

ORIGINAL RESEARCH ARTICLE

Identification of high-risk factors and construction of a risk stratification prediction model for postpartum hemorrhage in women with scarred uterus

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Abstract

This retrospective single-center study aimed to identify high-risk factors for postpartum hemorrhage (PPH) in women with scarred uterus and to construct a risk stratification prediction model. Clinical data from 271 women with scarred uterus who delivered between January 2019 and January 2025 were collected. PPH was defined as blood loss >500 mL after vaginal delivery or >1000 mL after cesarean section. The above women were randomly classified into train set (n=189) and test set (n=82) at a 7:3 ratio. Univariate analysis was applied to screen the potential risk factors, and multivariate logistic regression analysis was performed to identify independent predictors of PPH and establish a prediction model. The results showed that production times ≥ 2 , placenta accreta, and hemoglobin level were independent risk factors for PPH. A prediction model was constructed based on these variables. Receiver operating characteristic (ROC) analysis demonstrated a good discriminatory ability, with area under the curve (AUC) values exceeding 0.7 in both the train and test sets. Hosmer-Lemeshow test indicated a good model calibration degree, and decision curve analysis suggested favorable clinical utility. This model may provide a practical tool for early identification and risk stratification of PPH in women with scarred uterus. (*Afr J Reprod Health* 2026; 30 [7]: 29-38).

Keywords: Scarred uterus; Postpartum hemorrhage; Risk stratification; Logistic regression; Prediction model

Résumé

Cette étude rétrospective monocentrique visait à identifier les facteurs de risque élevés de l'hémorragie du post-partum (HPP) chez les femmes présentant un utérus cicatriciel et à construire un modèle prédictif de stratification du risque. Les données cliniques de 271 femmes ayant un utérus cicatriciel et ayant accouché entre janvier 2019 et janvier 2025 ont été recueillies. L'HPP a été définie comme une perte sanguine supérieure à 500 mL après un accouchement par voie basse ou supérieure à 1 000 mL après une césarienne. Ces patientes ont été réparties aléatoirement en un ensemble d'entraînement (n = 189) et un ensemble de test (n = 82) selon un ratio de 7:3. Une analyse univariée a été réalisée pour sélectionner les facteurs de risque potentiels, puis une régression logistique multivariée a été utilisée afin d'identifier les prédicteurs indépendants de l'HPP et d'établir un modèle prédictif. Les résultats ont montré que le nombre d'accouchements ≥ 2 , le placenta accreta et le taux d'hémoglobine étaient des facteurs de risque indépendants de l'HPP. Un modèle prédictif a été construit sur la base de ces variables. L'analyse de la courbe ROC (Receiver Operating Characteristic) a montré une bonne capacité discriminante, avec des valeurs de l'aire sous la courbe (AUC) supérieures à 0,7 dans les ensembles d'entraînement et de test. Le test d'Hosmer-Lemeshow a indiqué une bonne calibration du modèle, et l'analyse des courbes de décision a suggéré une utilité clinique favorable. Ce modèle pourrait constituer un outil pratique pour l'identification précoce et la stratification du risque d'HPP chez les femmes présentant un utérus cicatriciel. (*Afr J Reprod Health* 2026; 30 [7]: 29-38).

Mots-clés : Utérus cicatriciel ; Hémorragie du post-partum ; Stratification du risque ; Régression logistique ; Modèle prédictif

Introduction

Scarred uterus refers to the uterus which is formed after cesarean section or other invasive uterine myometrial surgeries (such as myomectomy, uterine perforation or rupture repair and uterine plasty).

Among various pathogenic factors, the history of cesarean section dominates the etiology of scarred uterus.¹ The current delivery modes of re-pregnant women with scarred uterus primarily include two schemes: trial of labor after cesarean section (TOLAC) and elective repeated cesarean section

