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ORIGINAL RESEARCH

Construction and Validation of a Prediction Model for Conversion to Cesarean Section in Primiparous Women Receiving Epidural Labor Analgesia: A Retrospective Cohort Study

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Purpose: To develop and validate a clinical prediction model for intrapartum conversion to cesarean section in primiparous women receiving epidural labor analgesia.

Patients and Methods: This retrospective cohort study included 1020 primiparous women who received epidural labor analgesia at a tertiary hospital in Wuxi, China. The model was developed to estimate cesarean conversion risk within this specific clinical cohort. Participants who delivered between March and December 2023 comprised the training cohort, whereas those who delivered between January and March 2024 comprised the validation cohort. Maternal, fetal, and intrapartum variables were extracted from electronic medical records, anesthesia records, and intrapartum fetal monitoring systems. A multivariable logistic regression model was developed to predict conversion to cesarean section, and a nomogram was constructed based on the final model. Model discrimination and calibration were assessed using the area under the receiver operating characteristic curve (AUC), the Hosmer–Lemeshow test, and calibration plots. Clinical utility was evaluated using decision curve analysis.

Results: The rate of conversion to cesarean section was 15.9% in the training cohort and 15.3% in the validation cohort. Six variables were identified as independent predictors of cesarean conversion: maternal age, intrapartum temperature, amniotic fluid characteristics, fetal heart rate status, use of oxytocin, and rupture of membranes during the first stage of labor. The prediction model showed good discrimination, with an AUC of 0.810 (sensitivity 0.822, specificity 0.606) in the training cohort. In the validation cohort, the AUC was 0.763 (sensitivity 0.786, specificity 0.592), indicating consistent predictive performance.

Conclusion: This prediction model provides reliable risk estimation for conversion to cesarean section within a specific cohort of primiparous women receiving epidural labor analgesia. It may support early intrapartum risk stratification and individualized clinical decision-making. Further multicenter studies are warranted to assess its generalizability.

Keywords: prediction model, cesarean section, epidural labor analgesia, primiparous women, intrapartum risk

Introduction

Labor pain is widely recognized as one of the most intense forms of physical discomfort experienced by women.[1] Effective pain management is therefore a critical component of obstetric care during childbirth. With advancements in medical technology and a growing emphasis on comfort-oriented maternity services, the use of labor analgesia has become increasingly common.[2] Among all analgesic techniques, epidural analgesia is considered the most effective for relieving labor pain and is regarded as the gold standard for comparison with other methods.[3]

Despite its advantages in labor pain relief, some women receiving epidural labor analgesia may still require cesarean delivery during labor, and timely risk assessment remains important for intrapartum management.[4,5] Primiparous women are

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particularly vulnerable because they often have a longer first stage of labor due to an undilated birth canal and the absence of prior delivery experience. As a result, they have a higher likelihood of cesarean section compared with multiparous women.[6–8] Managing labor progression in primiparous women therefore remains a significant clinical challenge.

Developing reliable prediction models is essential to help clinicians identify primiparous women at increased risk of intrapartum cesarean conversion at an early stage.[9] However, most previous studies have focused on the effects and complications of epidural analgesia.[10,11] Although several factors associated with intrapartum cesarean delivery have been reported, clinically applicable prediction models for primiparous women receiving epidural labor analgesia remain limited.[12,13] Primiparous women receiving epidural labor analgesia constitute a specific intrapartum population in whom early risk stratification is clinically important. Because labor progression and fetal status may change dynamically after analgesia initiation, a prediction model incorporating routinely collected intrapartum variables may support timely monitoring, multidisciplinary communication, and individualized intrapartum management.

In this study, we developed and validated a prediction model using routinely collected maternal, fetal, and intrapartum variables to estimate the risk of cesarean conversion among primiparous women receiving epidural labor analgesia. This model was developed to support risk assessment in this specific population and to facilitate early warning, multidisciplinary communication, and individualized intrapartum management.

Materials and Methods

Study Design and Participants

This retrospective cohort study was conducted in the delivery room of a tertiary hospital in Wuxi, Jiangsu Province, China. Clinical data were obtained from electronic medical records, anesthesia records, and intrapartum fetal monitoring systems. Eligible primiparous women who received epidural labor analgesia between March 2023 and March 2024 were retrospectively identified, and relevant clinical data were extracted in 2025 for analysis. Participants who delivered between March 2023 and December 2023 were included in the training cohort, whereas those who delivered between January 2024 and March 2024 were included in the validation cohort. The study protocol was reviewed and approved by the Research Ethics Committee of Wuxi People's Hospital (approval No. KY25157). Given the retrospective nature of the study and the use of routinely collected clinical data, the requirement for informed consent was waived by the ethics committee. All data were anonymized/de-identified before analysis. The study was conducted in accordance with the Declaration of Helsinki.

