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ORIGINAL RESEARCH

Development and Validation of a Predictive Model for Postpartum Hemorrhage in Non-Primiparous Women Who Deliver Vaginally

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Objective: To analyze the risk factors for postpartum hemorrhage in non-primary women giving birth naturally and construct a predictive model.

Methods: Retrospective analysis of the clinical data of 436 second-time mothers who underwent natural childbirth in the Department of Obstetrics, Hefei Third People's Hospital. The cases were divided into a bleeding group (n=41) and a non-bleeding group (n=395) based on whether there was bleeding greater than 500 mL within 24 hours after delivery. Independent risk factors were established through univariate and multivariate analyses, a logistic regression model was established, and bootstrap resampling was used to internally verify and assess the calibration of the model.

Results: Among the 436 cases of maternal delivery included in the study, 41 (9.40%) were cases of postpartum hemorrhage. The results of the multifactor analysis indicated that in vitro fertilization, body mass index (BMI), episiotomy, placenta previa, newborn weight, and manual removal of the placenta were independent risk factors for postpartum hemorrhage (PPH) in non-primary mothers. Subsequently, a model was constructed, exhibiting an AUC value of 0.839 (95% CI: 0.758–0.919). The Hosmer-Lemeshow test of the calibration curve yielded a chi-squared value of 8.1013 and a P-value of 0.4236, indicating an excellent performance of the DCA curve.

Conclusion: In vitro fertilization, body mass index (BMI), episiotomy, placenta previa, newborn weight, and manual removal of the placenta are identified as independent risk factors for postpartum hemorrhage (PPH) in non-primary mothers. The constructed logistic regression model is capable of more accurately identifying high-risk PPH mothers and providing a reference basis for individualized interventions.

Plain Language Summary: This study analyzed the risk factors for postpartum hemorrhage (PPH) in second-time mothers who gave birth naturally and developed a predictive model. Data from 436 cases were reviewed, identifying in vitro fertilization, BMI, episiotomy, placenta previa, newborn weight, and manual removal of the placenta as independent risk factors. A logistic regression model was constructed, showing good accuracy (AUC: 0.839) and calibration. The model can help identify high-risk PPH cases and guide personalized interventions.

Keywords: non-primary mother, postpartum hemorrhage, natural delivery, prediction model

Introduction

Postpartum hemorrhage (PPH) is traditionally defined as a blood loss of >500 mL within 24 hours of vaginal delivery or >1000 mL within 24 hours of cesarean delivery.[1] Postpartum hemorrhage (PPH) is the leading cause of maternal mortality worldwide. The majority of women who give birth naturally will experience prolonged labor, weak contractions, soft birth canal tears, placental factors, and other conditions that contribute to PPH.[2] Given that the volume of blood and cardiac output of the mother increase during pregnancy, cardiovascular adaptation occurs at an early stage of

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gestation and reaches its zenith in the third trimester. The changes in vital signs that result from postpartum hemorrhage may not be readily apparent, and the severity of shock cannot be accurately assessed, which can lead to delayed treatment.[3] Consequently, the early identification of high-risk groups for PPH and the prompt implementation of suitable interventions can potentially reduce the incidence of postpartum hemorrhage and mitigate its adverse effects on the mother to a certain extent.[4] With the relaxation of China's birth policy, the proportion of non-primiparous mothers is increasing, and their risk factors for PPH differ from those of primiparas. The majority of existing studies concentrate on the predictive indicators of the delivery process, with a paucity of research exploring the predictive value of prenatal indicators for PPH. This study aims to address this gap by investigating the risk factors for postpartum bleeding in non-primary mothers during natural childbirth, establishing a PPH risk prediction model, and identifying non-primary mothers at high risk of PPH in a timely manner to reduce the occurrence of PPH and its associated complications.