(ERCS).² The guidelines of the Royal College of Obstetricians and Gynecologists (RCOG, 2015), the American College of Obstetricians and Gynecologists (ACOG, 2019) and the Society of Obstetricians and Gynecologists of Canada (SOGC, 2019) all have recommend that eligible pregnant women should be encouraged to choose TOLAC under the premise of strict assessment of maternal-infant safety, so as to reduce the rate of cesarean section and the risk of long-term complications.³⁻⁵ However, the imbalanced distribution of medical resources in developing countries has resulted in persistently low TOLAC implementation rate and relatively high incidence rates of complications. In China, a cross-sectional study has revealed that 31.0% of obstetricians do not intend to recommend TOLAC to pregnant women with history of cesarean section, primarily due to the uncertainty of TOLAC safety in pregnant women with history of cesarean section (OR=0.49; 95%CI: 0.27-0.96) and concerns about medical litigation caused by adverse delivery outcomes (OR=0.14; 95%CI:0.07-0.31).⁶ However, regardless of delivery modes, postpartum hemorrhage (PPH) remains one of the primary causes of adverse pregnancy outcomes in pregnant women with scarred uterus. According to statistics, the risk of PPH in pregnant women with scarred uterus is significantly higher than that in pregnant women without scarred uterus. Additionally, the hemorrhage volume is large with fast speed, and it is often difficult to stop hemorrhage due to uterine inertia, placenta accreta and other factors, and in severe cases, it can cause life-threatening complications such as hemorrhagic shock, disseminated intravascular coagulation and even hysterectomy.⁷⁻⁸

Furthermore, the early identification and intervention of PPH in scarred uterus present considerable challenges. Currently, there is still a lack of efficient and accurate prediction tools, leading to the failure of timely treatment of partial high-risk women. Consequently, it is of great significance to explore the high-risk factors of hemorrhage in scarred uterus and construct a scientific risk stratification prediction model for optimizing clinical management strategies and improving maternal-infant prognosis.

The existing tools and models for predicting the risk of PPH, such as those released by the

California Maternal Quality Care Collaborative (CMQCC), the Association of Women's Health, Obstetric and Neonatal Nurses (AWHONN), the New York Safety Bundle Obstetric Hemorrhage (NYSBOH) as well as the American College of Obstetricians and Gynecologists (ACOG) safe motherhood initiative, have been put into clinical practice with some benefits. However, it is reported that the AUC values of these tools range from 0.69 to 0.77 when they are verified, indicating generally moderate predictive ability.⁹ Currently, there is still a lack of tools and models for predicting the risk of PPH in women with scarred uterus. Establishing a prediction model by incorporating different risk factors is a hot study topic. However, the risk prediction models constructed by various studies have limitations such as bias, lack of internal or external verification and small sample size.¹⁰⁻¹² With the development of artificial intelligence, the predictive ability of the model has been improved through machine and deep learning, but it is still necessary for researchers to develop a model with unified diagnostic criteria, wide application range and excellent predictive ability. By retrospectively analyzing the clinical data of women with scarred uterus, this study aimed to screen the independent risk factors for PPH and construct a risk prediction model based on multivariate logistic regression, thereby providing a reliable basis for clinical decision-making.

Methods

Study design and patients

The retrospective and single-center study was adopted to collect the data of 271 women with scarred uterus between January 2019 and January 2025, and divide them into PPH group and non-PPH group by taking total hemorrhage volume within 24 hours >500 mL after vaginal delivery or >1000 mL after cesarean section as the grouping boundary. Inclusion criteria: (1) Full-term singleton pregnancy with cephalic presentation; (2) History of cesarean section (with transverse incision in the lower uterine segment) resulting in scarred uterus; (3) Archiving, prenatal examination, delivery and treatment in this hospital; (4) Complete clinical related data of this study. Exclusion criteria: (1) Twin or multiple

pregnancy; (2) Concurrent hemorrhagic diseases, acute and chronic infections; (3) Blood system diseases such as coagulation dysfunction; (4) Concurrent uterine fibroids and other reproductive system diseases; (5) Incomplete clinical data; (6) Uterine rupture during pregnancy or delivery.

Evaluation methods

According to the guidelines for the evaluation of postpartum hemorrhage volume published in the American Journal of Obstetrics and Gynecology in 2019, the hemorrhage volume was evaluated by the combination of gauze weighing method and blood collection plate.

The postpartum hemorrhage volume was measured at the beginning of cesarean section skin incision, the beginning of vaginal hemorrhage during perioperative period of cesarean section and the beginning of vaginal delivery. Measurements were performed within 24 hours after surgery or vaginal delivery. The total hemorrhage volume within 24 hours was >500 mL in women receiving vaginal delivery or >1000 mL in women with cesarean section.

