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Prediction of Cesarean Delivery in Term Nulliparous Women with Dinoprostone

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ABSTRACT

Cesarean delivery after labor induction is a significant clinical concern, especially in nulliparous women with an unfavorable cervix. Early identification of patients at increased risk for cesarean section may support individualized obstetric care strategies. This study aimed to develop a predictive model for cesarean delivery among nulliparous women undergoing induction of labor with an unfavorable cervix. This retrospective cohort study included 532 nulliparous women with unfavorable cervices who underwent labor induction using a slow-release dinoprostone vaginal insert at a tertiary care center between October 2023 and January 2025. A penalized logistic regression model (PMLE) was used to identify independent predictors of cesarean delivery. Internal validation was performed using 1,000 bootstrap resamples, and a nomogram was constructed based on significant variables. The overall cesarean delivery rate was 38.0%. Multivariable analysis identified higher body mass index (BMI) (aOR: 1.095, 95% CI: 1.041–1.151; p = 0.001) and lower Bishop score (aOR: 0.828, 95% CI: 0.723–0.976; p = 0.026) as independent predictors of cesarean delivery. A nomogram was developed to estimate individualized cesarean risk, and decision curve analysis demonstrated potential clinical utility, particularly within the 15%–60% risk threshold range. This study presents a predictive nomogram to estimate cesarean delivery risk in nulliparous women undergoing labor induction with an unfavorable cervix. While further prospective validation is warranted, the model incorporating BMI and Bishop score may serve as a useful tool for future research on personalized induction strategies.

Keywords: Cesarean Section, Dinoprostone, Labor, Induced, Nomograms, Parity

Introduction

The initiation and progression of labor require significant cervical changes, including softening, effacement, and dilation. This physiological process, known as cervical ripening, is believed to occur through a complex interplay of biochemical, hormonal, and mechanical mechanisms (1, 2). In cases where the cervix is not yet favorable for labor, induction of labor (IOL) may be employed to stimulate uterine contractions through medical or mechanical interventions prior to the spontaneous onset of labor (3). One of the most critical determinants of successful IOL is the degree of cervical readiness. In clinical practice, this is most commonly assessed using the Bishop score, with scores of 6 or below indicating an unfavorable cervix (4).

Inadequate cervical ripening can result in prolonged labor and a significant increase in cesarean delivery rates, a risk that is particularly pronounced in nulliparous women (5). Various methods are utilized to promote cervical ripening and initiate labor. One such method is dinoprostone, a synthetic analogue of prostaglandin E2 (PGE2) (6, 7). The slow-release vaginal formulation of dinoprostone delivers a 10 mg dose at a constant rate of 0.3 mg per hour over a 24-hour period and offers a notable safety advantage due to its removability in cases of fetal distress (8). Moreover, dinoprostone is the only prostaglandin preparation approved by the U.S. Food and Drug Administration (FDA) for both cervical ripening and IOL (9).

A large-scale randomized controlled trial has demonstrated that planned IOL may reduce cesarean delivery rates in low-risk nulliparous women (10). Meanwhile, prostaglandin-based cervical ripening methods have been proven effective in initiating labor within 12–24 hours and expediting vaginal delivery, as supported by numerous randomized trials and meta-analyses

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(11–13). However, the effectiveness of these agents in reducing cesarean delivery rates remains a subject of debate, with no clear consensus in the literature.

To evaluate the likelihood of cesarean birth in women on slow-release dinoprostone, many prediction models have been created. There are currently few practical models that can detect nulliparous women with an unfavorable cervix who are at risk of an early emergency cesarean birth and unsuccessful labor induction. Developing a prediction model to evaluate the risk of cesarean birth in term nulliparous women undergoing dinoprostone-induced labor induction is the goal of this research.

Materials and Methods

Study Design and Participants: This retrospective cohort study was conducted in a tertiary obstetrics and gynecology clinic. Data were obtained retrospectively from the Hospital Information Management System (HBYS) for patients who underwent IOL between October 2023 and January 2025. The study was approved by the local Clinical Research Ethics Committee on February 19, 2025 (approval number: 151/2025) and was conducted in accordance with the principles of the Declaration of Helsinki. Eligible participants were nulliparous women with singleton pregnancies in cephalic presentation, without spontaneous onset of labor at admission, and with a Bishop score <6. This cutoff is widely accepted in the literature as an indicator of inadequate cervical ripening and an unfavorable cervix for IOL (14, 15). All Bishop assessments were performed via standard pelvic examination by obstetricians, and results were documented in the hospital's electronic medical system.