Materials and Methods

General Information

A retrospective analysis of the clinical data of second-time mothers who underwent natural childbirth in the obstetrics department of the Third People's Hospital of Hefei from January 2018 to February 2024. Obstetricians collected clinical history data during antenatal examinations or childbirth. The following criteria were used to determine which cases were included in the study: (1) All were non-primiparous women, defined as having a parity of at least one (previous delivery of a viable infant at ≥28 weeks' gestation), regardless of gravidity or history of pregnancy loss, and gave birth naturally; (2) singleton pregnancy; (3) all were in the head position; (4) all underwent antenatal examinations and exhibited no obvious abnormalities. The exclusion criteria are as follows: (1) History of uterine surgery or postpartum hemorrhage; (2) Abnormal birth canal; (3) Combined with giant uterine fibroids; (4) Combined with severe organic diseases, defined as advanced cardiac disease (New York Heart Association class III–IV), severe hepatic or renal insufficiency (eg, Child-Pugh class C, estimated glomerular filtration rate <30 mL/min/1.73 m²), decompensated respiratory disease, or malignant tumors under active treatment. Cases of placenta previa were limited to partial or marginal previa; vaginal delivery was allowed only if the placental edge was ≥2 cm from the internal cervical os and no other obstetric contraindications were present. No cases of complete placenta previa underwent vaginal delivery. A total of 436 patients were ultimately included in the study, and they were divided into two groups based on the presence or absence of postpartum hemorrhage (PPH) within 24 hours after delivery: a bleeding group (PPH) and a non-bleeding group (non-PPH).

Sample Size and Post Hoc Power

The sample size was determined by including all eligible cases that met the inclusion and exclusion criteria during the study period (January 2018 to February 2024). A post hoc power analysis for multivariable logistic regression (two-sided α=0.05) indicated that, with N=436 and an event fraction of 9.4% (41/436), the study had ≥80% power to detect an odds ratio (OR) ≥2.0 for a binary predictor with a prevalence of ≥10%, and >90% power to detect an OR ≥1.20 per 1-SD increase for continuous predictors (eg, BMI), consistent with the observed effect sizes. To limit overfitting given 41 events and six predictors (events-per-variable ≈6.8), we used bootstrap validation (1000 resamples) to quantify and correct for model optimism.

Methods

Data Collection

General data on the mother before birth was collected, including age, body mass index (BMI), pregnancy and childbirth history, and blood indicators before delivery. The duration of labor, midwifery measures, cervical lacerations, uterine contractions, placental adhesion, gestational hypertension, premature rupture of membranes, anemia, gestational diabetes, and newborn weight were observed and recorded. The Ethics Review Committee of Hefei Third People's Hospital approved this study (Approval Number: 2017LLW002) and waived the requirement for written informed consent due to its retrospective design, the use of de-identified data, and the absence of any intervention or potential risk to participants. All patient data were anonymized and handled with strict confidentiality. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (1964) and its later amendments. In this study, PPH was defined

as blood loss > 500 mL within 24h after spontaneous vaginal delivery, consistent with most obstetric research. To provide clinical context on more severe bleeding, we also report cases of severe PPH (≥ 1000 mL). In our cohort, 13 of 436 women (3.0%) met this threshold.

Measurement Methods

Volumetric Method: (1) The postpartum blood collector should be used to collect the mother's postpartum blood, after which the blood loss can be measured with a measuring cup. (2) Alternatively, the weighing method can be employed. The volume of blood lost (in milliliters) can be calculated using the following formula:

Blood loss (mL) = [wet weight of blood-collecting dressing after successful delivery (g) - dry weight of dressing before collection (g)]/1.05 The total blood loss within 24 hours postpartum is calculated by adding the blood volume in the collector within 24 hours postpartum, the estimated blood volume based on the soaked gauze, and the blood volume converted by weighing the bloodstained buttock pad.[5] If necessary, the blood loss is estimated based on the shock index and hemoglobin drop. Manual removal of the placenta was performed only when the placenta was not expelled within 30 minutes after delivery of the fetus or when significant hemorrhage occurred despite active management of the third stage of labor (AMTSL), which included prophylactic administration of uterotonics, controlled cord traction, and uterine massage. Vaginal delivery was considered for placenta previa only in cases of low-lying placenta (placental edge ≥2 cm from the internal cervical os on ultrasound in late pregnancy) with no evidence of placenta accreta spectrum and no antepartum hemorrhage. Manual removal of the placenta was performed if the placenta was not delivered within 30 minutes after delivery of the infant despite active management of the third stage of labor, or if there was evidence of placental retention with ongoing bleeding or hemodynamic instability.

