

A predictive model for caesarean section during labour in women with pre-eclampsia

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Research Article

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Abstract

Objective: To investigate the risk factors for caesarean section (CS) during delivery in patients with pre-eclampsia.

Methods: A retrospective cohort study was conducted at Gansu Provincial People's Hospital, a Grade A tertiary maternity centre, all women with pre-eclampsia who underwent trial of labour between 2005 and 2025 were identified. In accordance with inclusion and exclusion criteria, key data—including demographic characteristics and clinical monitoring indicators—were collected. Univariate and multivariate analyses were performed to identify factors associated with CD, and a scoring model was developed using receiver operating characteristic (ROC) curves to predict the need for CD.

Results: A total of 1,128 women with pre-eclampsia were identified, of whom 627 were included in the study. Among these, gestational age at delivery, weight gain during pregnancy, neonatal birth weight, preterm birth, oxytocin-induced labour, use of analgesic techniques, intrapartum fever, birth weight $\geq 2,500$ g, number of previous deliveries ≥ 2 , and 24-hour urine protein > 0.3 g/24 h were all identified as risk factors for intrapartum caesarean section. Subsequently, we developed a predictive scoring model for intrapartum caesarean section in women with pre-eclampsia; this model had an AUC of 0.601, demonstrating predictive efficacy (95% confidence interval 0.556–0.646, $p < 0.001$).

Conclusion: The occurrence of caesarean section during delivery in patients with pre-eclampsia is associated with maternal and intrapartum factors. A predictive model based on these factors can assist in identifying high-risk patients and provide a basis for formulating delivery plans.

Introduction

The timing and mode of delivery for women with pre-eclampsia (PE) remain a subject of debate. Guidelines frequently recommend elective caesarean section in cases of suspected foetal growth restriction or other significant risk factors^[1]. Studies have found that, compared with other low-risk pregnancies, women with PE have a higher incidence of non-elective caesarean section^[2] and an increased risk of postoperative complications^[3]. It is therefore crucial to develop an effective and reliable tool to assist clinicians and patients in making informed decisions, thereby reducing maternal and neonatal morbidity.

Methods

We conducted a retrospective cohort study of singleton pregnant women with pre-eclampsia who underwent trial of labour at Gansu Provincial People's Hospital, a Grade A Level 3 maternity centre, between 2005 and 2025. Exclusion criteria included elective caesarean section, pre-pregnancy hypertension, gestational hypertension, a history of caesarean section, and non-viable foetuses. We divided the women into two groups based on mode of delivery: those who underwent caesarean section during labour (the study group) and those who had a successful vaginal delivery (the control group). By

comparing the maternal and obstetric characteristics of the two groups, we sought to identify risk factors for caesarean section.

Data collection

We used the Jiahe Electronic Medical Record System to record the following demographic and obstetric variables, including: maternal age, pre-pregnancy body mass index (BMI), blood pressure, gestational age at delivery, parity, mode of conception (spontaneous conception versus in vitro fertilisation [IVF]), gestational diabetes, foetal growth restriction, amniotic fluid volume, anaemia, 24-hour urine protein quantification, placental abruption, intrahepatic cholestasis of pregnancy, hypoproteinaemia, mode of labour onset (spontaneous labour versus medically induced labour), use of oxytocin during labour, epidural anaesthesia, fever $\geq 38^{\circ}\text{C}$ during labour, meconium-stained amniotic fluid, and neonatal birth weight.

Definitions

We have adopted the inclusion criteria set out in the 10th edition of 'Obstetrics and Gynaecology' published by People's Medical Publishing House: systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg occurring after 20 weeks of gestation, accompanied by random urine protein (++) , or a urine protein-to-creatinine ratio ≥ 0.3 , or 24-hour urine protein ≥ 0.3 g; or, in the absence of proteinuria, the presence of any one of the following: 1) Thrombocytopenia (platelet count $< 100 \times 10^9/\text{L}$); 2) Impaired liver function (serum transaminase levels $\geq$ twice the upper limit of normal); 3) Impaired renal function (serum creatinine level > 1.1 mg/dl or $\geq$ twice the upper limit of normal); 4) Pulmonary oedema; 5) New-onset headache (unresponsive to medication and not attributable to other conditions); 6) Visual disturbances.