Inclusion criteria: (1) Gestational age $\geq$ 37 weeks with a full-term, singleton pregnancy in cephalic presentation; (2) Maternal age $\geq$ 20 years; (3) Eligibility for a vaginal trial of labor; (4) Willingness to undergo a trial of labor, either with spontaneous onset or following labor induction; (5) Category I fetal heart rate tracing before analgesia, defined according to the National Institute of Child Health and Human Development (NICHD) guidelines as a baseline of 110 to 160 bpm with moderate variability and no late or variable decelerations;[14] (6) Baseline maternal body temperature < 37.5°C.

Exclusion criteria: (1) Preterm birth; (2) Multiple pregnancies; (3) Severe maternal comorbidities that contraindicate vaginal delivery; (4) Previous cesarean section or uterine scarring; (5) Psychiatric disorders or inability to cooperate with the research procedures.

Outcome Definition

The primary outcome was first-stage intrapartum obstetric conversion to cesarean section after initiation of epidural labor analgesia. This outcome referred to cesarean delivery performed during the first stage of labor after a planned trial of vaginal delivery. The timing and clinical indications of cesarean delivery were confirmed by reviewing delivery records and operative records. In the original dataset, all cesarean conversions occurred during the first stage of labor, and no second-stage cesarean conversion was identified. The cesarean indications were obstetric in nature and mainly included relative cephalopelvic disproportion, persistent occiput posterior position, non-reassuring fetal heart rate status or suspected acute fetal compromise, and other obstetric indications.

Anesthesia records were also reviewed to identify serious anesthesia-related adverse events, including high or total neuraxial block, local anesthetic systemic toxicity, and severe hypotension. According to the available anesthesia,

delivery, and operative records, no cesarean delivery was documented as being directly caused by these serious anesthesia-related complications. Therefore, the outcome in this study primarily represented obstetric cesarean conversion during the first stage of labor rather than cesarean delivery directly attributed to anesthesia-related complications.

Variables and Definitions

Based on a comprehensive literature review, expert consultation, and clinical considerations, we identified a set of maternal, fetal, and intrapartum variables with potential relevance to intrapartum cesarean conversion among primiparous women receiving epidural labor analgesia.[15,16] Thirteen candidate predictors were included in this study: maternal age, height, BMI, gestational age, estimated fetal weight, cervical dilation at epidural placement, duration of epidural labor analgesia, intrapartum temperature, pregnancy complications (hypertension, diabetes, or hypothyroidism), amniotic fluid characteristics, fetal heart rate status, use of oxytocin, and rupture of membranes during the first stage of labor. All variables were extracted from electronic medical records, anesthesia documentation, and intrapartum fetal monitoring records. Fetal heart rate status referred to intrapartum fetal heart rate status after initiation of epidural labor analgesia and was classified according to NICHD criteria.[14] Category I fetal heart rate tracings were defined as normal, whereas Category II or III tracings during labor were grouped as non-normal fetal heart rate status for analysis. Amniotic fluid characteristics were categorized as clear or meconium-stained based on delivery records and intrapartum clinical documentation. A detailed description of each variable and its coding is provided in Table 1.

Table 1 Description of the Study Variables

SN	Predictor	Description	Type	Values/Coding
1	Maternal age	Maternal age at delivery (years)	Continuous	Actual value
2	Height	Maternal height (cm)	Continuous	Actual value
3	BMI	Body mass index (kg/m^2)	Continuous	Actual value
4	Gestational age	Gestational age at delivery (weeks)	Continuous	Actual value
5	Estimated fetal weight	Estimated fetal weight (g)	Continuous	Actual value
6	Cervical dilation at epidural placement	Cervical dilation at epidural placement (cm)	Continuous	Actual value
7	Duration of epidural labor analgesia	Duration of epidural labor analgesia (hours)	Continuous	Actual value
8	Intrapartum temperature	Maternal intrapartum temperature	Categorical	0 = < 37.5°C, 1 = 37.5–37.9°C, 2= ≥ 38.0°C
9	Pregnancy complications	Hypertension, diabetes, hypothyroidism	Categorical	0 = No, 1 = Yes
10	Amniotic fluid characteristics	Amniotic fluid characteristics	Categorical	0 = Clear, 1 = Meconium-stained
11	Fetal heart rate status	Fetal heart rate status	Categorical	0 = Normal (Category I), 1 = Non-normal (Category II–III)
12	Use of oxytocin	Use of oxytocin for labor induction or augmentation	Categorical	0 = No, 1 = Yes
13	Rupture of membranes during the first stage of labor	Rupture of membranes during the first stage of labor	Categorical	0 = No rupture, 1 = Spontaneous rupture of membranes, 2 = Artificial rupture of membranes

Abbreviation: SN, serial number.

Epidural Analgesia Method

All parturients received epidural labor analgesia using programmed intermittent epidural bolus (PIEB) technology combined with a patient-controlled epidural analgesia (PCEA) mode. The analgesic solution consisted of 150 mg of ropivacaine and 50 μg of sufentanil. The PIEB pump was programmed to deliver an 8–12 mL bolus every 45 minutes, while the PCEA mode allowed an additional 8–10 mL per self-administered dose with a lockout interval of 15–30 minutes.