Data Collection and Variables: The last period was used to figure out how many weeks along the pregnancy was, and the crown-rump length (CRL) measurement from a first-trimester scan confirmed the age. Before the slow-release dinoprostone vaginal insert (Propess®, Ferring Pharmaceuticals Ltd.) was given, cardiotocography (CTG) was used to confirm a healthy baby heart rate pattern according to FIGO 2015 standards (16). All eligible cases were included regardless of obstetric risk classification. Patients were excluded if they had abnormal placentation (e.g., placenta previa or accreta), antepartum hemorrhage, fetal malformations, malpresentation, planned cesarean delivery, a history of myomectomy or other uterine surgeries, clinical contraindications to Propess® (dinoprostone) or vaginal delivery, or if labor was induced using mechanical methods or pharmacological agents other than dinoprostone. The following variables were examined: preoperative hemoglobin level, mother age, height, weight, body mass index (BMI), gestational age, estimated fetal weight, and Bishop score with its subcomponents. Delivery details, such as time and method, were also noted. Premature rupture of membranes (PROM), fetal growth restriction (FGR), preeclampsia, intrahepatic cholestasis, gestational diabetes mellitus, gestational hypertension, late-term pregnancy, and amniotic fluid status (normal, oligohydramnios, or polyhydramnios) as determined by the amniotic fluid index (AFI) were among the obstetric and clinical parameters evaluated. Birth weight and APGAR ratings at 1 and 5 minutes were recorded, among other neonatal outcomes. The study did not include cases with incomplete or inconsistent data.

Institutional Protocol for Cervical Ripening and Induction of Labor with Slow-Release Dinoprostone Vaginal Insert: A slow-release dinoprostone vaginal insert (Propess®, 10 mg) was utilized for cervical ripening. The insert was maintained in a freezer at a temperature ranging from –20 °C to –10 °C, following the manufacturer's guidelines. The procedure was conducted under sterile conditions by the attending obstetrician or designated clinical personnel, with the insert positioned in the posterior fornix. It was designed to remain in position for no more than 24 hours. Prior to administration, all patients underwent continuous monitoring via cardiotocography (CTG) for a minimum duration of one hour. The obstetrician evaluated fetal heart rate patterns and uterine contractions. After insertion, patients were instructed to remain in a supine position for a minimum of two hours, and continuous fetal monitoring was maintained throughout the insert. In cases where uterine hyperstimulation occurred—defined as more than five contractions in 10 minutes lasting over 20 minutes, or any single contraction lasting more than 2 minutes—the insert was immediately removed (17). The system was also withdrawn in the event of fetal distress, severe maternal discomfort, or upon completion of the planned maximum duration. Supportive measures such as maternal repositioning and oxygen supplementation were implemented in cases of hyperstimulation, in addition to removal of the insert.

In cases of prolonged latent phase or failure of labor progression, oxytocin administration is routinely initiated (18). In our clinic, oxytocin infusion is initiated in patients who fail to achieve cervical ripening following administration of slow-release dinoprostone, or in whom ripening is achieved but there is no cervical change and no regular uterine contractions. To minimize the risk of uterine overstimulation, a waiting period of at least 30 minutes is observed before starting oxytocin.

A cesarean delivery in the early stages of labor is the result of failed induction, which is defined as the inability to reach the active phase of labor (≥6 cm cervical dilatation) after at least 12 hours of oxytocin administration post-membrane rupture, after a slow-release dinoprostone vaginal insert has been applied. In patients who have entered the active phase of labor (≥6 cm dilation) with ruptured membranes, the arrest of labor is defined as the absence of cervical progression following the administration of a slow-release dinoprostone vaginal insert, even though the patient has had adequate uterine contractions for at least 4 hours or insufficient contractions for at least 6 hours (20).

Statistical Analysis, Predictive Model Development, and Validation: Statistical analyses and figure generation were performed using R software (version 4.5.0). The Shapiro–Wilk test was employed to assess the distribution of continuous variables. Variables that did not meet normality assumptions were compared using the Mann–Whitney U test and are presented as medians with interquartile range (IQR). Categorical variables were expressed as counts and percentages and were compared using the chi-square test or Fisher's exact test, as appropriate.