Statistical analysis

We first performed univariate analyses on the data to identify differences between groups. For continuous variables, we used the two-tailed unpaired Student's t-test or the Mann-Whitney U test (when the variables did not follow a normal distribution) to assess statistical significance; for categorical variables, we used the chi-square test or Fisher's exact test. We subsequently constructed multivariate logistic regression models, controlling for variables associated with statistical differences between groups, to assess the impact of independent variables on the outcome.

Thereafter, receiver operating characteristic (ROC) curve analysis was used to determine the cut-off value, sensitivity and specificity for predicting the risk of caesarean section during labour. The area under the ROC curve (AUC) was used to assess the model's discriminatory ability, risk factors and scoring. Each predictor in the final model was assigned a point value based on its odds ratio (OR), which were then summed to form an overall risk score. Points were calculated as the nearest integer to the OR of the

selected predictor. Data analysis was performed using SPSS version 31.0, and a p-value < 0.05 was considered statistically significant.

Results

During the study period, a total of 53,527 women gave birth at our centre; of these, 1,128 (2.1%) were diagnosed with PE, and 628 (55.67%) met the inclusion criteria. 552 women (87.9%) underwent caesarean section during labour (study group), whilst 76 women (12.1%) delivered vaginally (control group).

Women in the intrapartum CD group had higher blood pressure, body mass index (BMI), parity and weight gain during pregnancy, whilst their gestational age at delivery and neonatal birth weight were lower. Furthermore, women in the study group exhibited increased rates of 24-hour urine protein quantification, foetal growth restriction and pathological findings associated with preterm birth. Regarding labour characteristics, the intrapartum CD group had higher rates of oxytocin induction, regional epidural anaesthesia, intrapartum fever and neonatal birth weight > 2500g, as shown in Table 1; the incidence of caesarean section indications is shown in Fig. 1.

Table 1
Maternal and labour characteristics of the study group and the control group

Characteristic	Study group (n = 552)	Control group (n = 76)	p value
Reproductive age, mean (SD)	28.70(±5.56)	28.00(±4.59)	0.291
Gestational age at delivery, IQR (25%-75%)	37±(35–39)	39±(37–39)	<0.05
systolic blood pressure, IQR (25%-75%)	150±(140–164)	150±(140–164)	<0.05
diastolic blood pressure, IQR (25%-75%)	100±(92–110)	100±(89–110)	<0.05
Weight gain during pregnancy, IQR (25%-75%)	15±(13–19)	150±(12–17)	<0.05
BMI, IQR (25%-75%)	29.5±(27.1–32)	29±(26.6–32)	0.191
Birth weight of newborns, IQR (25%-75%)	2600±(1900–3077)	2950±(2600–3300)	<0.05
BMI ≥ 30,n (%)	249 (45.1%)	30 (39.5%)	0.4
Birth weight ≥ 2500 g,n (%)	311 (60%)	62 (81.6%)	<0.05
Premature birth,n (%)	234 (42.4%)	15 (19.7%)	<0.05
previous births ≥ 2,n (%)	376 (68.1%)	74 (97.4%)	<0.05
IVF status,n (%)	102 (18.5%)	17 (22.4%)	0.385
Abnormal amniotic fluid volume,n (%)	182 (33%)	27 (35.5%)	0.665
Gestational diabetes,n (%)	143 (25.9%)	22 (28.9%)	0.527
Fetal growth restriction,n (%)	181 (32.8%)	15 (19.7%)	<0.05
anaemia,n (%)	301 (54.5%)	33 (43.4%)	0.086
Abnormal 24-hour urine protein levels,n (%)	299 (54.2%)	30 (39.5%)	<0.05
Intrahepatic cholestasis of pregnancy,n (%)	125 (22.6%)	12 (15.8%)	0.191
Hypoproteinaemia,n (%)	368 (66.7%)	51 (67.1%)	0.818
Vaginal delivery,n (%)	69 (12.5%)	12 (15.8%)	0.4
Induction of labour with oxytocin,n (%)	103 (18.7%)	37 (48.7%)	<0.05
Use of analgesic techniques,n (%)	105 (19%)	40 (62.6%)	<0.05
Fever during childbirth,n (%)	68 (12.3%)	18 (23.7%)	<0.05
Amniotic fluid contamination,n (%)	190 (34.4%)	18 (23.7%)	0.079

In a multivariate analysis assessing risk factors for intrapartum caesarean section (Table 2), several variables were found to be independently associated with intrapartum caesarean section, including gestational age at delivery, weight gain during pregnancy, neonatal birth weight, preterm birth, induction of labour with oxytocin, use of analgesic techniques, intrapartum fever, birth weight ≥ 2500 g, parity ≥ 2 , and abnormal 24-hour urine protein levels.

