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Nomogram based on clinical characteristics and ultrasound indicators for predicting severe postpartum hemorrhage in patients with anterior placenta previa combined with previous cesarean section: a retrospective case-control study

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Abstract

Background Placental accreta spectrum disorders (PAS) are a high-risk group for severe postpartum hemorrhage (SPPH), with the incidence of PAS increasing annually. Given that cesarean section and anterior placenta previa are the primary risk factors for PAS, therefore, our study aims to investigate the predictive value of clinical characteristics and ultrasound indicators for SPPH in patients with anterior placenta previa combined with previous cesarean section, providing a theoretical basis for early prediction of SPPH.

Methods A total of 450 patients with anterior placenta previa combined with previous cesarean section were retrospectively analyzed at Shengjing Hospital affiliated with China Medical University between January 2018 and March 2022. Clinical data and ultrasound indicators were collected. Patients were categorized into SPPH (blood loss >2000mL, 182 cases) and non-SPPH (blood loss ≤ 2000mL, 268 cases) groups based on the blood loss within 24 h postpartum. The population was randomly divided into training and validation cohorts at a 7:3 ratio. LASSO and multifactorial logistic regression analyses were utilized to identify independent risk factors for SPPH. Accordingly, a nomogram prediction model was constructed, the predictive performance was assessed using receiver operating characteristic (ROC) curves, calibration curves and decision curve analysis (DCA).

Results Among the 450 patients, 182 experienced SPPH (incidence rate, 40.44%). Preoperative systemic immune-inflammatory index, preoperative D-dimer level, preoperative placenta accreta spectrum ultrasound scoring system (PASUSS) score, and one-step-conservative surgery were identified as independent risk factors for SPPH in patients with anterior placenta previa combined with previous cesarean section. A nomogram was constructed based on these factors. The areas under the ROC curves for the training and validation cohorts were 0.844 (95%*CI*: 0.801–0.888)

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and 0.863 (95%*CI*: 0.803–0.923), respectively. Calibration curves and DCA indicated that this nomogram demonstrated good predictive accuracy.

Conclusions This nomogram presents an effective and convenient prediction model for identifying SPPH in patients with anterior placenta previa combined with previous cesarean section. It can guide surgical planning and improve prognosis.

Keywords Anterior placenta previa, Previous cesarean section, Placental accreta spectrum disorders, Severe postpartum hemorrhage, Prediction model

Background

Placental accreta spectrum disorders (PAS) refer to abnormal invasion of trophoblasts into the myometrium, which is classified into placenta accreta, increta, percreta based on the depth of invasion [1]. Due to the increaseing rate of the cesarean delivery, the incidence of PAS has significantly risen to approximately 0.3% [2]. PAS is a life-threatening condition primarily caused by severe postpartum hemorrhage (SPPH) [3, 4], with bleeding even exceeding 10,000 ml [5]. SPPH is a leading cause of maternal death, accounting for 27.1% of maternal deaths globally [6]. It significantly increases adverse pregnancy outcomes, such as acute renal failure, sepsis, and death [7]. Therefore, it is important to identify high-risk groups of PAS with SPPH and implement proactive measures through multidisciplinary collaboration during the perioperative period.

There are many risk factors for SPPH, such as age [8], anesthesia method [9], and prenatal anemia [10]. However, current researches focusing on populations with PAS mainly emphasize the use of ultrasound scoring system [11], MRI scores [12], and their comparative application values [13]. Due to the high cost and inconvenience of MRI, clinical practice often relies on ultrasound scoring system, which can be greatly influenced by individual differences and subjective factors, potentially impacting the accuracy of patient condition evaluations. Therefore, it is crucial to develop reliable predictive models.

The diagnosis of PAS relies on intraoperative findings or histopathology, presenting challenges in accurate preoperative diagnosis. Given that anterior placenta previa and previous cesarean section confer the highest risk for PAS [14], so this study aimed to predict the risk of SPPH in patients with anterior placenta previa combined with previous cesarean section based on clinical characteristics and ultrasound indicators, and to develop a nomogram to aid in clinical diagnosis and treatment.

Methods

Study subjects

The data of 581 patients with anterior placenta previa combined with previous cesarean section between January 2018 and March 2022 at Shengjing Hospital, affiliated with China Medical University, was retrospectively collected. The inclusion criteria were in line with the diagnosis of anterior placenta previa, previous cesarean section, gestational age at delivery ≥28 weeks, singleton pregnancy, cesarean delivery, and live birth. The exclusion criteria included twin and multiple pregnancies, fetal death in utero, non-delivery, cesarean delivery at another hospital, pregnancy combined with hematologic or autoimmune diseases, preoperative fever or infection, maternal organ dysfunction, malignant tumors, absence of ultrasound scoring system, pregnancy combined with uterine fibroids or ovarian cysts, and incomplete information. After applying strict inclusion and exclusion criteria, a total of 450 patients were included in the study. All patients were delivered by multidisciplinary team led by senior obstetricians. The surgeons are skilled in perioperative PAS management and capable of promptly and effectively addressing intraoperative emergencies. The patient selection flowchart is shown in Fig. 1.

Research indicators

The hospital electronic database was utilized to collect basic demographic and clinical information, including age, gravidity, parity, number of cesarean sections, history of myomectomy, number of intrauterine operations (such as artificial abortion, curettage, and hysteroscopy), gestational age at pregnancy termination, method of conception, bleeding during pregnancy, hypertensive disorders during pregnancy, diabetes (including pregestational and gestational diabetes mellitus), anesthesia method, timing of surgery, abdominal aortic balloon placement, intraoperative procedures such as uterine artery ligation and uterine tamponade (using gauze or balloon), hysterectomy, postoperative interventional embolization (including uterine artery or internal iliac artery), one-step-conservative surgery, ICU admission, postoperative hospitalization days, perioperative red blood cell transfusion, hospitalization costs, neonatal birth weight; neutrophil count, lymphocyte count, hemoglobin level, platelet count, activated partial thromboplastin time (APTT), prothrombin time (PT), fibrinogen (FIB), D-dimer within 48 h preoperatively; amniotic fluid index, and ultrasound scoring system within one week preoperatively. All data were based on the last preoperative examination and were included in the analysis.