Given the retrospective design of the study, sample size adequacy was evaluated based on the number of outcome events in relation to the number of predictors included in the final model. Among the 532 nulliparous women, 202 underwent cesarean delivery, resulting in an events-per-variable (EPV) ratio of approximately 22 for the nine predictors retained in the model. This value exceeds the commonly recommended threshold of EPV ≥10–20 for reliable multivariable logistic regression and predictive modeling, indicating that the sample size was sufficient and that the risk of model overfitting was low (23).

The modeling process was conducted in two stages. In the first stage, variable selection was performed using the Least Absolute Shrinkage and Selection Operator (LASSO) regression method, implemented via the *glmnet* package in R. LASSO was selected to address potential multicollinearity among predictors and to reduce model complexity by shrinking weak coefficients toward zero (21). The optimal penalty parameter (λ) was selected using 10-fold cross-validation, and variables with non-zero coefficients at the selected λ value were retained for entry into the multivariable model. All predictors were standardized prior to model fitting to ensure comparability across variables.

In the second stage, the variables selected by LASSO were entered into a penalized logistic regression model using Firth's bias-reduced maximum likelihood estimation, implemented via the *logistf* package. This approach was selected to minimize small-sample bias and mitigate the potential effects of separation arising from sparse predictors such as gestational diabetes and preeclampsia (22). Penalized maximum likelihood estimation provides more stable coefficient estimates in logistic regression models where rare events or imbalanced predictors may otherwise lead to inflated standard errors and unreliable inference (24). Multivariable results are reported as adjusted odds ratios (aORs) with 95% confidence intervals (CIs), and regression coefficients (β) represent the relative contribution of each predictor to the model.

Model discrimination was assessed using Harrell's concordance index (C-index), which ranges from 0.5 (no discrimination) to 1.0 (perfect discrimination), with higher values indicating better discriminatory performance. Calibration was evaluated using a calibration curve to compare predicted probabilities with observed outcomes, and overall prediction accuracy was quantified using the Brier score, with lower values indicating better predictive performance. The Nagelkerke R^2 was used as a pseudo-coefficient of determination to estimate the proportion of variance in the outcome explained by the model.

Internal validation was performed using bootstrapping with 1,000 resamples via the *calibrate()* function in the *rms* package. Bootstrapping was employed to provide bias-corrected estimates of model performance and to assess robustness against overfitting by repeatedly sampling from the original dataset with replacement and refitting the model.

To facilitate individualized risk estimation, regression coefficients were normalized to a 0–100 scale and translated into a graphical nomogram. The clinical utility of the nomogram was further evaluated using Decision Curve Analysis (DCA) with the *rmda* package in R. DCA quantifies net benefit by balancing true-positive and false-positive predictions across a range of threshold probabilities. It compares the model's performance with default strategies of treating all or none of the patients. A higher net benefit over clinically relevant thresholds indicates superior clinical decision support.

Results

The study included 532 nulliparous women. Of the total, 330 (62.00%) experienced vaginal delivery, whereas 202 (38.00%) underwent cesarean delivery. In the cohort of 202 cesarean cases, the predominant indication was non-reassuring fetal status after cervical ripening, noted in 84 patients (41.58%). Subsequently, there were 37 cases of failed induction (18.32%), 30 instances of non-reassuring fetal status prior to cervical ripening (14.85%), and 24 occurrences of labor arrest (11.88%). Fifteen cases (7.43%) of cesarean deliveries were conducted for alternative indications.

When comparing the clinical and maternal features of the vaginal and cesarean birth groups, the cesarean group had substantially higher mother height ($p = 0.009$), weight ($p = 0.001$), and BMI ($p = 0.001$). The group that had a cesarean section had a significantly lower Bishop score ($p = 0.001$). While preeclampsia ($p = 0.031$), gestational diabetes ($p = 0.031$), and cholestasis ($p = 0.031$) were more common in the cesarean group, PROM was more common in the vaginal birth group ($p = 0.011$). For the remaining factors, there were no statistically significant differences between the groups. Results are shown in Table 1.