Data collection

The data of the study subjects included age, BMI in early pregnancy (at the time of archiving), time since last cesarean section, gravidity, production times, history of abortion, history of premature rupture of membranes (full-term and preterm), history of postpartum hemorrhage, history of uterine fibroids, placenta accreta, hypertensive disorder complicating pregnancy, abnormal blood glucose during pregnancy, pregnancy with blood system disease, pregnancy with immune system disease, use of aspirin during pregnancy, and use of low molecular weight heparin during pregnancy. Laboratory indicators were preoperative hemoglobin (HGB), hematocrit (HCT), platelet (PLT), fibrinogen (Fib) and thyroid function indicators (FT3, FT4, TSH). Maternal-infant outcomes encompassed vaginal trial of labor status (no, success, failure), current vaginal delivery process (statistics of the number of cases with successful vaginal trial of labor) and newborn weight.

Statistical analysis

Data processing was performed by SPSS27.0 statistical software. Continuous variables consistent with normal distribution were represented as mean \pm standard deviation, and continuous variables that did not conform to the normal distribution were denoted as median and [M (Q₁, Q₃)], and categorical variables were manifested as [n (%)]. Continuous variables were compared by one-way analysis of variance if they met normal distribution and homogeneity of variance, or by Mann-Whitney *U* test if they failed normal distribution or/and homogeneity of variance. Count data were expressed as rates (%) and were compared by chi-square test. Differences between groups were considered statistically significant if $P < 0.05$ was used for variables in both groups.

Multivariate binary logistic regression analysis included variables with $P < 0.05$, and STEPWISE method was used for variable screening. Regression model formula was manifested as logit $P = \ln [P/(1-P)] = B_0X_0 + B_1X_1 + \dots + B_kX_k$. In this formula, *P* was the incidence rate of PPH in women with scarred uterus, and *B* value indicated the risk coefficient of a risk factor, and *X* value represented the risk factor status of a specific patient. The discrimination degree of the model was predicted by the area under the curve (AUC) of receiver operating characteristic (ROC). The goodness-of-fit of the final model was detected by Hosmer-Lemeshow test.

Ethical principles

Basic principle: This study was formally approved by the Medical Ethics Committee of Zhejiang Provincial People's Hospital Fuyang Campus (Hangzhou Fuyang District First People's Hospital) (Approval No. 2025-KY-012). As this was a retrospective study, the requirement for informed consent was waived by the ethics committee.

Principle of confidentiality: All data during the study process were kept by the team, and were not allowed to be used for any commercial purposes except for article publication and ethical review. The data recorded and used during the study process were encoded to ensure no infringement of personal

privacy of patients.

Principle of safety: Regardless of the treatment method, the study process would not cause any potential harm to the study subjects.

Results

Characteristics, medical history and laboratory examination analysis of model construction patients

Shapiro-Wilk normality test found that age ($p=0.004$), time since last cesarean section ($p<0.001$), HCT ($p=0.005$) and Fib ($p=0.007$) did not conform to the normal distribution. The enrolled 271 women with scarred uterus were randomized into train set (189 cases) and test set (82 cases) according to the ratio of 7:3 by using the `train_test_split` function. As shown in Table 1, no statistical differences were exhibited between the two groups in terms of BMI in early pregnancy, HGB, PLT, TSH, FT4, FT3, age, time since last cesarean section, HCT, Fib, gravidity ≥ 3 times, production times ≥ 2 , number of abortions ≥ 2 , history of premature rupture of membranes, history of postpartum hemorrhage, history of uterine fibroids, placenta accreta, hypertensive disorder complicating pregnancy, abnormal blood glucose during pregnancy, pregnancy with blood system disease, pregnancy with immune system disease, aspirin, low molecular weight heparin, vaginal trial of labor status, current vaginal delivery process and newborn weight ($p>0.05$).

Logistic regression results

The train set data were applied for modeling, including 60 cases in PPH group and 129 cases in non-PPH group. Univariate logistic regression results in Table 2 indicated that the differences in production times ≥ 2 , placenta accreta and HGB were statistically significant, while other factors exhibited no statistical differences. Multivariate logistic regression results in Table 3 suggested that production times ≥ 2 (OR=3.20, 95%CI: 1.55-6.61, $p=0.002$), placenta accreta (OR=2.64, 95%CI: 1.32-5.27, $p=0.006$) and HGB (OR=1.05, 95%CI: 1.01-

1.08, $p=0.006$) were independent risk factors affecting PPH in women with scarred uterus.