Sample Size Calculation

The prediction model included 13 independent variables. For logistic regression models, the required sample size is commonly estimated as five to ten times the number of predictors. Given that the model included 13 variables and the incidence of intrapartum cesarean conversion among women receiving epidural labor analgesia is approximately 18%,[17] the minimum required sample size was estimated to be at least 803 participants after accounting for an expected 10–20% sample loss. According to the recommended 4 to 1 sample size ratio between the training and validation cohorts,[18] the validation cohort required at least 161 participants. Ultimately, 850 primiparous women receiving epidural labor analgesia were enrolled in the training cohort from March 2023 to December 2023, and 170 women were enrolled in the validation cohort from January 2024 to March 2024 (Figure 1).

Statistical Analysis

Data were processed and analyzed using SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA) and R software version 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria). Categorical variables were summarized as frequencies and percentages (%), and group comparisons were performed using the χ^2 test. Continuous variables with a normal distribution were expressed as mean ± standard deviation (SD), and differences between groups were assessed using the independent samples *t*-test.

All 13 candidate predictors were first evaluated using univariate analysis. Variables with $P < 0.05$ in the univariate analysis were then assessed for multicollinearity using variance inflation factors (VIFs). Variables without evidence of

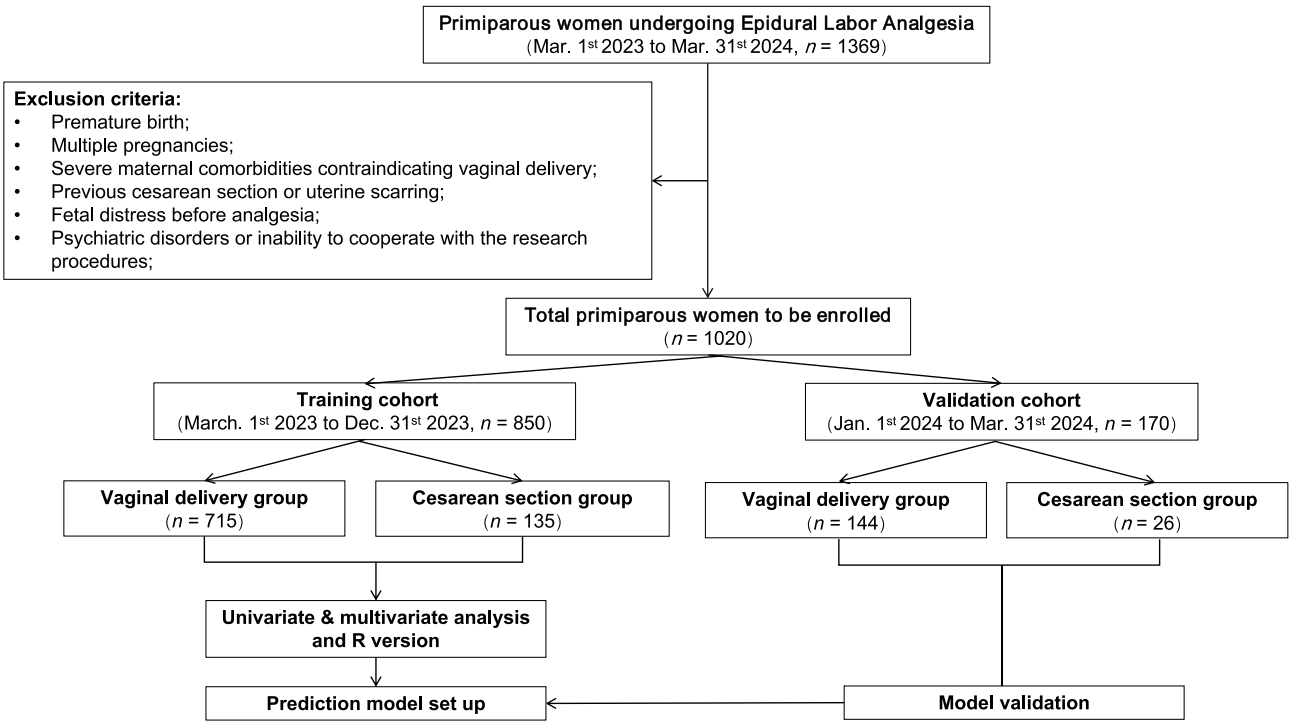

Figure 1 Study flow diagram.

multicollinearity were included in the multivariable logistic regression model to identify independent predictors and construct the final prediction model. Based on the final multivariable logistic regression model, a nomogram was constructed to provide an intuitive graphical representation of the prediction model for individualized risk estimation. Model discrimination was evaluated using the receiver operating characteristic (ROC) curve, and calibration was assessed using the Hosmer–Lemeshow goodness-of-fit test.

Validation was subsequently performed. A calibration curve was generated to assess the agreement between predicted and observed probabilities. Decision curve analysis (DCA) was used to quantify the net clinical benefit of the prediction model across a range of threshold probabilities. All statistical tests were two-sided, and a $P < 0.05$ was considered statistically significant.