The penalized logistic regression model for predicting cesarean delivery identified BMI and Bishop score as significant predictors. Each one-unit increase in BMI correlated with a 9.5% rise in the risk of cesarean delivery (aOR: 1.095, 95% CI: 1.041–1.151; $p = 0.001$). Conversely, each one-point increase in Bishop score was linked to a 17.2% reduction in the risk of cesarean delivery (aOR: 0.828, 95% CI: 0.723–0.976; $p = 0.026$). Other variables failed to achieve statistical significance. Model discrimination was assessed using a C-index of 0.661, a Brier score of 0.216, and a Nagelkerke R^2 of 0.111. Results are presented in Table 2.

The predicted probability of cesarean delivery for an individual patient can be visually estimated by calculating the total score derived from the contribution of each variable (Figure 1).

A nomogram designed to predict the likelihood of cesarean delivery in nulliparous women undergoing labor induction with a slow-release dinoprostone vaginal insert was developed in this study. Although it was not implemented in routine clinical practice during the study period, the nomogram facilitates individualized risk assessment based on the clinical variables incorporated into the model.

As an illustrative example, a 25-year-old patient without preeclampsia, gestational diabetes, hypertension, or fetal growth restriction had an age-related score of 18 points. A height of 160 cm corresponded to 32 points, a BMI of 30 kg/m² to 38 points, the presence of PROM to −8 points, and a Bishop score of 1 to 42 points.

The aggregate of these values resulted in a total nomogram score of 122 points, which correlates to an estimated probability of cesarean delivery of approximately 70%.

Figure 2 shows the relative contribution of each variable in the PMLE model.

The calibration and clinical applicability of the developed model were evaluated using multiple approaches. Examination of the calibration curve demonstrated strong agreement between predicted and observed probabilities of cesarean delivery, with the bias-corrected curve closely following the ideal reference line (Figure 3).

In the DCA conducted to explore the model's potential clinical benefit, the nomogram demonstrated a higher net benefit compared to both the "treat all" and "treat none" strategies across a broad range of risk thresholds, particularly between 15% and 60% (Figure 4).

The 1-minute and 5-minute Apgar scores of newborns delivered via cesarean section were lower, and the differences were statistically significant ($p=0.001$). Furthermore, the group that had cesarean delivery had a significantly greater birth weight ($p = 0.031$). Additionally, the incidence of NICU hospitalizations was significantly higher for cesarean births than for vaginal deliveries ($p = 0.004$). It is noteworthy that there was no discernible difference in newborn gender across the groups ($p = 0.279$). Table 3 presents the findings in detail.

Discussion

In this study, a predictive model was developed to estimate the likelihood of cesarean delivery in nulliparous women with an unfavorable cervix undergoing induction of labor with a slow-release dinoprostone vaginal insert. The model aims to stratify risk based on individual clinical characteristics, which may help identify patients with an increased likelihood of cesarean delivery due to factors such as fetal distress or prolonged labor. The findings indicated that higher body mass index and lower Bishop scores were independently associated with an increased risk of cesarean delivery. The resulting nomogram provides individualized risk estimates, although it has not yet been validated for clinical use.

Table 1: Comparison of Maternal and Clinical Characteristics Vaginal and Cesarean Delivery Groups

Variables	Vaginal Delivery (n=330)	Cesarean Delivery (n=202)	p-value
Age (years)	22 [20–26]	23 [20–26]	0.129
Height (cm)	165 [160–165]	162 [160–165]	0.009
Weight (kg)	72 [66–80]	75 [70–84]	0.001
BMI (kg/m²)	27.3[25.4–29.4]	28.3 [25.7–31.2]	0.001
Gestational week	40 [39–41]	40 [38–41]	0.738
Preoperative Hgb (g/dL)	12 [11–13]	12 [11–13]	0.467
Estimated fetal weight	3300 [2990–3500]	3280 [2992–3600]	0.575
Bishop score	2 [1–2]	1 [0–2]	0.001
Gestational Diabetes Mellitus	1 (0.30%)	5 (2.48%)	0.031†
Gestational Hypertension	4 (3.64%)	7 (8.42%)	0.113†
PROM	107 (32.42%)	44 (21.78%)	0.011
Cholestasis	1 (0.30%)	5 (2.48%)	0.031†
Preeclampsia	12 (3.64%)	17 (8.42%)	0.031
Late-term pregnancy	102 (30.91%)	42 (29.21%)	0.751
FGR	16 (4.85%)	18 (8.91%)	0.094
AFI			
Normal	157 (47.58%)	91 (45.05%)	0.316
Oligohydramnios	171 (51.82%)	107 (52.97%)	
Polyhydramnios	2 (0.61%)	4 (1.98%)	

Continuous variables are presented as median [interquartile range], and categorical variables as n (%). † Fisher's exact test was used when expected cell counts were small; otherwise, the Chi-square or Mann–Whitney U tests were applied as appropriate.