Establishment of prediction model for PPH

According to the results of multivariate analysis, a prediction model for PPH in women with scarred uterus was constructed by considering comprehensive influence of multiple factors. The prediction model formula was established as $\text{logit } P = \ln [P/(1-P)] = -7.17 + 1.16 * \text{production times} \geq 2 + 0.97 * \text{placenta accreta} + 0.05 * \text{HGB (yes=1, no=0)}$ (categorical data were substituted into 0/1 based on absence or presence of occurrence, and measurement data were calculated in the formula according to the actual values). The constructed prediction model was presented in the form of a nomogram, as shown in Figure 1.

Evaluation of the prediction model

Internal validation of the model was performed by 1000 times of Bootstrap method sampling, and ROC curve of the prediction model was drawn and displayed that the AUC of the train set was 0.71 (0.63-0.79) and that of the test set was 0.73 (0.60-0.85), revealing a good discrimination degree of the model (Figure 2, Table 4). Hosmer-Lemeshow goodness-of-fit test discovered that the predicted value of the model had a good consistency with the actual observed value ($\chi^2=5.77$, $df=8$, $p=0.672$) and was suitable for clinical practice, suggesting a good calibration degree of the model (Figure 3A). Decision curve of the train set was higher than the two extreme curves when the decision probability ranged from 0.18 to 0.9, indicating good clinical utility of the model (Figure 3B).

Discussion

When women with scarred uterus are re-pregnant, it may occur that the uterine muscle fibers are unable to contract and repair rapidly during delivery, causing uterine atony and increasing PPH risk, thus endangering maternal life. Therefore, it is necessary to achieve early detection and early treatment so as to improve the prognosis and enhance the quality of life.

Table 1: Analysis of social demographic characteristics of the study subjects

Variables	test (n=82)	train (n=189)	P-value
BMI in early pregnancy (kg/m ²)	23.04 ± 2.33	22.88 ± 2.45	0.636
HGB (g/L)	120.30 ± 10.46	121.14 ± 10.31	0.544
PLT (10 ⁹ /L)	209.35 ± 27.61	211.69 ± 26.84	0.514
TSH (mIU/L)	2.73 ± 0.62	2.71 ± 0.60	0.804
FT4 (pmol/L)	7.87 ± 1.64	7.92 ± 1.58	0.803
FT3 (pmol/L)	4.30 ± 0.60	4.20 ± 0.59	0.207
Age (years)	33.00 (31.00, 35.00)	33.00 (31.00, 35.00)	0.541
Time since last cesarean section (years)	2.00 (1.00, 2.00)	2.00 (1.00, 3.00)	0.543
HCT (%)	34.50 (31.25, 37.00)	34.00 (31.00, 36.00)	0.530
Fib (g/L)	4.02 (3.02, 4.53)	4.18 (3.45, 4.86)	0.121
Gravidity ≥ 3 times (%)	58 (70.73)	128 (67.72)	0.624
Production times ≥ 2 (%)	21 (25.61)	46 (24.34)	0.824
Number of abortions ≥ 2 (%)	12 (14.63)	32 (16.93)	0.638
History of premature rupture of membranes (%)	4 (4.88)	15 (7.94)	0.365
History of postpartum hemorrhage (%)	6 (7.32)	12 (6.35)	0.769
History of uterine fibroids (%)	4 (4.88)	10 (5.29)	1.000
Placenta accreta (%)	15 (18.29)	56 (29.63)	0.051
Hypertensive disorder complicating pregnancy (%)	10 (12.20)	26 (13.76)	0.728
Abnormal blood glucose during pregnancy (%)	12 (14.63)	22 (11.64)	0.494
Pregnancy with blood system disease (%)	5 (6.10)	6 (3.17)	0.432
Pregnancy with immune system disease (%)	8 (9.76)	17 (8.99)	0.842
Aspirin (%)	5 (6.10)	14 (7.41)	0.698
Low molecular weight heparin (%)	9 (10.98)	19 (10.05)	0.819
Vaginal delivery time (h)	8.86 ± 1.77	7.69 ± 1.32	0.111
Newborn weight (kg)	3.28 ± 0.72	3.35 ± 0.67	0.460
TOLAC (%)			0.514
Failure	7 (8.54)	10 (5.29)	
No	68 (82.93)	166 (87.83)	
Success	7 (8.54)	13 (6.88)	

Data are presented as n (%) or mean ± SD.