Results

Baseline Characteristics of the Training and Validation Cohorts

Baseline characteristics of the training and validation cohorts are presented in Table 2. The two cohorts were comparable in maternal age, height, body mass index, gestational age, estimated fetal weight, fetal heart rate status, use of oxytocin, and amniotic fluid characteristics ($P > 0.05$). Differences were observed in intrapartum temperature distribution and pregnancy

Table 2 Baseline Characteristics of the Training and Validation Cohorts

		Training Cohort (n = 850)	Validation Cohort (n = 170)	P-value
Maternal age (years)		27.96 ± 3.04	27.92 ± 2.97	0.873
Height (cm)		162.52 ± 5.08	162.42 ± 4.63	0.796
BMI (kg/m^2)		27.14 ± 5.08	26.90 ± 3.21	0.380
Gestational age (weeks)		39.41 ± 1.01	39.65 ± 0.91	0.917
Estimated fetal weight (g)		3342.02 ± 385.96	3325.88 ± 378.26	0.613
Cervical dilation at epidural placement (cm)		0.98 ± 0.88	0.98 ± 0.89	0.802
Duration of epidural labor analgesia (h)		8.74 ± 5.48	8.00 ± 4.73	0.013
Intrapartum temperature	< 37.5°C	651 (76.6%)	108 (63.5%)	0.001
	37.5–37.9°C	179 (21.1%)	58 (34.1%)	
	≥ 38.0°C	20 (2.4%)	4 (2.4%)	
Pregnancy complications	Yes	531 (62.5%)	49 (28.8%)	0.031
	No	319 (37.5%)	121 (71.2%)	
Amniotic fluid characteristics	Clear	697 (82.0%)	139 (81.8%)	0.942
	Meconium-stained	153 (18.0%)	31 (18.2%)	
Fetal heart rate status	Normal	684 (80.5%)	137 (80.6%)	0.972
	Non-normal	166 (19.5%)	33 (19.4%)	
Use of oxytocin	Yes	536 (63.1%)	107 (62.9%)	0.977
	No	314 (36.9%)	63 (37.1%)	
Rupture of membranes during the first stage of labor	No rupture	341 (40.1%)	54 (31.8%)	0.095
	Spontaneous rupture of membranes	137 (16.1%)	35 (20.6%)	
	Artificial rupture of membranes	372 (43.8%)	81 (47.6%)	

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complications ($P < 0.05$). The duration of epidural labor analgesia also differed between the cohorts ($P = 0.013$), whereas the distribution of rupture of membranes during the first stage of labor did not differ significantly ($P = 0.095$).

Univariate Analysis

Among the 850 primiparous women who received epidural labor analgesia in the training cohort, 135 (15.9%) converted to cesarean section and 715 (84.1%) delivered vaginally. All cesarean conversions occurred during the first stage of labor. Participants were therefore categorized into the vaginal delivery group (n = 715) and the cesarean section group (n = 135). Univariate analysis showed that maternal age, cervical dilation at epidural placement, duration of epidural labor analgesia, intrapartum temperature, amniotic fluid characteristics, fetal heart rate status, use of oxytocin, and rupture of membranes during the first stage of labor were significantly associated with conversion to cesarean section ($P < 0.05$). The detailed clinical characteristics of the two groups are summarized in Table 3.

The eight variables identified as significant in the univariate analysis were subsequently assessed for multicollinearity. The VIF values for all variables were less than 5, indicating no evidence of multicollinearity among the predictors.

Table 3 Comparison of Clinical Characteristics Between the Vaginal Delivery and Cesarean Section Groups in the Training Cohort

		Vaginal Delivery Group (n = 715)	Cesarean Section Group (n = 135)	χ^2/t	*P*-value
Maternal age (years)		27.88 ± 2.87	28.67 ± 3.34	−2.833	0.007
Height (cm)		162.85 ± 5.00	160.71 ± 5.14	4.539	0.938
BMI (kg/m^2)		26.97 ± 3.33	28.05 ± 3.62	−3.408	0.445
Gestational age (weeks)		39.60 ± 1.01	39.90 ± 0.85	−3.264	0.259
Estimated fetal weight (g)		3325.90 ± 381.84	3442.22 ± 369.64	−3.263	0.595
Cervical dilation at epidural placement (cm)		2.04 ± 0.37	1.98 ± 0.26	1.834	0.004
Duration of epidural labor analgesia (h)		8.56 ± 5.31	9.77 ± 6.19	−2.366	0.039
Intrapartum temperature	< 37.5°C	563	88	74.344	< 0.001
	37.5–37.9°C	149	30		
	≥ 38.0°C	3	17		
Pregnancy complications	Yes	446	87	0.207	0.649
	No	269	48		
Amniotic fluid characteristics	Clear	606	90	25.046	< 0.001
	Meconium-stained	109	45		
Fetal heart rate status	Normal	614	68	90.264	< 0.001
	Non-normal	101	67		
Use of oxytocin	Yes	433	105	14.491	< 0.001
	No	282	30		
Rupture of membranes during the first stage of labor	No rupture	304	37	30.843	< 0.001
	Spontaneous rupture of membranes	127	10		
	Artificial rupture of membranes	284	88		