Abbreviations: BMI, body mass index; Hgb, hemoglobin; PROM, premature rupture of membranes; FGR, fetal growth restriction; AFI, amniotic fluid index

Table 2: Penalized Logistic Regression Analysis Predicting Cesarean Delivery

Variables	Coefficient (β)	aOR (95% CI)	p-value
Maternal age	0.03	1.030 (0.987 - 1.076)	0.173
Height	-0.028	0.972 (0.932 - 1.014)	0.174
BMI	0.09	1.095 (1.041 - 1.151)	0.001
PROM	-0.232	0.793 (0.499 - 1.259)	0.329
FGR	0.637	1.893 (0.912 – 3.927)	0.329
Bishop score	-0.189	0.828 (0.723 - 0.976)	0.026
Preeclampsia	0.387	1.474 (0.629 - 3.455)	0.369
Gestational Diabetes Mellitus	1.751	5.762 (0.652 – 50.903)	0.118
Gestational Hypertension	0.527	1.694 (0.445 – 6.445)	0.441

aORs were derived from a penalized logistic regression model. C-index indicates discrimination ability; higher values reflect better model performance. Brier score reflects overall prediction error; lower values indicate better accuracy. Likelihood Ratio Chi-square = 45.65, $p < 0.001$; Nagelkerke $R^2 = 0.111$; C-index = 0.661; Dxy = 0.323; Brier score = 0.216.

Abbreviations: aOR, adjusted odds ratio; CI, confidence interval; BMI, body mass index; PROM, premature rupture of membranes; FGR, fetal growth restriction.

Table 3: Comparison of Neonatal Outcomes According to Mode of Delivery

Variable	Vaginal Delivery (n=330)	Cesarean Delivery (n=202)	p-value
1-minute Apgar score	9 [8–9]	8 [7–8]	0.001
5-minute Apgar score	10 [9–10]	9 [9–9]	0.001
Birth weight (g)	3100 [2840–3350]	3180 [2880–3500]	0.031
Gender			
Male	152 (46.06%)	107 (52.97%)	0.279
Female	178 (53.94%)	95 (47.03%)	
NICU admission			
Yes	31 (9.39%)	37 (20.3%)	0.004
No	299 (90.61%)	165 (79.7%)	

Continuous variables are presented as median [interquartile range], and categorical variables as n (%).
Abbreviations: NICU, neonatal intensive care unit

The area in which the nomogram provides the highest potential clinical utility is among cases with a predicted cesarean delivery risk between 15% and 60%, where there is clinical uncertainty regarding the mode of delivery. In the low-risk group (<15%), the model confirms the high probability of vaginal delivery, which may offer reassurance for expectant management. In the high-risk group (>60%), clinicians are already more likely to consider cesarean delivery. However, in patients with an intermediate risk—for example, around 30%—the mode of delivery is not clearly defined. In such cases, the model may help inform clinical decision-making by supporting enhanced monitoring, patient counseling, and timely intervention if validated and implemented in practice. Therefore, this nomogram may assist in cases where clinical equipoise exists, although its role in real-time labor management requires further prospective validation (Figure 3).

In a prospective study involving 65 nulliparous women, Tseng et al. reported a vaginal delivery rate of 74.5%, and noted that all multiparous participants delivered vaginally (23). Similarly, Nguyen et al. reported a successful vaginal delivery rate of 67.6% in a study of low-risk pregnancies, highlighting that the rate of cesarean delivery was 3.8 times higher in nulliparous women compared to multiparous women (24). In the present study, which focused exclusively on nulliparous women, the vaginal delivery rate was 62%, while the cesarean delivery rate was 38%. These differences may reflect variations in patient characteristics, clinical protocols, and population risk profiles across different study settings.