Table 2: Univariate logistic regression results

Variables	β	S.E	Z-value	P-value	OR (95%CI)
Gravidity ≥ 3 times	-0.29	0.33	-0.88	0.379	0.75 (0.39 ~ 1.43)
Production times ≥ 2	1.05	0.35	3.00	0.003	2.86 (1.44 ~ 5.70)
Number of abortions ≥ 2	0.14	0.41	0.35	0.726	1.15 (0.52 ~ 2.58)
History of premature rupture of membranes	0.69	0.54	1.27	0.203	2.00 (0.69 ~ 5.79)

History of postpartum hemorrhage	-0.89	0.79	-1.13	0.260	0.41 (0.09 ~ 1.93)
History of uterine fibroids	-15.88	758.80	-0.02	0.983	0.00 (0.00 ~ Inf)
Placenta accreta	0.93	0.33	2.77	0.006	2.52 (1.31 ~ 4.85)
Hypertensive disorder complicating pregnancy	0.35	0.44	0.79	0.430	1.41 (0.60 ~ 3.33)
Abnormal blood glucose during pregnancy	-0.51	0.53	-0.96	0.338	0.60 (0.21 ~ 1.71)
Pregnancy with blood system disease	-15.83	1199.77	-0.01	0.989	0.00 (0.00 ~ Inf)
Pregnancy with immune system disease	-0.84	0.66	-1.28	0.201	0.43 (0.12 ~ 1.57)
Aspirin	0.19	0.58	0.33	0.741	1.21 (0.39 ~ 3.79)
Low molecular weight heparin	-0.61	0.59	-1.04	0.297	0.54 (0.17 ~ 1.71)
Age	0.01	0.04	0.18	0.853	1.01 (0.93 ~ 1.09)
BMI in early pregnancy	-0.05	0.06	-0.78	0.438	0.95 (0.84 ~ 1.08)
Time since last cesarean section	1.02	1.03	1.00	0.318	2.79 (0.37 ~ 20.82)
HGB	0.04	0.02	2.72	0.006	1.04 (1.01 ~ 1.08)
HCT	0.03	0.04	0.76	0.446	1.03 (0.96 ~ 1.11)
PLT	0.00	0.01	0.39	0.698	1.00 (0.99 ~ 1.01)
Fib	0.12	0.16	0.71	0.476	1.12 (0.82 ~ 1.54)
TSH	0.05	0.26	0.19	0.848	1.05 (0.63 ~ 1.76)
FT4	-0.07	0.10	-0.70	0.484	0.93 (0.77 ~ 1.13)
FT3	-0.33	0.27	-1.22	0.224	0.72 (0.42 ~ 1.22)
Vaginal delivery time	0.25	0.53	0.48	0.634	1.29 (0.46 ~ 3.62)
Newborn weight	-0.12	0.23	-0.50	0.617	0.89 (0.56 ~ 1.40)
TOLAC Failure					1.00 (Reference)
No	0.68	0.81	0.85	0.397	1.98 (0.41 ~ 9.65)
Success	-0.15	0.22	-0.61	0.501	0.86 (0.56 ~ 1.32)

OR: Odds Ratio, CI: Confidence Interval

Table 3: Multivariate logistic regression results

Variables	β	S.E	Z	P	OR (95%CI)
Intercept	-7.17	2.12	-3.38	<0.001	0.00 (0.00 ~ 0.05)
Production times ≥ 2	1.16	0.37	3.14	0.002	3.20 (1.55 ~ 6.61)
Placenta accreta	0.97	0.35	2.74	0.006	2.64 (1.32 ~ 5.27)
HGB	0.05	0.02	2.77	0.006	1.05 (1.01 ~ 1.08)