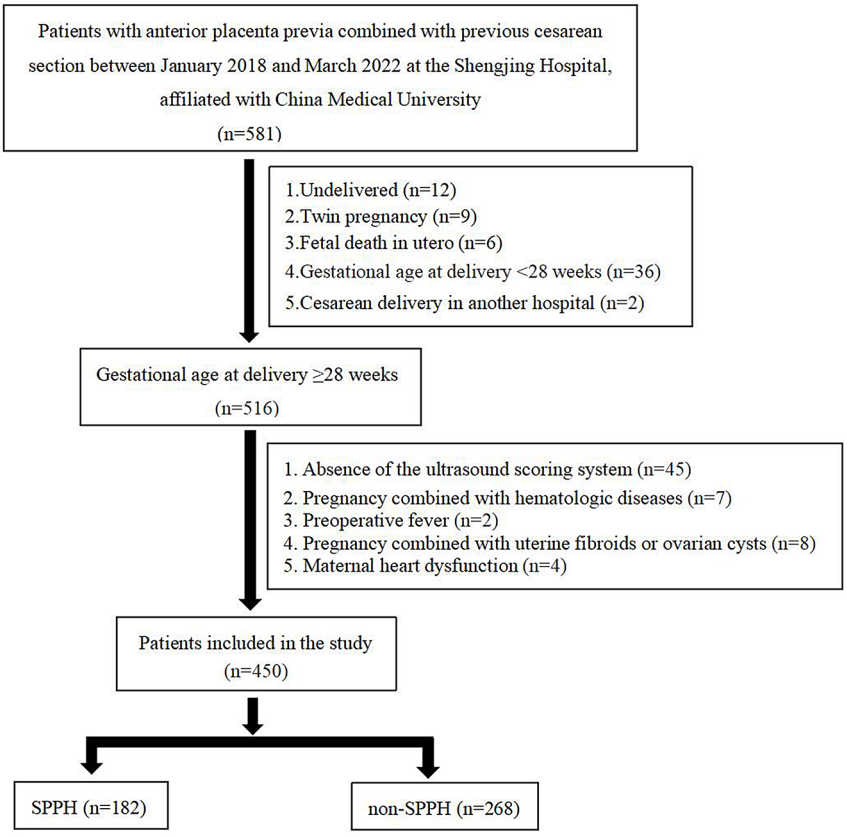

Fig. 1 Patient selection flowchart

Table 1 Placenta accreta spectrum ultrasound scoring system (PASUSS)

Item	0 points	1 point	2 points
Placenta position	Normal	Marginal placental previa or low-lying placenta	Complete placental previa
Placental thickness	< 3 cm	3–5 cm	> 5 cm
The hypoechoic retroplacental zone	Continuity	Local interruption	Disappeared
Bladder line	Continuity	Local interruption	Disappeared
Placental lacunae	None	Present	Fused with boiling water sign
Condition of the subplacental vascularity	Normal blood flow	Increased, forming a cluster	"Transboundary" blood vessels
Cervical blood sinus	None	Present	Fused with boiling water sign
Cervical morphology	Complete	Incomplete	Disappeared
Number of pervious cesarean deliveries	0	1	≥ 2

Related definitions

This study defined SPPH as blood loss exceeding 2000 ml within 24 h postoperatively, based on the RCOG guidelines [15] PAS was confirmed and staged in accordance with the clinical and histologic classification criteria of FIGO, when the clinical and histologic diagnoses were inconsistent, the higher stage was used as the final stage [16]. The systemic-immune inflammation index (SII) was calculated based on neutrophil, lymphocyte, and platelet counts (SII = neutrophil count × platelet count/lymphocyte count). The Placenta Accreta Spectrum Ultrasound Scoring System (PASUSS) is a preoperative ultrasound scoring system, which was established by Peking University Third Hospital. PASUSS includes 9 scoring items that are used as indicators for diagnosing PAS. Each item is rated as 0, 1, or 2 points, with the total score reflecting the severity of PAS (Table 1). A score of 3 to 5 points indicated accreta; 6 to 9 points indicated increta; and 10 or more points indicated percreta [17]. One-step-conservative surgery is a safe and reproducible conservative-reconstructive technique for PAS, which implies removing the part of the uterus invaded by the placenta the subsequent reconstruction anatomy [18].

Statistical analysis

R software (version 4.2.2) was utilized for the statistical analysis. The data were randomly divided into training and validation cohorts at a 7:3 ratio and compared. Continuous data were expressed as mean ± standard

deviation or median (interquartile range), while frequencies are expressed as percentages. Chi-square tests were applied for categorical variables, and t-tests or rank-sum tests were used for continuous variables. In the training cohort, LASSO and multifactorial logistic regression analyses were conducted to identify independent risk factors and develop a nomogram prediction model for SPPH. The performance of the nomogram was assessed using receiver operating characteristic (ROC) and calibration curves, and decision curve analysis (DCA) was used to determine the net benefit of prediction; $P<0.05$ was considered statistically significant.