Multivariable Logistic Regression Analyses

Based on the univariate analysis, eight variables were initially included in the multivariable logistic regression model. After the multivariable analysis, cervical dilation at epidural placement and the duration of epidural labor analgesia were excluded ($P > 0.05$). As shown in Table 4, the final model retained six significant predictors of conversion to cesarean section: maternal age, intrapartum temperature, amniotic fluid characteristics, fetal heart rate status, use of oxytocin, and rupture of membranes during the first stage of labor ($P < 0.05$). Among these predictors, maternal age and fetal heart rate status were identified as independent risk factors (OR >1, $P < 0.05$). The final multivariable logistic regression model was further visualized as a nomogram to facilitate individualized risk estimation.

Development of the Risk Prediction Nomogram

Based on the final multivariable logistic regression model, a risk prediction nomogram was developed to estimate the probability of conversion to cesarean section among primiparous women receiving epidural labor analgesia. The nomogram incorporated the independent predictors identified in the multivariable analysis, including maternal age, intrapartum temperature, amniotic fluid characteristics, fetal heart rate status, use of oxytocin, and rupture of membranes during the first stage of labor (Figure 2).

In the nomogram, each predictor corresponds to a specific point value according to its relative contribution to the model. The total score is obtained by summing the points for all predictors, and the corresponding probability of conversion to cesarean section can be determined by projecting the total score onto the probability scale. Higher total points indicate a higher predicted risk of conversion to cesarean section.

Model Construction and Predictive Performance

Based on the results of the logistic regression analysis, the Hosmer-Lemeshow goodness-of-fit test was performed to assess the model calibration. The test yielded a *P*-value of 0.916 ($P > 0.05$), indicating good agreement between the predicted and observed outcomes and suggesting that the model was well calibrated.

The model's discriminatory performance was evaluated using the receiver operating characteristic (ROC) curve. The area under the ROC curve (AUC) was 0.810 (95% CI: 0.768–0.851, $P < 0.001$), demonstrating good predictive accuracy in distinguishing primiparous women who converted to cesarean section from those who delivered vaginally. The Youden index was 0.428, with a sensitivity of 0.822, and a specificity of 0.606, indicating good overall discriminatory ability (Figure 3).

Table 4 Multivariable Logistic Regression Analyses

		B	SE	Wald	*df*	*P*	OR	95% CI
Maternal age		0.100	0.036	7.795	1	0.005	1.105	[1.030, 1.186]
Intrapartum temperature	37.5–37.9°C	−3.603	0.681	28.008	2	0.001	0.027	[0.007, 0.103]
	≥ 38.0°C	−3.463	0.702	24.298	1	0.001	0.031	[0.008, 0.124]
Amniotic fluid characteristics		−0.760	0.250	9.247	1	0.002	0.468	[0.287, 0.763]
Fetal heart rate status		1.858	0.225	67.963	1	0.001	6.413	[4.123, 9.976]
Use of oxytocin		−0.629	0.262	5.772	1	0.016	0.533	[0.319, 0.891]
Rupture of membranes during the first stage of labor	Spontaneous rupture of membranes	−0.642	0.251	6.519	1	0.011	0.526	[0.322, 0.861]
	Artificial rupture of membranes	−1.132	0.380	8.885	1	0.003	0.322	[0.153, 0.679]
Constant		−1.115	1.206	0.855	1	0.355	0.328	

Notes: Reference categories: intrapartum temperature < 37.5°C; clear amniotic fluid; normal fetal heart rate status; no oxytocin use; no rupture of membranes during the first stage of labor.
Abbreviations: SE, standard error; OR, odds ratio; CI, confidence interval.