OR: Odds Ratio, CI: Confidence Interval

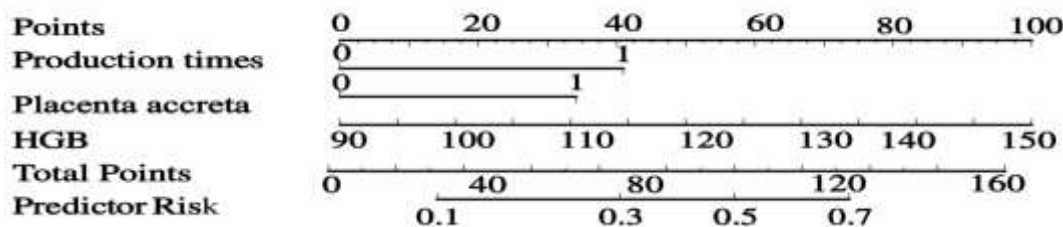


Figure 1: Prediction model for PPH in women with scarred uterus

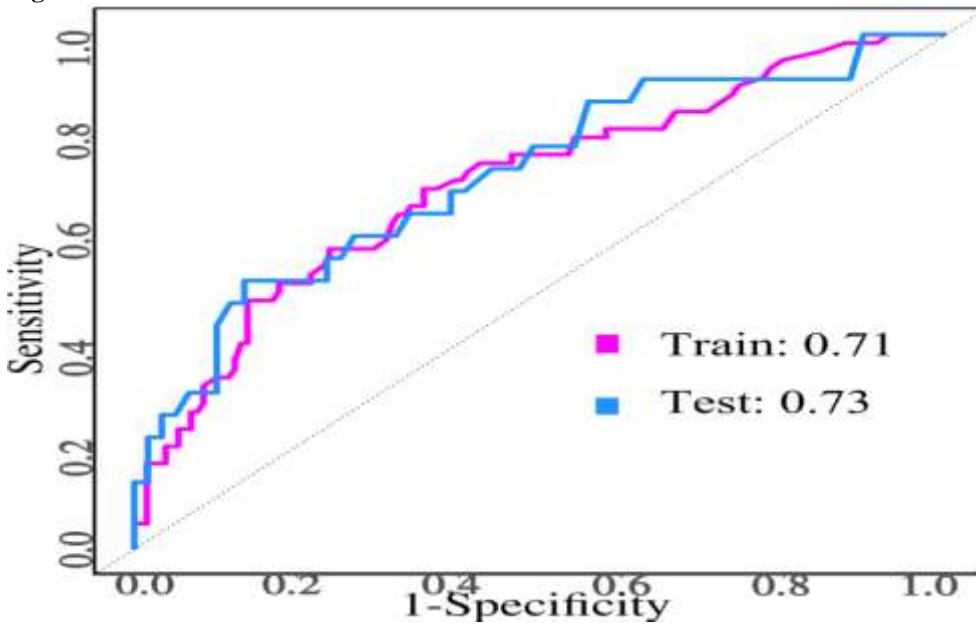


Figure 2: ROC curve of the prediction model for PPH in women with scarred uterus

Table 4: Confusion matrix of train set and test set

Data	AUC (95%CI)	Accuracy (95%CI)	Sensitivity (95%CI)	Specificity (95%CI)	PPV (95%CI)	NPV (95%CI)	cut off
Train	0.71(0.63-0.79)	0.74 (0.67-0.80)	0.86 (0.80 - 0.92)	0.48 (0.36 - 0.61)	0.78 (0.71 - 0.85)	0.62 (0.48 - 0.76)	0.435
Test	0.73 (0.60-0.85)	0.77 (0.66-0.85)	0.90 (0.82 - 0.98)	0.43 (0.23 - 0.64)	0.80 (0.71 - 0.90)	0.63 (0.39 - 0.86)	0.435

AUC, area under the curve; ppv, positive predictive value; npv, negative predictive value.