Statistical Methods

The statistical analysis of the data was conducted using SPSS 26.0 and R (version 4.2.3). Continuous variables with a normal distribution were expressed as the mean ± standard deviation, and an independent sample *t*-test was employed for comparisons between the two groups. Continuous variables with a non-normal distribution were expressed as median (interquartile range), and the Mann–Whitney *U*-test was employed for comparisons between the groups. Categorical variables were expressed as composition ratios or rates, and the chi-squared test was employed for comparison. The aforementioned data were subjected to univariate regression analysis to ascertain potential risk factors. Subsequently, variables with a P-value less than 0.05 were incorporated into a multivariate logistic regression model for multifactorial analysis, with a P-value less than 0.05 considered statistically significant. A prediction model was constructed using R software, based on the weight coefficient of independent risk factors. The area under the receiver operating characteristic curve (AUC) and its 95% confidence interval (CI) were employed to assess the predictive capacity of the constructed prediction model. An AUC of 0.5 indicates a lack of predictive power, whereas an AUC of 1.0 indicates completely accurate predictive power. The line chart was also verified using the bootstrap internal validation method, with 1000 self-sampling times, and calibration curves and clinical decision curves (DCA) were plotted.

Results

Construct a Predictive Model

General Information

The study population consisted of 436 second-time mothers who had given birth naturally. Of these, 41 (9.40%) developed PPH, with an average maternal age of (28.97±3.96) years. Among 436 deliveries, PPH occurred in 41 women (9.40%), of whom 13 (3.0%) experienced severe PPH (≥ 1000 mL). Due to the limited number of severe events, multivariable modeling was not pursued for this subgroup.

Identify Potential Risk Factors for PPH

A univariate analysis of the patients' general information indicates that age, BMI, gestational week, in vitro fertilization, number of pregnancies, duration of the first and second stages of labor, newborn weight, placenta previa, placenta accreta, oxytocin-induced labor, in vitro fertilization, antepartum hemorrhage, episiotomy, and manual removal of the placenta are potential risk factors for PPH in second-time mothers giving birth vaginally. Please refer to Table 1 for further details.

Table 1 Maternal General Information and Screening of Potential Risk Factors for PPH

variant	PPH Group (n=41)	Non-PPH Group (n=395)	*P*-value
Age (years)	30.22±3.48	28.84±3.99	0.034
BMI (kg/m^2)	30.52±3.23	28.71±2.84	<0.001
High blood pressure	3 (7.3%)	24 (6.1%)	0.754
Diabetes	2 (4.9%)	38 (9.6%)	0.317
Fibroid tumor of the uterus	1 (2.4%)	9 (2.3%)	0.948
Gestation period			0.013
<35 weeks	5 (12.2%)	33 (8.4%)	
35-40 weeks	34 (82.9%)	360 (91.1%)	
>40 weeks	2 (4.9%)	2 (0.5%)	
Number of pregnancies (times)	2 (2, 3)	3 (2, 3)	0.327
History of abortion	23 (56.1%)	160 (40.5%)	0.054
In vitro fertilization	6 (14.6%)	1 (0.3%)	<0.001
History of antepartum hemorrhage	3 (7.3%)	9 (2.3%)	0.061
Prenatal hemoglobin (g/L)	117.70±14.55	115.71±11.66	0.310
Prenatal platelet count (×10^9 /L)	234.22±31.17	243.45±31.89	0.078
Duration of first stage of labor (h)	8.47±1.56	8.02±1.31	0.042
Duration of second stage of labor (min)	22.39±6.96	19.87±7.91	0.050
Duration of third stage of labor (min)	6.01±1.46	6.09±1.55	0.766
Induction of labor with induced abortion	15 (36.6%)	84 (21.3%)	0.026
Placenta praevia	6 (14.6%)	3 (0.8%)	<0.001
Placental adhesion	3 (7.3%)	8 (2.0%)	0.040
Perineal incision	8 (19.5%)	30 (7.6%)	0.010
Premature rupture of the membranes of the fetus	3 (7.3%)	9 (2.3%)	0.061
Hand-removed placenta	5 (12.2%)	1 (0.3%)	<0.001
Newborn weight (g)	3556.37±442.27	3187.52±289.93	<0.001