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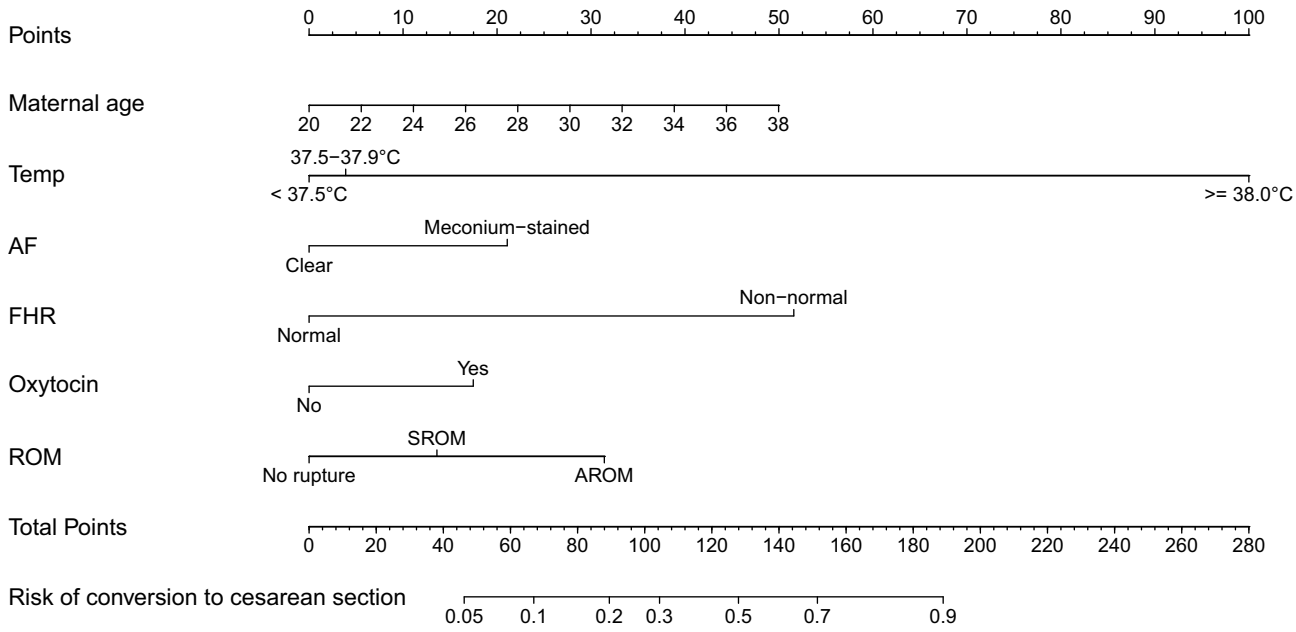

Figure 2 Nomogram for predicting conversion to cesarean section in primiparous women receiving epidural labor analgesia.
Abbreviations: Temp, intrapartum temperature; AF, amniotic fluid characteristics; FHR, fetal heart rate status; Oxytocin, use of oxytocin; ROM, rupture of membranes during the first stage of labor; SROM, spontaneous rupture of membranes; AROM, artificial rupture of membranes.

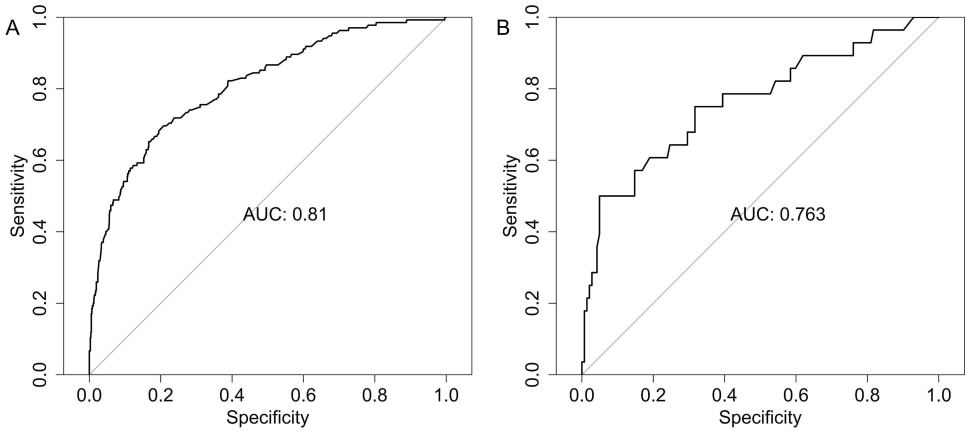

Figure 3 Receiver operating characteristic curves of the prediction model for conversion to cesarean section. (**A**) training cohort; (**B**) validation cohort.

Validation of the Clinical Application Effect

For validation of the prediction model, 170 primiparous women were included in the validation cohort, among whom 26 (15.3%) converted to cesarean section. The model achieved a sensitivity of 0.786 and a specificity of 0.592 (Figure 3). The AUC for the validation cohort was 0.763 (95% CI: 0.655–0.871, $P < 0.001$), demonstrating good discriminatory ability.

The calibration curves showed that the predicted probabilities were reasonably well aligned with the observed outcomes. In both the training and validation cohorts, the calibration plots approached the ideal 45° reference line (Figure 4), suggesting good agreement between predicted and actual risks and indicating satisfactory model calibration.

Decision curve analysis demonstrated that the prediction model provided a positive net benefit across a range of clinically relevant threshold probabilities in both the training and validation cohorts (Figure 5). Compared with the "treat all" and "treat none" strategies, the model yielded higher net benefit within this range, indicating potential clinical usefulness for decision-making regarding conversion to cesarean section.

