, and immunity). The placenta is the foundation of fetal growth and development. It is the bridge connecting mother and fetus. The mother supplies nutrients to the fetus through the placenta. Low placental function is not conducive to the maintenance of fetal growth and development, thus increasing the possibility of premature delivery and further increasing the incidence of adverse pregnancy outcomes [24].

A good prediction model could accurately predict the possibility of disease progression. Close monitoring and effective intervention in high-risk groups could reduce the risk of disease. The selection of effective indicators is the key to establish a prediction model [25, 26]. In this study, logistic regression analysis was conducted to screen risk factors affecting the outcome of the delivery outcome in women with scarred uterus based on ultrasonic parameters, and a prediction model was established according to the regression coefficients and constant terms of each variable. The AUC of the model obtained by ROC analysis was 0.959, indicating that the model had high prediction efficiency. And the Homer-Lemeshow goodness of fit test was $P = 0.693$. This predictive model was used to test the pregnant women in this study, and the prediction sensitivity and specificity were 85.71 and 87.04, respectively. The above results suggested that this prediction model had good predictive ability and certain applicable value in clinical evaluation of the delivery outcome in women of scarred uterus. Taking active measures for high-risk pregnant women could largely reduce the incidence of bad delivery outcome of women with scarred uterus.

Advantages and limitations

This study had a breakthrough, namely, using AVSS system to detect the repeatability and consistency of the muscle layer of the lower segment of scarred uterus during pregnancy was better than conventional two-dimensional ultrasound, with higher accuracy and better application value. We used AVSS system combined with clinical conditions to observe the thickness and continuity of the lower muscularis of pregnant women, which had guiding significance for the rational choice of delivery mode. AVSS system was used to detect the thickness and continuity of muscle layer in the lower segment of uterus to provide a powerful ultrasound image basis for observation and timing of cesarean section. According to this study, AVSS system was used to scan and measure the thickness and continuity of the lower segment of uterus and evaluate the risk of uterine rupture combined with clinical indicators, which had important guiding value for the safety of childbirth and the reduction of maternal and infant complications. Its clinical application would increase predictive accuracy and reduce the incidence of adverse pregnancy outcomes. However, this study was a single-center study with a small sample size, thus the results may be biased. It is expected to increase the sample size for multi-center studies in the future to enhance the reliability of the results.

Conclusion

To sum up, low Hb before delivery, low grade of uterine scar, low musculature thickness of

lower uterine segment, and low blood flow index are the risk factors for poor pregnancy outcome of women with scarred uterus. The establishment of the prediction model based on risk factors can effectively evaluate the risk of poor delivery outcome of women with scarred uterus.

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Disclosure of conflict of interest

None.

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