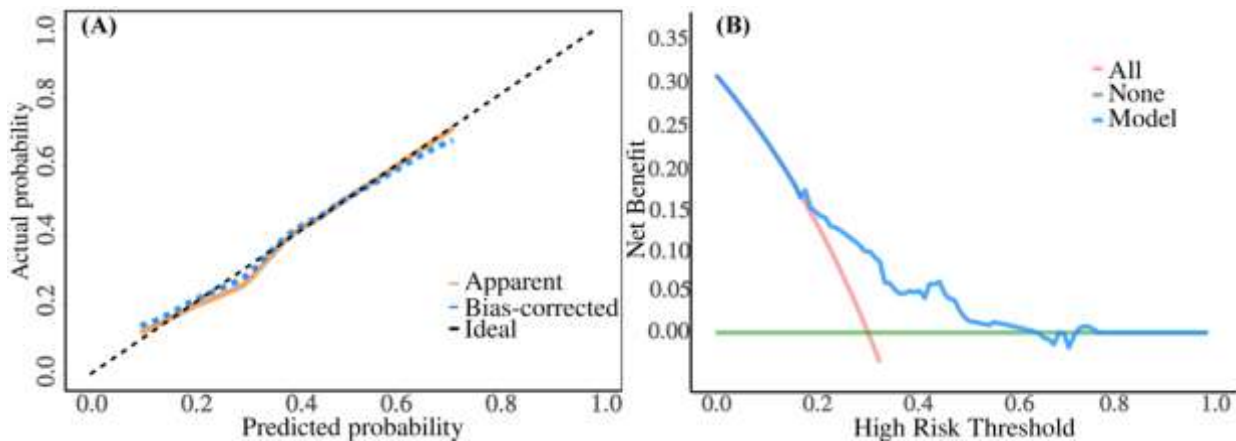


Figure 3: Verification of the prediction model. (A): Calibration curve of the prediction model for PPH in women with scarred uterus; (B): Decision curve of the prediction model for PPH in women with scarred uterus.

The identification of the three independent risk factors in this study provided valuable information for the establishment of the nomogram model, with prediction model formula as $\text{logit } P = \ln [P/(1-P)] = -7.17 + 1.16 * \text{production times} \geq 2 + 0.97 * \text{placenta accreta} + 0.05 * \text{HGB (yes=1, no=0)}$. ROC analysis, Hosmer-Lemeshow goodness-of-fit test and decision curve test confirmed that the prediction model in this study had good discrimination degree, consistency and practicality. Current studies suggest that pregnant women with placenta accreta are more prone to PPH. For women with scarred uterus, fibrous tissue replaces the original myometrium and may lead to poor formation of decidua basalis, and villi are more likely to penetrate the myometrium, thus increasing the risk of placental abnormality to a certain extent. Additionally, the placenta of such women cannot be completely stripped after delivery, and conducting an artificial stripping may destroy the blood sinus on the stripping surface, triggering hemorrhage.¹³⁻¹⁴ This study also found that placenta accreta was independently associated with PPH in women with scarred uterus. This study discovered that production times ≥ 2 was an independent risk factor for PPH in women with scarred uterus. Currently, it is not clear whether there are regenerative stem cells in uterine smooth muscle to promote uterine involution. Some researchers believe that with the increase of pregnancy and delivery times as well as the damage of age and scar to the uterus, blood flow to the uterus may alter due to the damage of uterine blood vessels. Concurrently, there may be a decrease in uterine collagen fibers and a decrease in uterine smooth muscle contractility, so hemorrhage is more likely to occur.¹⁵⁻¹⁶ Therefore, strengthening the education on fertility and contraception knowledge and raising self-care awareness play a positive role in reducing the incidence rate of PPH in women with scarred uterus. Although HGB was also considered as an independent factor for PPH in this study, its OR value of 1.05 was close to 1. This phenomenon may be attributed to the fact that the HGB level not only reflects the overall anemia status of the body, but also has a limited specific indicative role regarding local uterine tissue vascular perfusion and hemorrhage risk. Changes in local blood circulation in women with scarred uterus may be more complex and not entirely dependent on systemic HGB level.