Multivariate Analysis

After incorporating the aforementioned variables with a P-value of less than 0.05 into the multivariate analysis, it was determined that in vitro fertilization, body mass index (BMI), episiotomy, placenta previa, newborn weight, and manual removal of the placenta were independent risk factors for postpartum hemorrhage (PPH) during natural childbirth in women who were giving birth for the second time. Please refer to Table 2 for further details.

Construct a Linear Model

The independent risk factors identified through multifactor logistic regression analysis should be selected, and a linear model should be constructed using the rms package in R to predict the risk factors for PPH in natural childbirth for second-time mothers, as illustrated in Figure 1.

Table 2 Independent Risk Factors for PPH in second-Trimester Women in Spontaneous Labor

Variant	B-value	Standard Deviation	OR (95% CI)	*P*-value
BMI	0.213	0.072	1.238 (1.074–1.427)	0.003
In vitro fertilization	3.562	1.297	35.239 (2.771–448.177)	0.006
Perineal incision	1.673	0.604	5.330 (1.632–17.405)	0.006
Placenta praevia	3.834	1.349	46.236 (3.288–651.006)	0.004
Newborn weight	0.003	0.001	1.003 (1.002–1.004)	<0.001
Hand-removed placenta	3.240	1.587	25.545 (1.139–572.679)	0.041

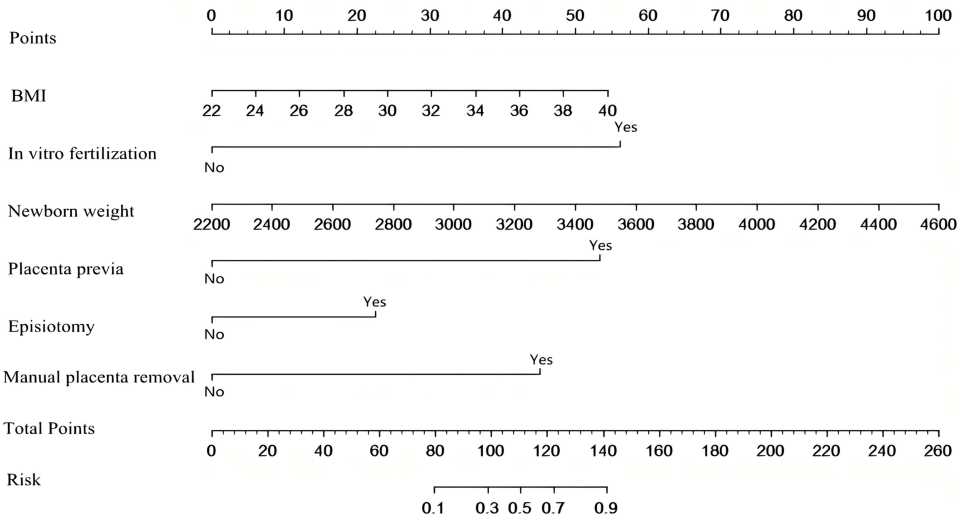

Figure 1 Nomogram for predicting postpartum hemorrhage risk in non-primiparous women undergoing spontaneous delivery. Points are assigned for each risk factor, and the total points correspond to predicted probability.