Table 2
Multivariate analysis

Characteristic	OR	95% CI	p value
Gestational age at delivery	0.84	0.74–0.95	<0.05
systolic blood pressure	1.01	0.99–1.02	0.577
diastolic blood pressure	1.01	0.99–1.03	0.306
Weight gain during pregnancy	1.08	1.02–1.15	<0.05
Birth weight of newborns	1.00	0.99–1.00	<0.05
Premature birth	0.314	0.161–0.612	<0.05
FGR	0.598	0.308–1.162	0.129
Induction of labour with or without oxytocin	3.626	2.106–6.241	<0.05
Whether analgesic techniques were used	4.451	2.593–7.639	<0.05
Fever during labour	2.751	1.425–5.311	<0.05
Birth weight ≥ 2500 g	3.696	1.986–6.878	<0.05
previous births ≥ 2	0.029	0.004–0.209	<0.05
Abnormal 24-hour urine protein levels	0.564	0.345–0.922	<0.05

- We developed a risk scoring system based on multivariate logistic regression to estimate the likelihood of CD during labour in women with PE (Table 3). Patients were divided into three risk groups, revealing a clear dose-response relationship: Group A (score ≤ 4) had an incidence of intrapartum CD of 36.2%, Group B (score 4–7) had an incidence of 27.76%, and Group C (score ≥ 7) had an incidence of 36.04%. We subsequently evaluated the model's performance using a receiver operating characteristic (ROC) curve (Fig. 2), yielding an area under the curve (AUC) of 0.601 (95% CI, 0.556–0.646).

Table 3
Predictive risk scores for CD during labour in women with PE

Characteristic	OR	95% CI	p value	β	score
Premature birth	0.314	0.161–0.612	<0.05	1.276	2/0
Induction of labour with or without oxytocin	3.626	2.106–6.241	<0.05	-1.28	2/0
Whether analgesic techniques were used	4.451	2.593–7.639	<0.05	-1.507	3/0
Fever during labour	2.751	1.425–5.311	<0.05	-1.015	2/0
Birth weight $\geq$ 2500 g	3.696	1.986–6.878	<0.05	1.307	2/0
previous births $\geq$ 2	0.029	0.004–0.209	<0.05	-3.545	6/0
Abnormal 24-hour urine protein levels	0.564	0.345–0.922	<0.05	-0.573	1/0

Discussion

Researchers have developed a personalised risk scoring model using readily available clinical and laboratory variables, designed to identify individuals at the highest or lowest risk of complications within 48 hours of admission, thereby optimising management and enabling timely intervention to prevent serious adverse outcomes. The model incorporates parameters such as systolic blood pressure, platelet count, serum creatinine, aspartate transaminase (AST), clinical symptoms (such as headache and visual disturbances), gestational age at admission, foetal growth restriction, and maternal antihypertensive therapy [4]. The model's ability to predict adverse outcomes has been validated across multiple geographical regions, including Canada, the United States, Finland, the United Kingdom, Brazil, Mexico and India^[5].

An early gestational age at admission or delivery is a significant predictor of caesarean section at delivery. In cases of severe pre-eclampsia, measures to induce preterm delivery are often required to reduce risks to both mother and baby. Although pathological manifestations associated with preterm delivery are not direct indications for surgery, they reflect underlying complications that frequently lead to preterm delivery^[6]; in such cases, the mode of delivery may be influenced by factors such as foetal presentation, maternal condition and the progress of labour. Furthermore, higher weight gain during pregnancy is not only a known risk factor for pre-eclampsia but is also associated with an increased probability of caesarean section at delivery. Machine learning models have been developed specifically to predict caesarean section in obese pregnant women, highlighting the importance of this factor^[7].

As a diagnostic criterion for pre-eclampsia, elevated 24-hour urine protein levels reflect the extent of renal involvement^[8] and may indicate a more severe condition, thereby influencing the decision to perform a caesarean section. In the absence of spontaneous labour, induction is usually required; it is more common to use oxytocin induction to initiate or augment contractions. Although induction may

facilitate vaginal delivery, induction failure or inadequate cervical response may lead to an intrapartum caesarean section^[9].