As early as 2010, CMQCC established a risk assessment tool for predicting PPH, and AWHONN and NYSBOH tools also constructed corresponding assessment tools based on expert opinions and a review of previous studies assessing the risk of PPH. CMQCC, AWHONN and NYSBOH are widely used in the United States, and studies have verified the above assessment tools and have suggested that the AUC values of CMQCC, AWHONN and NYSBOH were 0.77 (95%CI: 0.71-0.84), 0.69 (95%CI: 0.65-0.74) and 0.73 (95%CI: 0.67-0.79), and they are considered to have moderate predictive ability, while a large proportion of hemorrhage (up to 43%) occurs in those considered to be low-risk populations.⁹ This limitation may stem from the fact that these tools are developed through expert consensus and there remains a lack of evidence of systematic review to support or refute the included risk factors. Domestic researchers are also actively exploring the construction of PPH prediction models. Zhang Y's risk prediction model for PPH after cesarean section in twin pregnancy has exhibited good predictive ability (AUC: 0.778, 95%CI: 0.732-0.825).¹⁷ The risk model for predicting PPH in placenta previa constructed by Chen C has revealed a predictive sensitivity of 0.765, a specificity of 0.900 and an AUC of 0.840.^[18] Chen B has established a model to predict the risk of PPH in singleton pregnant women with cesarean section in northern China, suggesting its AUC of 0.90.¹⁹ Numerous prediction models for risk factors have been published, but they have limitations such as low sensitivity or specificity, high risk of bias, poor accuracy and lack of verification. Although some progress has been made in the study of PPH in women with scarred uterus and clinicians have accumulated some experience, no clinically operable individualized risk prediction model for the probability of massive hemorrhage has yet been established. Therefore, this study preliminarily designed the relevant model based on clinical data. This study also constructed a risk prediction model for PPH in women with scarred uterus with predictive efficiency of 0.71 and 0.73, and obtained the specific individualized hemorrhage risk probability value of women with scarred uterus before treatment, thereby guiding the clinical formulation of treatment regimen. The design model of this study incorporates biological indicators and

pregnancy physiological indicators, and the preliminary application of the model is credible for the individualized prediction of the risk of massive hemorrhage. The model validation reveals that the nomogram drawn in this study is a simple tool that can be used in clinical practice to predict intraoperative massive hemorrhage in cesarean scar pregnancy, and it can effectively screen out high-risk women with PPH in scarred uterus, and provide a scientific basis for clinicians to choose the appropriate treatment regimen.

Regarding strengths of this study, through retrospective analysis, this study preliminarily identifies and validates three independent risk factors for PPH in scarred uterus, constructing a structurally simple and clinically operable risk prediction model. The model demonstrates good discrimination degree ($AUC > 0.70$) and calibration degree in both the train and set sets, with decision curve analysis confirming its clinical utility within a specific threshold range. Furthermore, the study strictly adheres to ethical guidelines, and the data collection and processing methods possess a degree of reproducibility, providing a foundation for subsequent study. Limitations of this study include the following aspects: (1) The samples originate from a single medical center with a relatively limited sample size ($n=271$), potentially introducing selection bias and limiting generalization ability of the model. (2) This study belongs to a retrospective analysis and an exploratory study that does not include all possible influencing factors, such as mental factors, ultrasound indicators and maternal family history. This exclusion results from certain factors being relatively subjective or not covered during medical history collection. (3) Despite internal validation, the stability and generalizability of the model require further verification due to the absence of external independent cohort validation. (4) The OR value of HGB in the prediction model is close to 1, necessitating cautious interpretation of its clinical significance. This may indicate that it is not a strong predictor or that it interacts with other factors. In terms of implications for policy development and practical application, the risk stratification prediction model constructed in this study provides a quantitative tool for clinically identifying high-risk population with postpartum hemorrhage among women with scarred uterus,

facilitating individualized risk assessment and hierarchical management. At the policy level, the model can drive risk-based obstetric resource allocation and emergency response plan formulation. In clinical practice, this model serves as an auxiliary decision-making tool, enabling physicians to identify high-risk women earlier during prenatal assessment and develop targeted delivery regimens in advance, thereby reducing the incidence rate of PPH in women with scarred uterus. Additionally, the findings suggest that it is necessary to strengthen pregnancy monitoring and health education for pregnant women with scarred uterus who have history of multiple deliveries, placenta accreta or anemia status, so as to improve maternal self-management awareness and medical cooperation efficiency.

Conclusion

This study establishes a prediction model of logit $P = \ln[P/(1-P)] = -7.17 + 1.16 * \text{production times} \geq 2 + 0.97 * \text{placenta accreta} + 0.05 * \text{HGB}$ by retrospective data of 271 women, demonstrating good predictive efficiency on PPH in women with scarred uterus.

Author's contribution

HuanLin Ma were responsible for conception and design, collection and assembly of data and manuscript writing. All authors were responsible for manuscript writing. All authors were responsible for the final approval of the manuscript.

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