Results

The impact of PAS or SPPH in patients with anterior placenta previa combined with previous cesarean section

This study included 450 patients, 387 patients with PAS were confirmed by clinical or histologic criteria. Among them, 182 patients were in the SPPH group and 268 were in the non-SPPH group (Fig. 1). The ICU admission, postoperative hospitalization days, red blood cell transfusion, abdominal aortic balloon placement, intraoperative uterine tamponade, intraoperative uterine artery ligation, hysterectomy or postoperative interventional embolization, one-step-conservative surgery, and hospitalization costs were significantly higher in the PAS or SPPH groups compared to the non-PAS or non-SPPH groups. The incidence of PAS in the SPPH group or the incidence of SPPH in the PAS group were higher than that in control group (Table 2).

Table 2 Impact of PAS or SPPH in patients

Feature	PAS		*P*	SPPH		*P*
	No (*n* = 63)	Yes (*n* = 387)		No (*n* = 268)	Yes (*n* = 182)	
ICU admission	0 (0.0%)	62 (16.0%)	0.001	7 (2.6%)	55 (30.2%)	0.000
Postoperative hospitalization days(day)	3.00 (3.00–4.00)	4.00 (3.00–5.00)	0.000	3.00 (3.00–4.00)	4.50 (4.00–6.00)	0.000
Red blood cell Transfusion (units)						
≥0	5 (7.9%)	262 (67.7%)	0.000	88 (32.8%)	179 (98.4%)	0.000
≥4	0 (0.0%)	176 (45.5%)	0.000	26 (9.7%)	150 (82.4%)	0.000
≥10	0 (0.0%)	63 (16.3%)	0.001	0 (0.0%)	63 (34.6%)	0.000
Abdominal aortic balloon placement	0 (0.0%)	26(6.7%)	0.034	3 (1.1%)	23(12.6%)	0.000
Intraoperative uterine tamponade	10 (15.9%)	220 (56.8%)	0.000	119 (44.4%)	111 (61.0%)	0.001
Intraoperative uterine artery ligation	22 (34.9%)	306 (79.1%)	0.000	177 (66.0%)	151 (83.0%)	0.000
Hysterectomy or postoperative interventional embolization	0(0.0%)	16 (4.1%)	0.100	0(0.0%)	16 (8.8%)	0.000
One-step-conservative surgery	4(6.3%)	224 (57.9%)	0.000	91 (34.0%)	137 (75.3%)	0.000
SPPH	1(1.6%)	181 (46.8%)	0.000	-	-	-
PAS	-	-	-	206 (76.9%)	181 (99.5%)	0.000
Hospitalization costs (RMB)	16295.14(13537.78-19800.91)	26727.12(20579.84-34084.21)	0.000	20598.47(16295.14-26009.90)	32788.92(26874.52-47305.64)	0.000

Values are presented as n (%) or median (IQR)

Table 3 Characteristics of patients with anterior placenta previa combined with previous cesarean section

Feature	Training cohort (*n* = 315)	Validation cohort (*n* = 135)	*P*
Age (≥ 35 years)	132 (41.9%)	61 (45.2%)	0.519
In vitro fertilization	1 (0.3%)	2 (1.5%)	0.215
Gestational age at pregnancy termination (≥ 34 weeks)	276 (87.6%)	122 (90.4%)	0.403
Gravidity (≥ 3 times)	233 (74.0%)	105 (77.8%)	0.392
Parity (≥ 2 times)	47 (14.9%)	24 (17.8%)	0.446
History of myomectomy	2 (0.6%)	3 (2.2%)	0.162
Number of intrauterine operations (≥ 2 times)	118 (37.5%)	63 (46.7%)	0.214
Pregnancy interval (years)			0.790
≤ 2	16 (5.1%)	9 (6.7%)	
3–5	61 (19.4%)	25 (18.5%)	
≥ 6	238 (75.6%)	101 (74.8%)	
Bleeding during pregnancy	112 (35.6%)	61 (45.2%)	0.054
Hypertensive disorders during pregnancy	15 (4.8%)	6 (4.4%)	0.884
Diabetes	60 (19.0%)	25 (18.5%)	0.895
Preoperative hemoglobin < 110 g/L	118 (37.5%)	49 (36.3%)	0.815
Preoperative PT (s)	10.40 (10.20–10.80)	10.50 (10.10–10.90)	0.647
Preoperative APTT (s)	27.00 (26.00–28.00)	27.00 (26.00–28.00)	0.443
Preoperative FIB (g/L)	4.10 (3.70–4.50)	4.10 (3.75–4.60)	0.715
Preoperative D-dimer level (μg/L)	617 (445–987)	595 (416–907)	0.443
Preoperative SII ($\times 10^9$/L)	878 (669–1190)	901 (696–1255)	0.366
Amniotic fluid index	10.0 (8.0–12.0)	10.0 (8.5–13.0)	0.230
PASUSS score	8.0 (6.0–10.0)	9.0 (6.0–11.0)	0.118
Neonatal birth weight (≥ 4 kg)	6 (1.9%)	0 (0.0%)	0.185
Anesthesia method			0.635
Epidural-spinal anesthesia	57 (18.1%)	27 (20.0%)	
General anesthesia	258 (81.9%)	108 (80.0%)	
Timing of surgery			0.484
Emergency surgery	22 (7.0%)	12 (8.9%)	
Elective surgery	293 (93.0%)	123 (91.1%)	
Abdominal aortic balloon placement	16 (5.1%)	10 (7.4%)	0.332
Intraoperative uterine tamponade	156 (49.5%)	74 (54.8%)	0.304
Intraoperative uterine artery ligation	224 (71.1%)	104 (77.0%)	0.195
Hysterectomy or postoperative interventional embolization	12 (3.8%)	4 (3.0%)	0.786
One-step-conservative surgery	154 (48.9%)	74 (54.8%)	0.249

Values are presented as n (%) or median (IQR)

Population characteristics

In this study, the population was randomly divided into training and validation cohorts at a 7:3 ratio. The characteristics of the cohorts included in this predictive research study have been carefully analyzed and presented in Table 3, demonstrating comparable characteristics between the two cohorts.