Validation of the Prediction Model

Model Discrimination

The score for each included mother was calculated according to the scoring system, and the receiver operating characteristic (ROC) curve was plotted using the "pROC" package in the R language software to determine the discrimination of the prediction model, as illustrated in Figure 2. The AUC value of the prediction model is 0.839 (95% CI: 0.758–0.919), and the C-index of the prediction model is 0.825, which was obtained through 1000 internal sampling validations (bootstrap). These results indicate that the line chart prediction model has good performance in terms of discrimination.

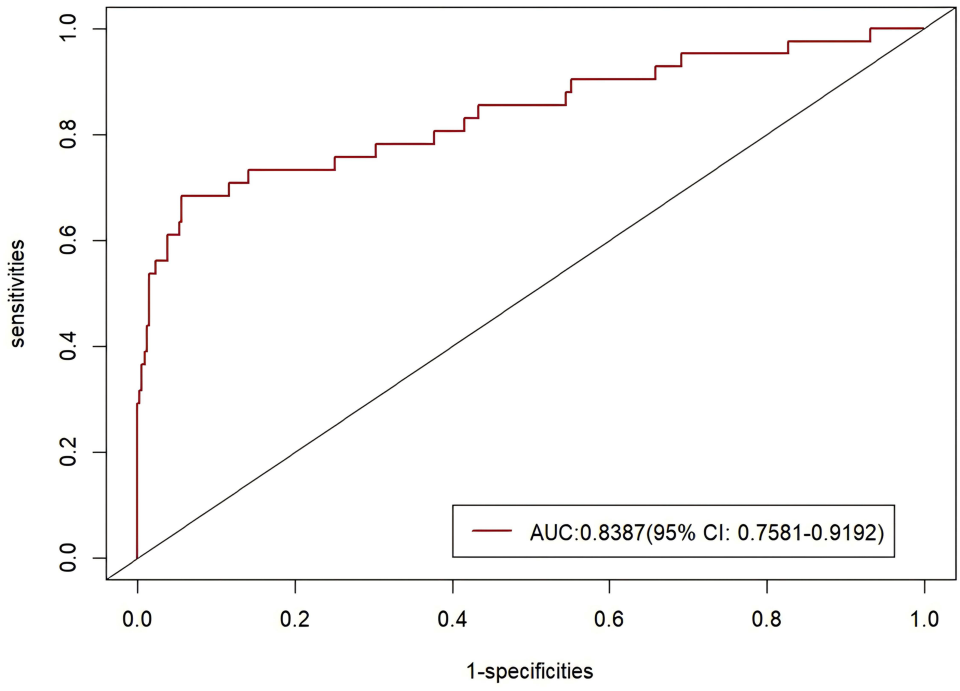

Figure 2 Receiver operating characteristic (ROC) curve for the nomogram model. The model shows good discrimination with an AUC of 0.839 (95% CI: 0.758–0.919).

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Model Calibration

The Hosmer-Lemeshow goodness-of-fit test was employed to ascertain the calibration of the model, while the bootstrap internal validation method was utilized to substantiate the line chart. A total of 1000 bootstrap samples were generated, and the calibration curve was plotted (Figure 3). The results of the Hosmer-Lemeshow goodness-of-fit test yielded a chi-squared statistic of 8.1013 and a P-value of 0.4236, which is greater than 0.05. This indicates that the model has a high level of predictive accuracy.

Evaluation of the Clinical Value of the Model

To assess the clinical value of the linear model, a clinical decision curve (DCA) was constructed using the R statistical software (Figure 4). The results demonstrate that when the risk threshold is >0.1, the clinical net benefit derived from implementing the linear model for the entire population is greater than the benefit of not intervening at all or intervening on the entire population. This indicates that the model can provide a superior clinical decision-making strategy.