Intra-labour fever may be a sign of amniotic cavity infection; careful selection of the mode of delivery is crucial for optimising antenatal management and minimising potential complications. By assessing patients' predictive characteristics and integrating antenatal and intrapartum features, personalised and fully informed diagnostic and treatment strategies can be proposed to improve overall patient outcomes. Future research must validate these findings and refine the predictive model to enhance its accuracy and applicability across various clinical settings. Furthermore, its effectiveness in different patient populations needs to be evaluated in subsequent studies to ensure its broader applicability and accuracy.

Declarations

Contribution Statement: Lei Kangqing was responsible for data collection, organisation and the initial drafting of the manuscript, whilst Sun Xiaotong was responsible for revising the manuscript and data processing. All authors consent to the publication of this manuscript and declare that there are no conflicts of interest.

Ethical approval and informed consent: Informed consent has been obtained from all participants in the study.

Ethical approval and informed consent: An application has been submitted to the Ethics Committee of Gansu Provincial People's Hospital; the approval number will be uploaded once the application has been processed.

Consent to publication: All authors of this article consent to its publication

Conflicts of interest: No conflicts of interest

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Figures

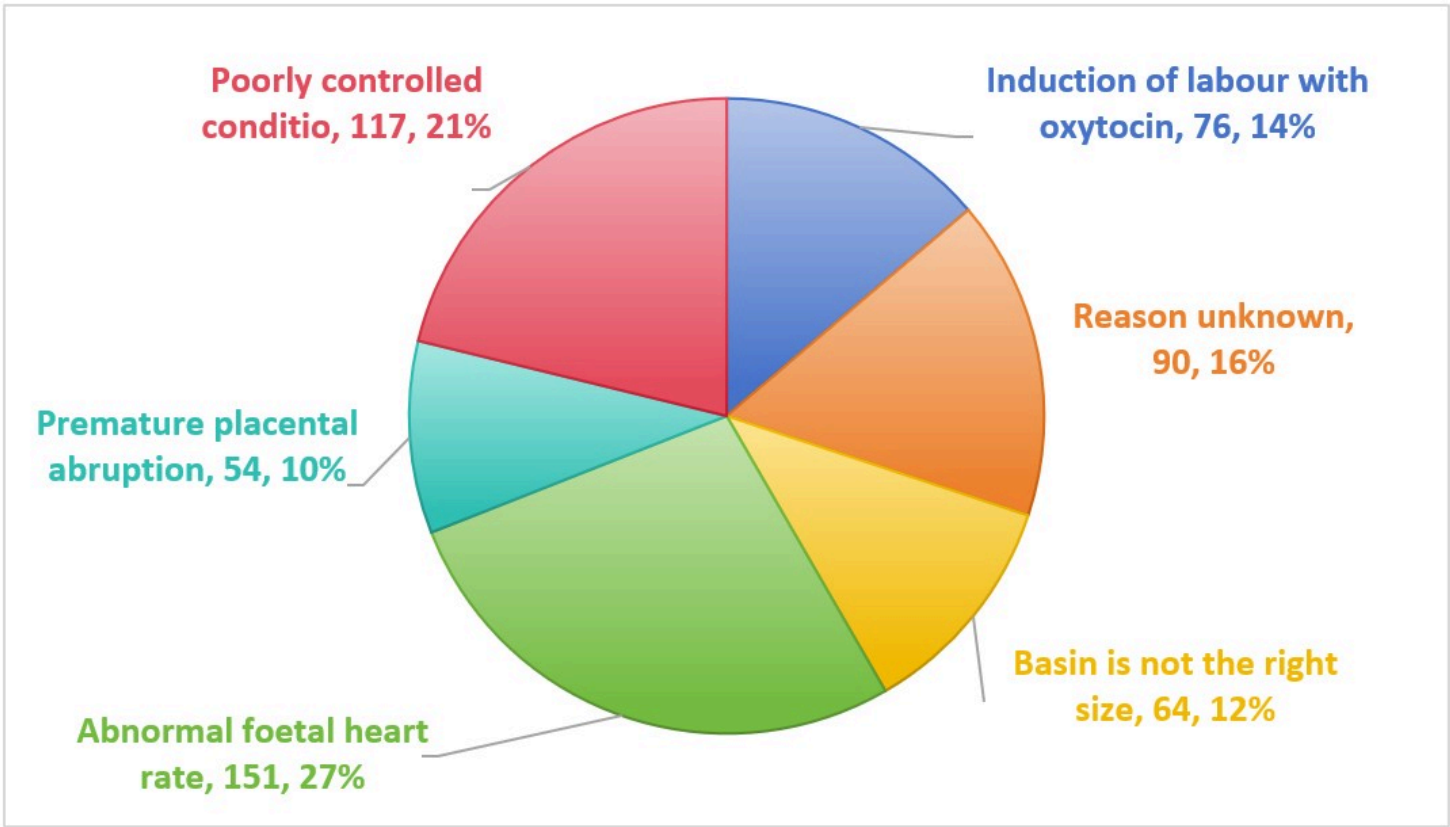


Figure 1

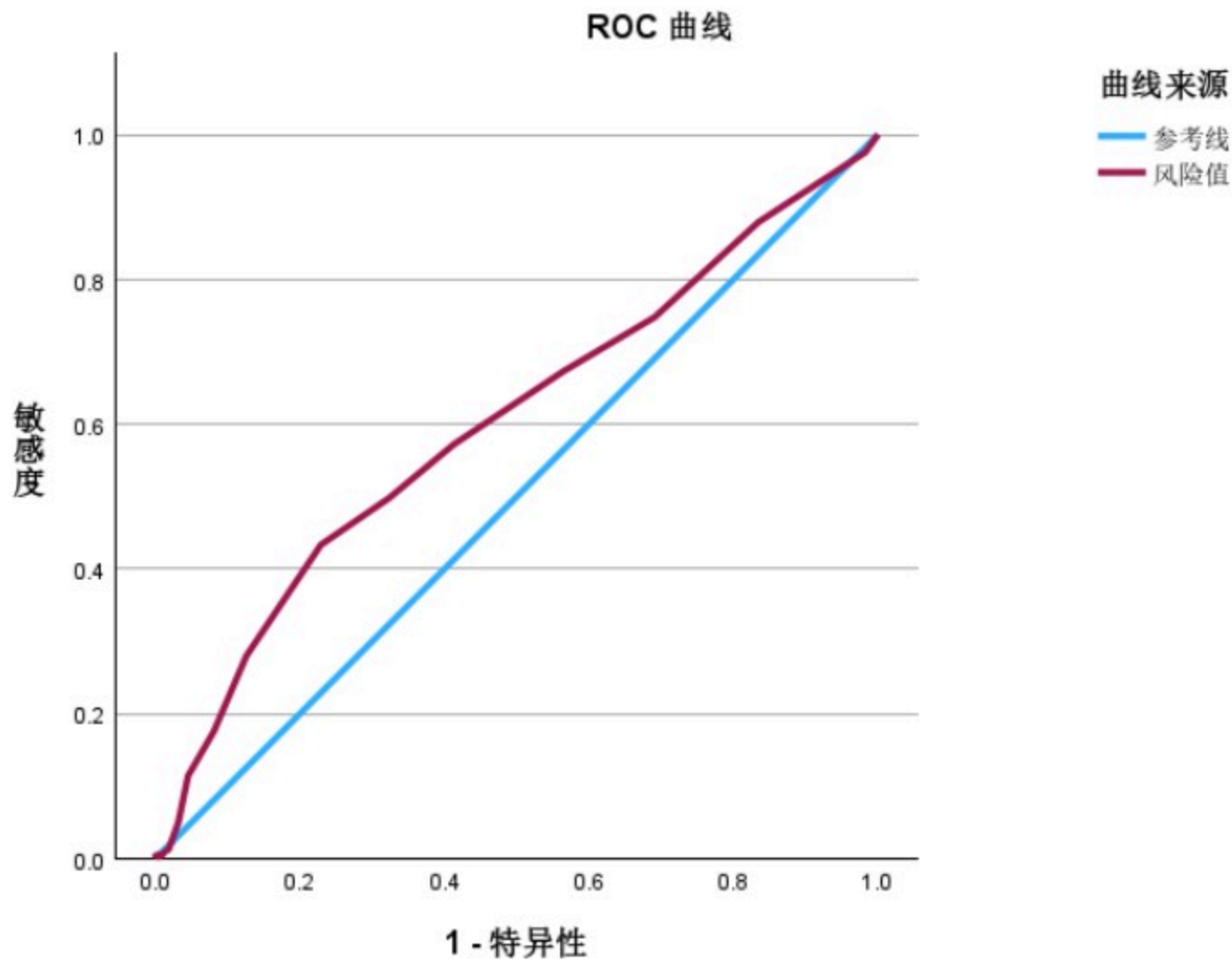


Figure 2

Receiver operating characteristic (ROC) curve for participants who underwent caesarean section during labour