Selection of risk factors for SPPH in patients with anterior placenta previa combined with previous cesarean section

All candidate factors were included in this study. In the training cohort, LASSO regression analysis identified eight potential predictors, the LASSO coefficient path and cross-validation plots are shown in Fig. 2, and the coefficients are presented in Table 4. Further multivariate logistic analyses revealed that preoperative SII, preoperative D-dimer level, one-step-conservative surgery and PASUSS score were independent predictors for SPPH (Table 4). ROC curve analysis was conducted for the final four factors, with the PASUSS score showing the largest area under the curve (0.798) (Fig. 3).

Construction of a nomogram for SPPH in patients with anterior placenta previa combined with previous cesarean section

Based on the regression analysis results, a nomogram model was constructed using four variables: one-step-conservative surgery, preoperative SII, preoperative D-dimer level, and PASUSS score. Scores were assigned to each variable and totaled to assess the risk of SPPH (Fig. 4).

Diagnostic performance analysis of the Nomogram Model

The areas under the ROC curve for the training and validation cohorts were 0.844 (95%*CI*: 0.801–0.888) and 0.863 (95%*CI*: 0.803–0.923), respectively (Fig. 5). These values were higher than that for the PASUSS score alone. Calibration curves (Fig. 6) and DCA (Fig. 7) were plotted for both the training and validation cohorts, showing that the predicted probabilities of the nomogram closely aligned with the actual probabilities. The constructed model demonstrated good reliability and provided substantial net benefits for clinical application.

Discussion

Previous studies have reported that maternal mortality rates in cases of PAS were approximately 7%, which could be reduced to 0.05% with prenatal diagnosis and multidisciplinary expert management. Despite advancements, SPPH remains a leading cause of maternal death in PAS [19]. In this study, no patients died. The incidence rate of SPPH in patients with anterior placenta previa combined with previous cesarean section was 40.44%, which was significantly higher than that in the general population.

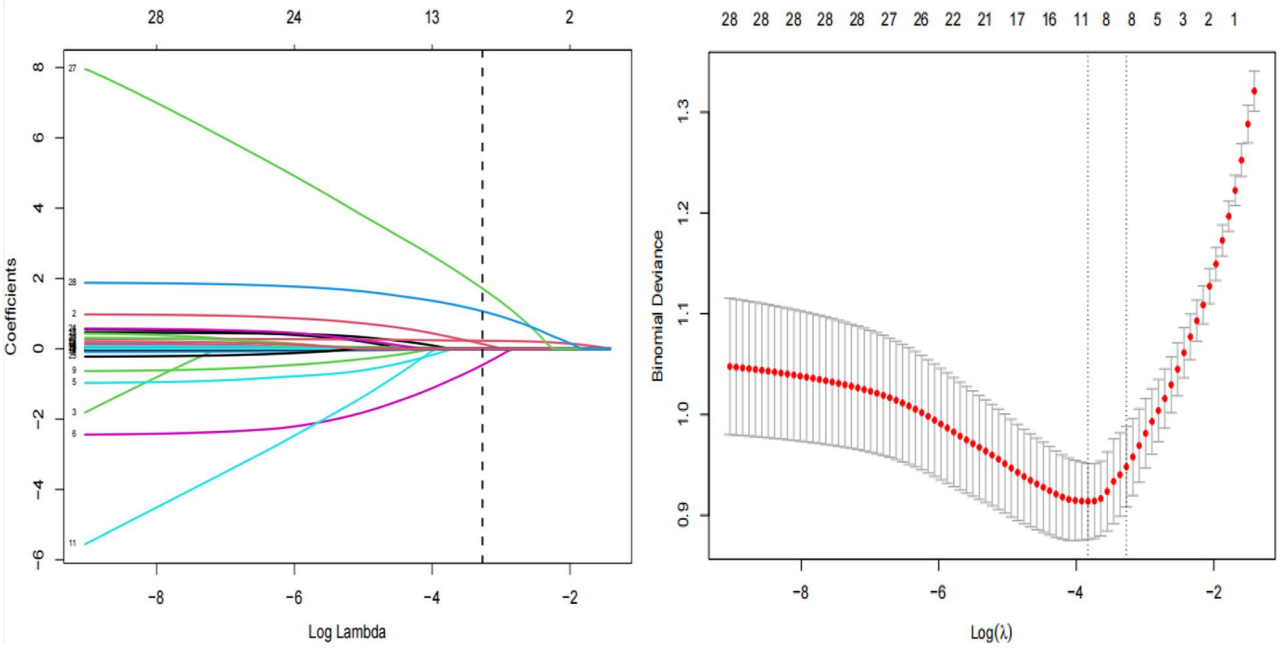

Fig. 2 LASSO regression coefficient path and cross-validation plots

Table 4 LASSO and multifactorial logistic regression analysis in the training cohort

	LASSO coefficient	Multivariate logistic analyses				
		N	Event *N*	OR	95% CI	*P*
Hypertensive disorders during pregnancy	-0.4601					
Yes		300	117	—	—	
No		15	1	0.11	0.01, 1.08	0.058
Preoperative D-dimer level (μg/L)	0.0002	315	118	1.001	1.0001, 1.0011	0.019
Preoperative SII ($\times 10^9$/L)	0.0003	315	118	1.001	1.0002, 1.0016	0.007
PASUSS score	0.2293	315	118	1.294	1.1481, 1.4585	< 0.001
Anesthesia method	0.1378					
Epidural-spinal anesthesia		57	5	—	—	
General anesthesia		258	113	2.39	0.79, 7.26	0.124
Preoperative PT (s)	0.0120	315	118	1.23	0.68, 2.22	0.496
Hysterectomy or postoperative interventional embolization	1.7149					
No		303	106	—	—	
Yes		12	12	60,112,865.27	0.00, Inf	0.986
One-step-conservative surgery	1.0677					
No		161	30	—	—	
Yes		154	88	5.84	2.98, 11.44	< 0.001

This study used clinical characteristics and ultrasound examinations to analyze and quantify all factors, identifying preoperative SII, preoperative D-dimer level, one-step-conservative surgery, and PASUSS score as independent risk factors for SPPH. A nomogram model constructed based on these four risk factors can help clinicians in early identification of high-risk SPPH groups, comprehensive assessment of preoperative conditions, multidisciplinary collaboration, and development of detailed surgical plans to reduce adverse outcomes associated with SPPH.