Discussion

Incidence of PPH

Postpartum hemorrhage remains a major cause of maternal morbidity and mortality worldwide, affecting an estimated 14 million women each year.[6] A recent meta-analysis reported that approximately 17% of women have blood loss >500 mL after vaginal delivery, and more than 6% experience ≥1000 mL.[7] Although some guidelines define PPH as ≥1000 mL, we adopted the >500 mL threshold for primary modeling to align with most obstetric prediction studies and ensure adequate event counts for robust regression. Nevertheless, our observed severe PPH rate (≥1000 mL) of 3.0% provides useful benchmarking, and highlights the need for larger datasets to enable predictive modeling for this outcome.

Established PPH risk factors include uterine atony, genital tract trauma, retained placenta, and coagulation disorders. While multiple pregnancies, primiparity, and cesarean delivery have been widely studied,[8–12] little evidence exists for non-primiparous women with singleton, spontaneous vaginal births. With the relaxation of China's birth policy, the proportion of such women has increased, underscoring the importance of tailored prevention and management strategies.

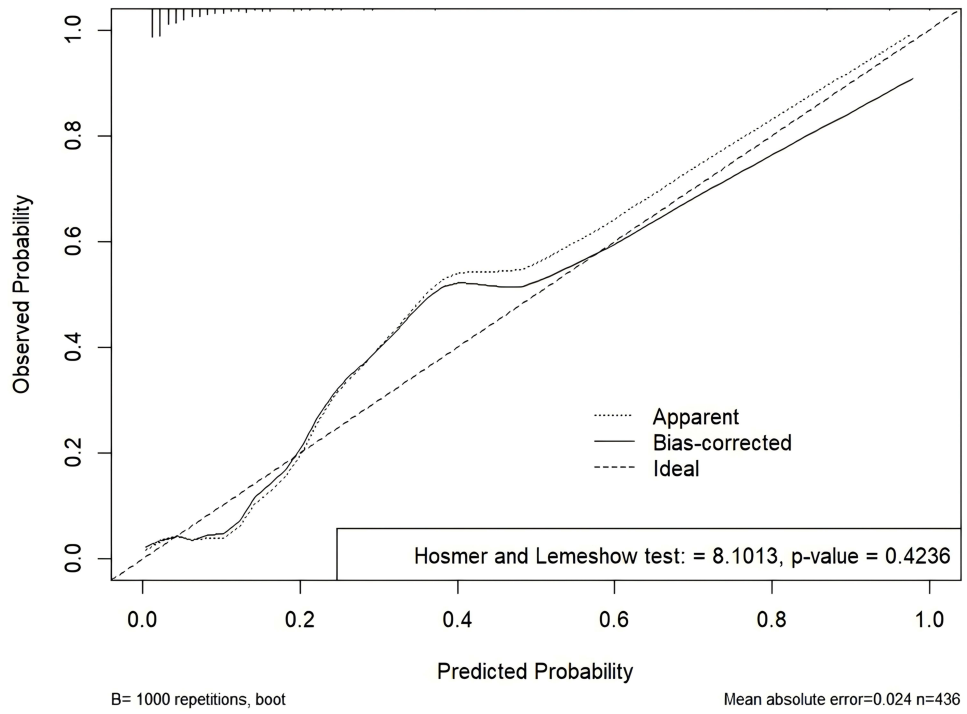

Figure 3 Calibration curve of the nomogram model. The Hosmer–Lemeshow test yielded P = 0.4236, indicating good fit.