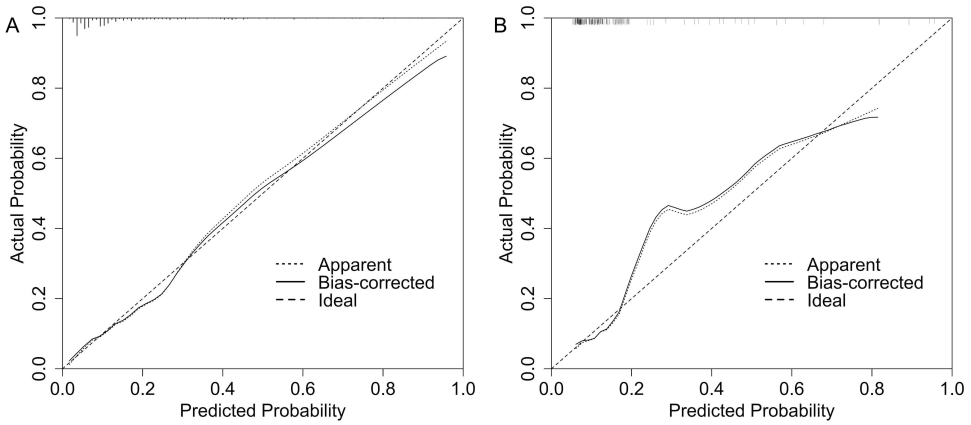

Figure 4 Calibration curves of the prediction model for conversion to cesarean section. (**A**) training cohort; (**B**) validation cohort.

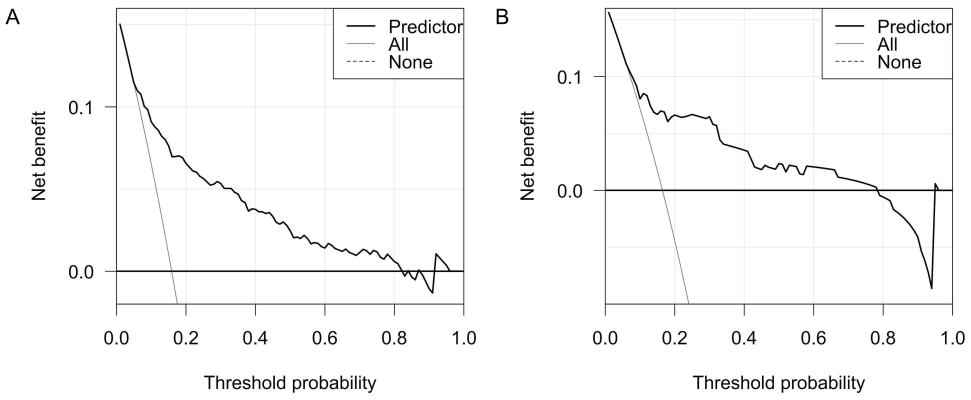

Figure 5 Decision curve analysis of the prediction model for conversion to cesarean section. (**A**) training cohort; (**B**) validation cohort.

Discussion

This study examined factors associated with intrapartum cesarean conversion among primiparous women receiving epidural labor analgesia and developed a prediction model to estimate this risk. Epidural labor analgesia defined the study cohort and was not evaluated as an independent exposure variable. Therefore, the findings should be interpreted as predictors of cesarean conversion within this cohort, rather than as evidence of the effect of epidural analgesia on cesarean delivery. The results showed that maternal age, intrapartum temperature, amniotic fluid characteristics, fetal heart rate status, use of oxytocin, and rupture of membranes during the first stage of labor were significant predictors of cesarean conversion. The prediction model demonstrated good discriminatory performance, with an area under the curve (AUC) of 0.810, a sensitivity of 0.822, and a specificity of 0.606, indicating satisfactory validity and accuracy. These findings suggest that the model may serve as an early warning tool in clinical practice to help clinicians identify women at increased risk of cesarean conversion and support timely monitoring and appropriate intrapartum management.

Maternal age emerged as an important predictor in our model. This finding is consistent with previous prediction model studies that have reported a higher likelihood of cesarean delivery following labor induction as maternal age increases.[19,20] In China, the proportion of older primiparous women has continued to rise in recent years,[21] highlighting the clinical relevance of maternal age in obstetric practice. In addition, several large epidemiologic studies have shown that advanced maternal age is associated with increased obstetric and neonatal risks as well as greater psychological stress.[22–24] By incorporating maternal age into a multivariable prediction framework tailored to primiparous women receiving epidural labor analgesia, our study provides quantitative evidence that maternal age contributes meaningfully to individualized intrapartum risk assessment. This information may help clinicians identify women who would benefit from closer monitoring or earlier intervention during labor.

Fetal heart rate status was classified as normal (Category I) or non-normal (Category II–III). Non-normal FHR status emerged as one of the strongest predictors in our model, with women in this group having more than a sixfold increased likelihood of conversion to cesarean section. This finding is consistent with previous studies showing that non-reassuring fetal heart rate patterns or suspected intrapartum fetal compromise are associated with an increased likelihood of operative or cesarean delivery.[25,26] According to current international guidelines, FHR status is interpreted using a three-tier classification system (Category I–III).[27] Non-normal FHR status may arise from multiple mechanisms. On the one hand, epidural labor analgesia can induce sympathetic blockade and maternal hypotension, potentially reducing uteroplacental perfusion and contributing to transient FHR changes.[28,29] On the other hand, persistent non-normal FHR patterns may indicate possible fetal compromise, representing early signs of impaired oxygenation or altered autonomic regulation.[30,31] In such cases, timely clinical assessment and intervention may be required to prevent further deterioration. Integrating FHR status into a multivariable prediction model provides an effective approach to identifying women at high risk of cesarean conversion during epidural labor analgesia, supporting closer intrapartum surveillance and timely intrapartum management.