Given the non-invasiveness and convenience of ultrasound examinations, they have become the most widely used method for preoperatively diagnosing PAS. In clinical practice, we often rely on PASUSS to assess placenta accreta conditions. Studies have indicated that higher PASUSS scores are associated with an increased risk of placenta accreta, postpartum hemorrhage, and hysterectomy [20–22]. However, the PASUSS score can be significantly influenced by individual variations and operators, potentially impacting clinical decision-making when used as the sole basis. Therefore, it is crucial to establish a reliable prediction model. The nomogram model,

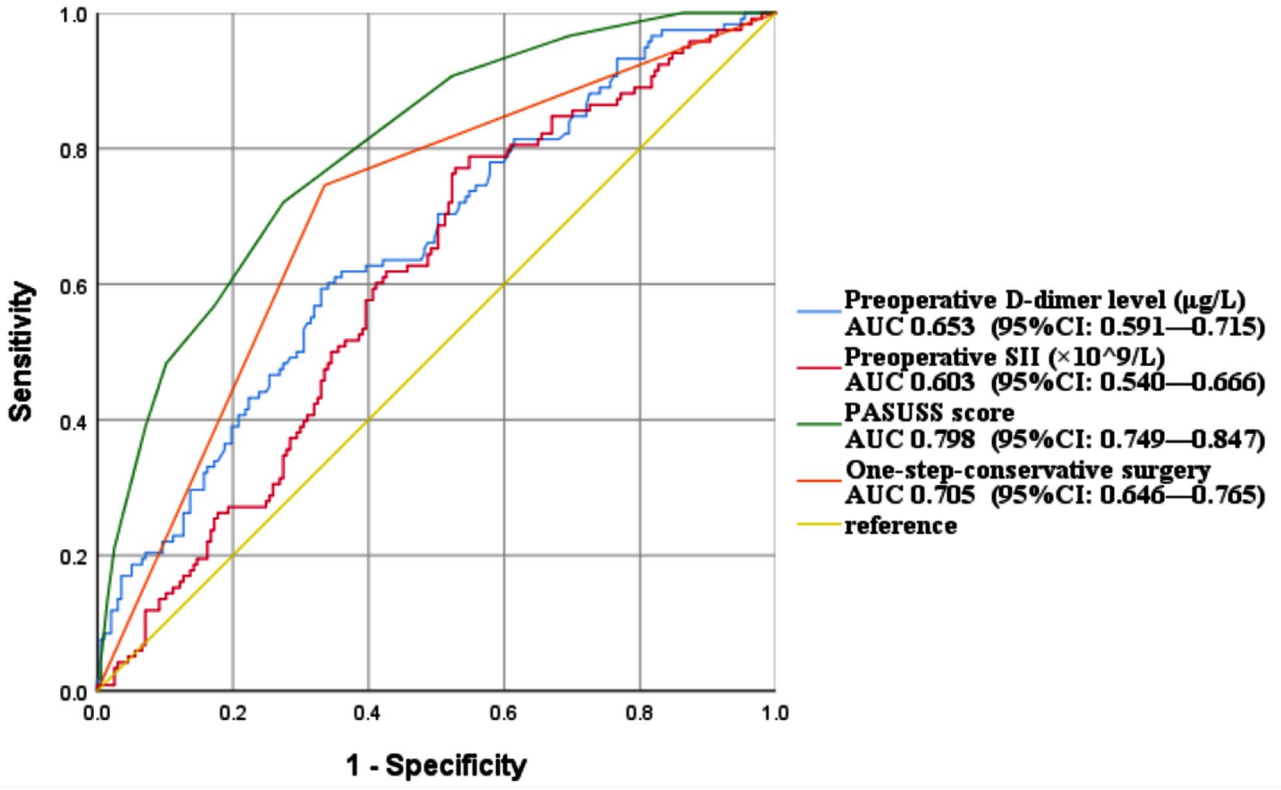

Fig. 3 ROC curve analysis of four candidate indicators

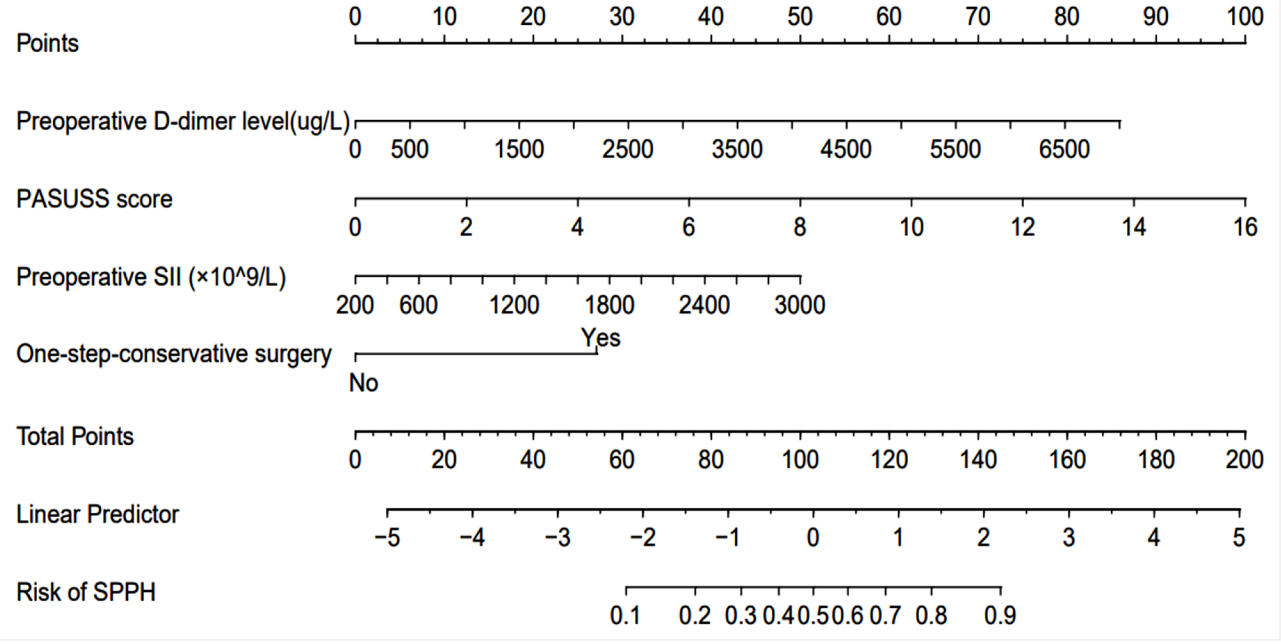

Fig. 4 Nomogram for SPPH in Patients with anterior placenta previa combined with previous cesarean section

constructed based on clinical characteristics and ultrasound examinations, exhibited significantly higher predictive accuracy for SPPH compared to a model relying solely on the PASUSS.

Elevated preoperative D-dimer levels are independent risk factors for SPPH, consistent with previous research findings [9, 23]. D-dimer levels are associated with placental development, and clinical observations