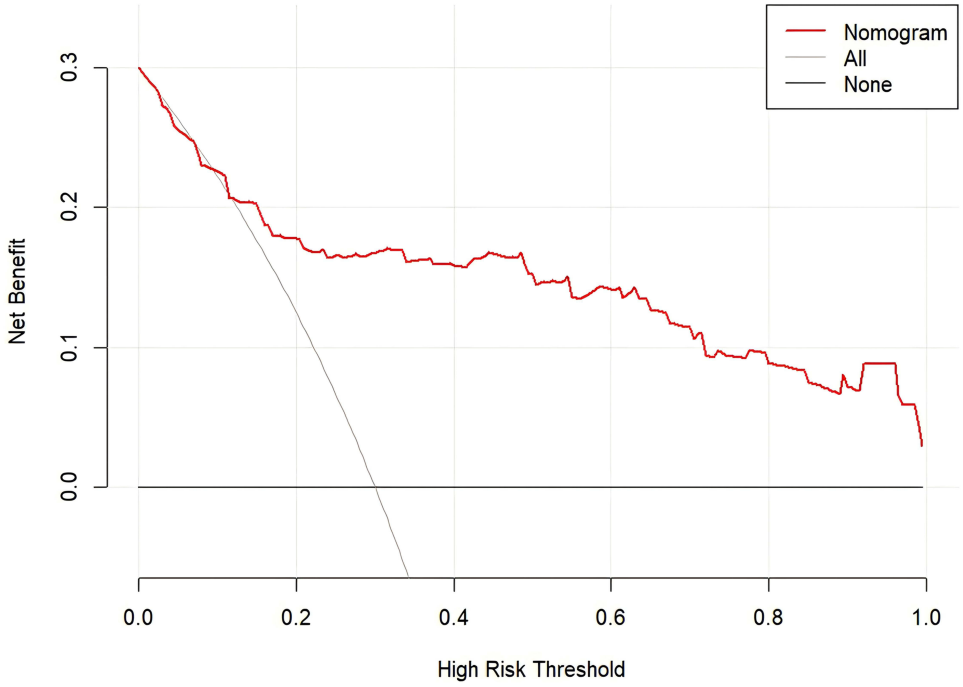

Figure 4 Decision curve analysis (DCA) for the nomogram model, demonstrating net benefit when the risk threshold exceeds 0.1.

Our lower PPH incidence compared with prior reports may be partly attributable to protective factors in this population, such as parity ≥1 and vaginal delivery.

Analysis of Risk Factors for PPH in Non-Primigravid Women

During the third stage of labor, the placenta normally detaches from the uterine wall and is expelled spontaneously. In abnormal cases, placental villi may invade into the myometrium, a condition known as placenta accreta spectrum (PAS).[13–15] With the increased use of assisted reproductive technologies, particularly in vitro fertilization (IVF), the incidence of PAS has also risen,[16,17] likely due in part to the programmed endometrial preparation cycles used before embryo transfer.[18] Retained placenta in such cases greatly increases the risk of postpartum hemorrhage. Multiple gestations have also been associated with higher PAS rates following IVF.[19,20] These observations underscore the need for careful antenatal imaging assessment of placental location and adherence in women with prior IVF, allowing timely planning of delivery and preventive interventions.

In the management of PAS, treatment options range from aggressive cesarean hysterectomy to conservative local resection or even planned retention of the placenta. Regardless of the approach, the guiding principle is to avoid forcible manual removal, which can precipitate massive hemorrhage and threaten maternal life.[21] Van Starlin et al reported that direct removal significantly increases the risk of PPH.[22] In cases of retained or abnormally adherent placenta, forcible extraction can leave fragments embedded in the myometrium, leading to uncontrolled bleeding. Conservative measures such as uterine massage and timely administration of uterotonics should be attempted first, with close monitoring of blood loss. If hemostasis cannot be achieved, interventions such as partial hysterectomy—when the placenta has not invaded the cervix or parametrium—may be considered to control bleeding while minimizing the morbidity associated with total hysterectomy.[23]

Higher prenatal BMI has been consistently identified as a risk factor for PPH in multiple studies.[24,25] A maternal BMI ≥30 kg/m² is considered obese and has been linked to a range of adverse obstetric outcomes, including miscarriage, gestational diabetes mellitus, venous thromboembolism, and increased likelihood of cesarean delivery.[26] Mechanistically, obesity is associated with impaired uterine contractility, which can predispose to greater blood loss after vaginal birth. A large population-based cohort study by Butwick et al,[27] found that obese women had higher odds of hemorrhage

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following transvaginal delivery but lower odds after cesarean delivery. These findings reinforce the importance of weight management for women planning vaginal delivery, emphasizing dietary control and appropriate exercise during pregnancy to mitigate PPH risk.