Isono et al. developed a predictive model for cesarean delivery risk in nulliparous women undergoing induction of labor, specifically focusing on 392 cases diagnosed with PROM (25). In their study, the cesarean delivery rate was reported as 15.6% in the low-risk group and 33.8% in the high-risk group. Similarly, in the present study, among 151 nulliparous women with PROM, 70.87% (n = 107) had a vaginal delivery, while only 29.13% (n = 44) underwent cesarean section. PROM was found to be significantly more frequent in the vaginal delivery group compared to the cesarean group (p = 0.011).

In a retrospective study conducted in Thailand, Kamlungkuea et al. reported a cesarean delivery rate of 43.4% among women undergoing labor induction with vaginal misoprostol. Predictors of successful vaginal delivery included a maternal BMI of less than 25 kg/m² and multiparity (26). In contrast, in the present study—which focused exclusively on nulliparous women undergoing induction with slow-release dinoprostone—both BMI (aOR: 1.095, 95% CI: 1.041–1.151; p = 0.001) and Bishop score (aOR: 0.828, 95% CI: 0.723–0.976; p = 0.026) emerged as statistically significant predictors of cesarean delivery.

In a prospective, two-center study, Kamel et al. developed a predictive model for cesarean delivery in nulliparous women undergoing labor induction. Transabdominal and transperineal ultrasound assessments were performed in all cases, and multivariable analysis identified maternal age, cervical length, resting angle of progression, and occiput posterior position as significant predictors (27). In our study, only clinical variables and basic ultrasound measurements were included, without the use of specialized techniques such as transperineal ultrasound. Maternal age was not significantly associated with cesarean delivery (median 22 vs. 23 years; p = 0.111).

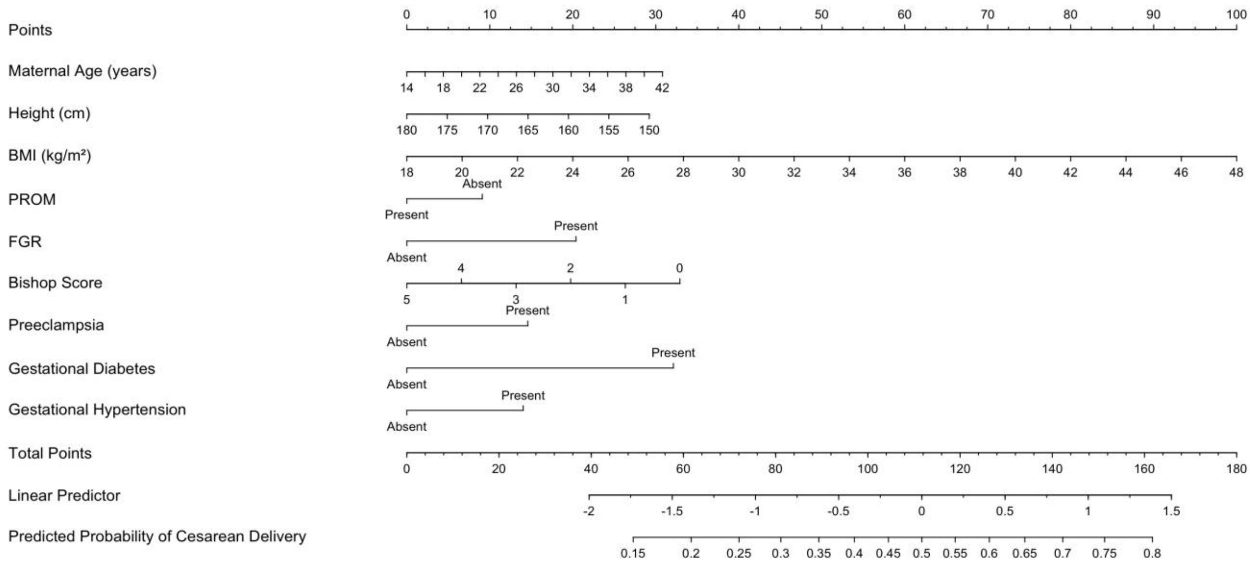

Fig. 1. Nomogram for Predicting the Probability of Cesarean Delivery in Nulliparous Women Undergoing Labor Induction (The nomogram estimates the individualized risk of cesarean delivery based on maternal and obstetric characteristics, including maternal age, height, BMI, presence of PROM, fetal growth restriction, Bishop score, preeclampsia, gestational diabetes, and gestational hypertension. For each variable, a corresponding score is assigned based on its contribution to the model. The total score is then mapped to a linear predictor and converted into the predicted probability of cesarean delivery.)