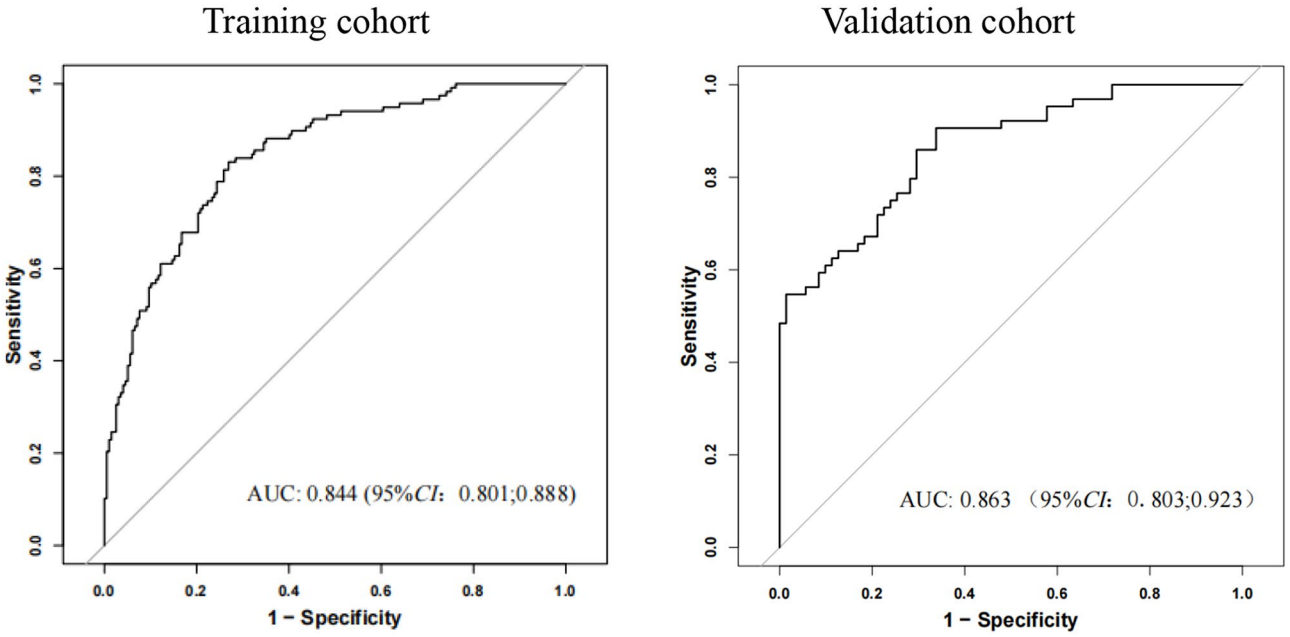

Fig. 5 ROC curves of the model in the training and validation cohorts

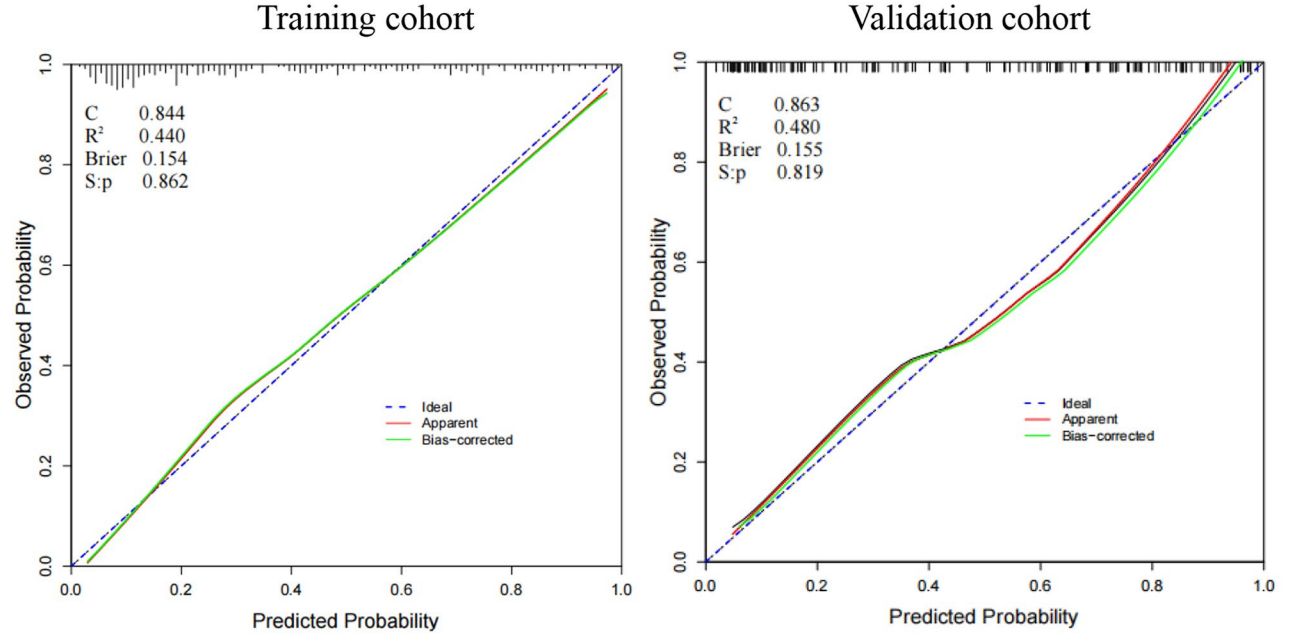

Fig. 6 Calibration curves of the model in the training and validation cohorts

have indicated a significant increase in D-dimer levels as normal pregnancy progresses. Furthermore, elevated D-dimer levels are closely linked to abnormal cell invasion and vascular remodeling [24–26].

The SII is an burgeoning indicator widely used in cancer research [27]. Studies have demonstrated that elevated SII levels in cancer patients are associated with advanced staging, grading, and increased postoperative recurrence rates [28, 29]. Due to the significant biological similarities between trophoblasts and cancer cells, this study innovatively incorporated the SII. It was observed that as preoperative SII levels increased, the likelihood of developing SPPH in patients with anterior placenta previa combined with previous cesarean section significantly rose. In this study, only 133 patients had pathological results. The results revealed that preoperative SII levels in patients with PAS were significantly higher than those in patients without PAS. However, no difference was found