In our model, intrapartum temperature was analyzed as a three-level categorical variable. Both moderate temperature elevation (37.5–37.9°C) and fever (≥ 38.0°C) were associated with odds ratios below 1 compared with the reference group (< 37.5°C). This unexpected inverse association should be interpreted cautiously and should not be considered evidence that elevated intrapartum temperature has a true protective effect against cesarean conversion. Instead, it may be partly explained by institution-specific intrapartum management patterns, early interventions after temperature elevation, differences in labor progression, and residual confounding. At our institution, clinical management is initiated once maternal temperature reaches 37.5°C, including intravenous fluid administration, antipyretic treatment, and enhanced electronic fetal monitoring. These interventions may help stabilize maternal-fetal status and prevent further deterioration in some cases. In addition, non-infectious epidural-related maternal fever is thought to involve sterile inflammatory activation and altered thermoregulatory control during epidural analgesia, leading to transient temperature elevation without necessarily compromising fetal oxygenation.[32,33] In contrast, women with temperatures <37.5°C may have included those with prolonged labor or poor progress but without fever, who were more likely to require cesarean delivery for labor arrest despite normothermia. Nevertheless, maternal fever remains clinically important. Febrile parturients receiving epidural labor analgesia have been reported to show higher cesarean rates,[34] and chorioamnionitis is strongly associated with maternal fever and adverse outcomes.[35] Furthermore, intrapartum fever may trigger inflammatory pathways and alter placental microcirculation, potentially impairing fetal oxygenation.[36,37] Therefore, the observed ORs below 1 for higher temperature categories should be interpreted as model-specific associations influenced by clinical management patterns and residual confounding rather than as evidence of a protective effect. These findings highlight the importance of careful assessment for possible infection and close maternal-fetal monitoring during labor.

Oxytocin promotes prostaglandin synthesis in the decidua and amnion, which facilitates cervical ripening and strengthens myometrial contractions.[38] In clinical practice, oxytocin is often used together with artificial rupture of membranes to enhance uterine activity and support labor progress. Recent studies indicate that timely oxytocin augmentation can shorten labor duration, improve contraction efficiency, and reduce the risk of intrapartum cesarean delivery in women with delayed labor progress.[39,40] Combined oxytocin and artificial rupture of membranes strategies have also been shown to be more effective than artificial rupture of membranes alone.[41] Although earlier studies have suggested that rupture of membranes increases the risk of intrapartum fever,[42,43] our collinearity assessment showed variance inflation factor values below five for all predictors, indicating that their correlation did not introduce instability into the model. Both variables contributed independently to the prediction of cesarean conversion. In addition, use of oxytocin was associated with an adjusted odds ratio below one, consistent with evidence that timely oxytocin augmentation can improve uterine contraction efficiency, support labor progress, and lower the likelihood of cesarean conversion.

In summary, this prediction model provides a practical and evidence-based tool for early identification of primiparous women at increased risk of intrapartum cesarean conversion within an epidural labor analgesia cohort. The model uses routinely collected maternal, fetal, and intrapartum variables and could be integrated into electronic medical record systems or simple clinical tools to support risk assessment during labor and individualized care. Its use may help clinicians recognize concerning labor patterns earlier, strengthen intrapartum monitoring, and adjust management in a timely manner. Future studies should validate this model in different populations and develop accessible digital tools to support its use in everyday practice.

Limitations

This study has several limitations. First, the retrospective design may introduce potential selection bias and unmeasured confounding. Second, although all cesarean conversions occurred during the first stage of labor and no cesarean delivery was documented as being directly caused by serious anesthesia-related complications, the retrospective design limited our ability to fully assess the potential indirect effects of physiological changes related to epidural labor analgesia on labor progression and fetal status. Finally, this was a single-center study, which may limit the generalizability of the prediction model to other institutions or populations. Although the model demonstrated good performance in the validation cohort, external validation in multicenter cohorts is warranted to confirm its broader applicability. Future studies incorporating additional clinical variables and advanced modeling approaches, including machine learning techniques, may further improve predictive performance and clinical utility.

Conclusion

Maternal age, intrapartum temperature, amniotic fluid characteristics, fetal heart rate status, use of oxytocin, and rupture of membranes during the first stage of labor were identified as key predictors of intrapartum cesarean conversion among primiparous women receiving epidural labor analgesia. This study developed and validated a logistic regression prediction model for risk assessment within this specific intrapartum cohort. The model demonstrated good discrimination, calibration, and clinical utility, indicating its potential value for early warning and individualized intrapartum management. Future studies should include multicenter external validation and integration of the model into practical clinical tools to enhance its applicability.

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Disclosure

The authors report no conflicts of interest in this work.

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