Placenta previa, characterized by abnormal implantation of the placenta in the lower uterine segment, is a well-recognized risk factor for significant perinatal hemorrhage.[28] In some cases, it coexists with placenta accreta spectrum (PAS), further increasing the risk of massive bleeding. The condition is more prevalent among non-primigravid women, likely due to endometrial changes from advanced maternal age, multiple pregnancies, or prior cesarean sections. Baba et al[29] identified three predictors of PPH in the context of placenta previa: ultrasound evidence of abnormal placental adhesion, a history of cesarean delivery, and imaging suggesting placenta previa over a previous uterine scar. Mechanistically, placenta previa in the lower segment is associated with a larger placental separation surface, poor contractility of the lower uterine segment after delivery, and difficulty in compressing the venous sinuses, all of which contribute to increased bleeding risk.

Birth canal trauma is a major cause of PPH in vaginal deliveries. Prolongation of the second stage of labor increases the risk of severe perineal lacerations, and episiotomy is often performed to expedite delivery in such cases. However, episiotomy involves incision through multiple tissue layers and disruption of more blood vessels, which can increase postpartum blood loss—a finding consistent with previous research by Girault et al.[30] These observations highlight the importance of selective use of mediolateral episiotomy and meticulous suturing techniques to achieve complete hemostasis and reduce the risk of PPH.

Excessive neonatal weight (macrosomia) has been identified as a risk factor for PPH in prior studies, including findings by Davey et al.[8] Macrosomia can lead to overdistension of the uterus, resulting in weak postpartum contractions that fail to adequately close the venous sinuses at the placental site. In addition, large infants increase the likelihood of birth canal trauma, such as perineal tears and cervical lacerations, and often prolong labor, leading to maternal fatigue and further impairment of uterine contractility. These factors collectively elevate the risk of PPH. Optimizing maternal health before conception—including maintaining a healthy weight, engaging in regular exercise, and achieving good physical fitness—can help reduce the risk of macrosomia and, in turn, lower the incidence of PPH.

Evaluation of the Effectiveness of the Prediction Model

Few previous studies have developed predictive tools for PPH specifically in non-primiparous women with spontaneous vaginal deliveries. Our nomogram integrates multiple antenatal and intrapartum risk factors to estimate individual PPH risk and demonstrated good discrimination and calibration in internal validation. The decision curve analysis suggests that applying the model for targeted preventive measures could yield greater net clinical benefit than strategies of treating all or no patients. Nevertheless, the model was derived from single-center, retrospective data with a limited sample size, and external validation in larger, multicenter cohorts is needed to confirm its generalizability.

Conclusions

This study retrospectively analyzed the general data, past medical history, antenatal conditions, and delivery process of 436 non-primiparas. Binary Logistic multivariate regression analysis showed that in vitro fertilization, BMI, episiotomy, placenta previa, neonatal weight, and manual placenta extraction were independent risk factors for PPH in non-primiparas. According to the weight coefficient of each variable, we constructed a nomogram model for predicting PPH in non-primiparas, with an AUC value of 0.839 (95% CI: 0.758–0.919). The calibration curve and DCA curve performed well, which can provide a reference for individualized intervention measures for high-risk PPH puerperae in clinical practice.

Data Sharing Statement

The datas used and/or analyzed during the current study are available from the corresponding author.

Human Ethics and Consent to Participate Declarations

This study was approved by the Human Ethics Committee of Hefei Third People's Hospital (Approval Number: 2017LLW002). Given its retrospective nature, use of de-identified records, and no potential harm to participants, the requirement for written informed consent was waived by the committee. All procedures complied with the ethical standards of the institutional and/or national research committee and with the Declaration of Helsinki (1964) and its later amendments.

Consent to Publish Declaration

All participants agreed to publish.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors state that they have no financial or commercial ties to other entities that could be seen as a conflict of interest in the research.

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