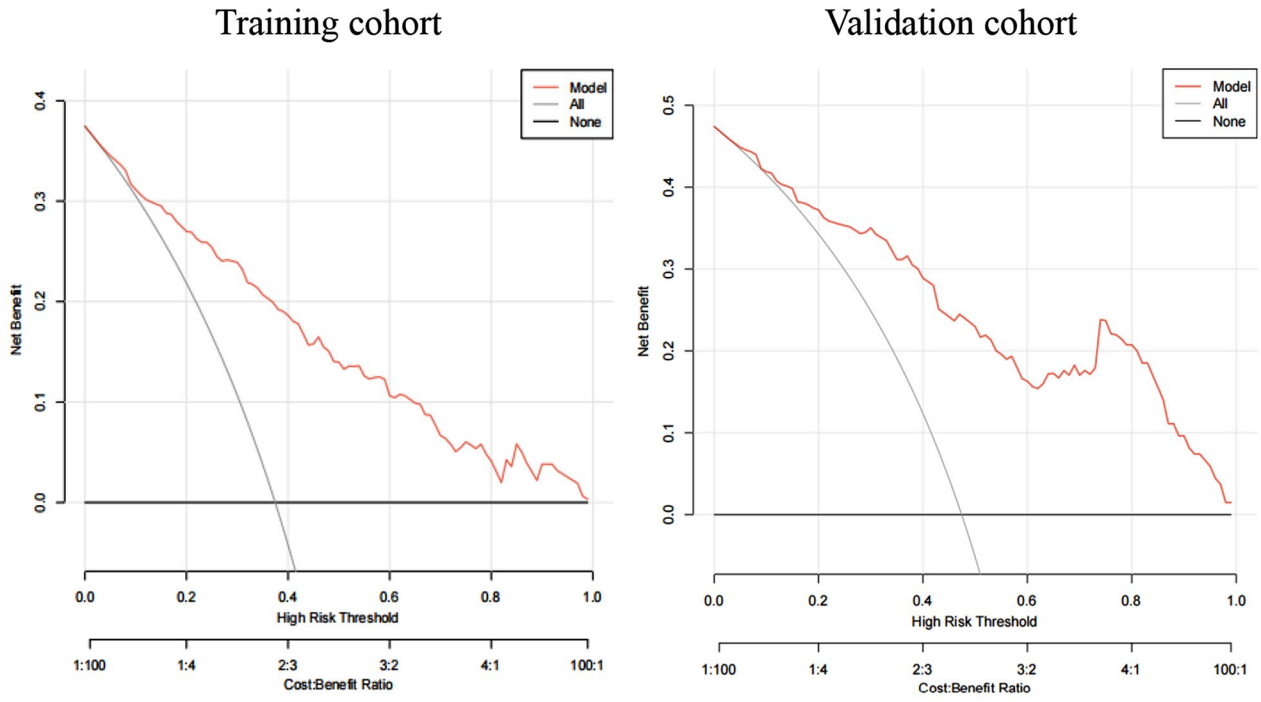

Fig. 7 DCA of the model in the training and validation cohorts

between invasive and adhesive PAS (see Additional file 1). Previous research has demonstrated that a high SII level is an independent risk factor for PAS in patients with placenta previa. However, there was no observed correlation between the SII level and the staging of PAS [30], which is consistent with the findings of our study. Given the small sample sizes and limitations in sampling sites for the diagnosis of PAS, it is possible for placenta accreta, increta, and percreta to coexist in the same patient. In addition, our study did not differentiate between placenta increta and percreta, collectively known as invasive PAS, which may influence the grouping. Future studies should increase the sample size and refine the grouping to further investigate the relationship between the preoperative SII and trophoblast invasion depth.

In this study, the rates of one-step-conservative surgery, abdominal aortic balloon placement, intraoperative uterine tamponade, uterine artery ligation, hysterectomy or postoperative interventional embolization were significantly higher in the SPPH group compared to the non-SPPH group. However, apart from one-step-conservative surgery, other operations were not causally related to the occurrence of SPPH. The use of abdominal aortic balloons remains controversial; some studies suggest that they can reduce intraoperative blood loss and lower the risks of hysterectomy and secondary surgery [31, 32]. However, other studies indicate that the use of abdominal aortic balloons not only fails to reduce bleeding and transfusion volumes but also prolongs surgery duration and increases hospitalization costs [33]. In this study, the incidence of SPPH was 40.44%, and the rate of abdominal aortic balloon placement was 5.78%. Patients undergoing abdominal aortic balloon placement are often preoperatively assessed as individuals with a high risk of bleeding or a greater likelihood of requiring a hysterectomy. In recent years, due to advancements in surgical techniques and the increasing incidence of complications following abdominal aortic balloon placement, the clinical applications of this procedure have gradually decreased. In this study, the rates of uterine artery ligation and uterine tamponade were 72.89% and 51.11%, respectively. When excessive bleeding occurs after fetal or placenta delivery, most surgeons ligate the uterine artery regardless of whether it is PAS or not. When massive bleeding is under control, but there is still oozing of blood in the uterine wall where the placenta was attached, most surgeons insert an intrauterine balloon or gauze before suturing the uterus to reduce the risk of subsequent bleeding in PAS. Most surgeons in non-PAS would opt for local suturing to achieve hemostasis, which typically yields favorable outcomes, and uterine tamponade is only used when sutures are ineffective. Hysterectomy or postoperative interventional embolization is typically considered as a last resort when SPPH has occurred and other treatments have proven ineffective. Although they cannot reduce the incidence of SPPH, their roles in reducing perioperative bleeding are undeniable. One-step-conservative surgery does not remove the placenta, but instead

directly excise the uterine wall invaded by the placenta and perform uterine reconstruction [18]. This procedure can prevent excessive bleeding caused by aggressive placental dissection. However, in our study, one-step conservative surgery was identified as a risk factor for SPPH, which appears to contradict previous research findings. This discrepancy may be attributed to the fact that our target population included patients with anterior placenta previa who had previous cesarean sections, while not all patients had PAS. The majority of patients undergoing one-step-conservative surgery in our study had PAS, which is a high-risk factor for SPPH. Furthermore, our analysis revealed that one-step-conservative surgery was a protective factor against hysterectomy or postoperative interventional embolization (see Additional file 2 and 3).

The associations between age, bleeding during pregnancy, and diabetes with SPPH have been discussed in previous studies [6, 8], but the findings remain inconclusive. In our study, there were no significant differences were observed in terms of age, bleeding during pregnancy, or diabetes between the two groups, which could be attributed to the selection criteria of the study population and the definition of SPPH.

Strengths and limitations

The strength of this study lies in that Shengjing Hospital is a large Class A tertiary hospital, and almost all of patients with anterior placenta previa combined with previous cesarean section in Northeast China who were preoperative suspected with PAS are delivered in this hospital. Therefore, despite the relatively rare incidence of PAS, the sample size of this study is relatively large. The PASUSS scores are conducted by two experienced physicians at our hospital to minimize bias resulting from human factors. Nonetheless, we acknowledge that our study has some limitations. Firstly, the cohort was limited to patients from a single hospital and may not be representative of the broader population. Validation in future prospective cohorts is necessary. Secondly, PASUSS consists of nine items, not all of which have a causal relationship with the occurrence of SPPH. In this study, the individual items of PASUSS were not analyzed in detail but were evaluated as a total score.

Conclusions

This study found that intraoperative hemostatic measures, such as intraoperative uterine tamponade, uterine artery ligation, and hysterectomy or postoperative interventional embolization, did not reduce the occurrence of SPPH in patients with anterior placenta previa combined with previous cesarean section. A nomogram constructed based on preoperative SII, preoperative D-dimer level, PASUSS score, and one-step-conservative surgery can help clinicians identify high-risk groups for SPPH in patients with anterior placenta previa combined with previous cesarean section. This tool can assist in thorough preparation, appropriate surgical planning, and improved prognosis.

Abbreviations

SPPH	Severe postpartum hemorrhage
PAS	Placenta accreta spectrum disorders
SII	Systemic immune-inflammatory index
ROC	Receiver operating characteristic
DCA	Decision curve analysis
APTT	Activated partial thromboplastin time
PT	prothrombin time
FIB	Fibrinogen
PASUSS	Placenta accreta spectrum ultrasound scoring system

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12884-024-06706-6.

Supplementary Material 1

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Author contributions

P.C. and L.J. planned the study design. L.J. contributed to the collection of data. P.C. and L.J. performed the data analyses. P.C. wrote the first draft of the article, which was revised and critically reviewed by C.Q. All authors approved the final version.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Shengjing Hospital affiliated with China Medical University (No.2021PS381K), the informed written consent was obtained from all participants. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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