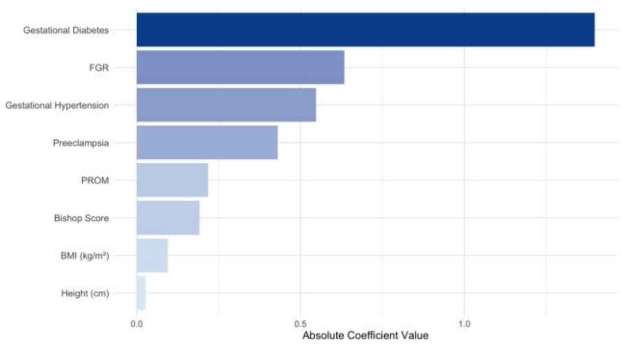

Fig. 2. Relative contribution of variables included in the PMLE-based nomogram model. (Bar chart displaying the absolute coefficient values of predictors used in the penalized logistic regression model. Darker bars indicate greater influence on the predicted probability of cesarean delivery.)

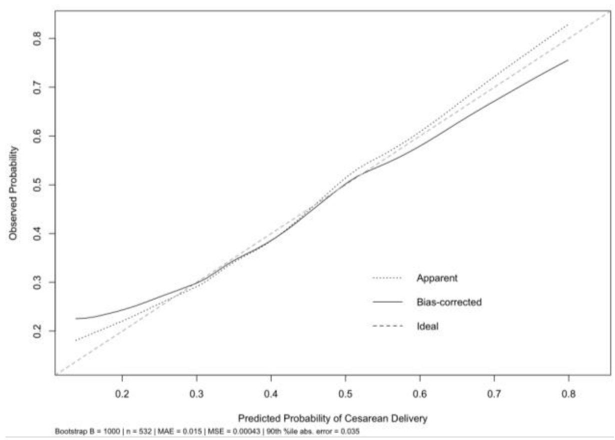

Fig. 3. Calibration Plot of the Cesarean Delivery Prediction Model (The calibration plot displays the relationship between predicted and observed probabilities of cesarean delivery. The solid line (bias-corrected) represents the performance after internal validation using 1000 bootstrap resamples. The dotted line (apparent) reflects the model's performance on the original dataset, while the dashed line (ideal) indicates perfect calibration.)

Bademkıran et al. developed a predictive model using the PMLE method based on eight clinical variables to estimate cesarean delivery risk after labor induction with dinoprostone in term pregnancies (28). Significant predictors in their multivariable analysis included a low Bishop score (OR: 0.64, 95% CI: 0.52–0.79; p = 0.001), nulliparity (OR: 1.5, 95% CI: 1.08–2.0; p = 0.015), longer induction duration (OR: 1.27, 95% CI: 1.16–1.40; p = 0.001), and male fetal sex, with a reported C-index of 0.762. In our study, nine variables were evaluated, including maternal age, height, BMI, Bishop score, PROM, FGR, preeclampsia, gestational hypertension, and gestational diabetes. The model developed with the PMLE method identified Bishop score as a significant predictor, and the C-index was calculated as 0.661. Unlike their model, variables such as gestational age, fetal sex, and induction

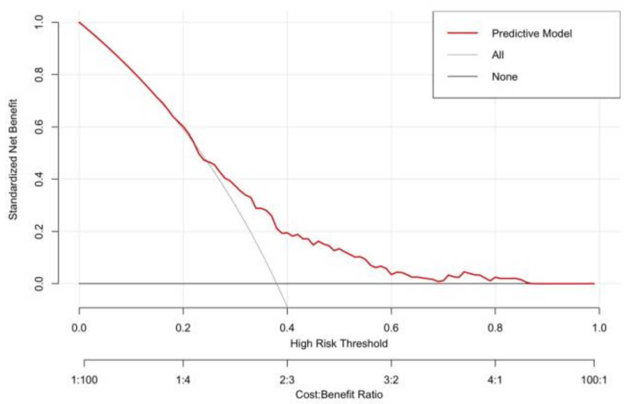

Fig. 4. Decision Curve Analysis for the Cesarean Delivery Predictive Model (The decision curve shows the net benefit of using the predictive model to guide clinical decisions regarding cesarean delivery, compared to "treat all" and "treat none" strategies. Across a wide range of threshold probabilities (particularly between 0.15 and 0.60), the model provides a greater net benefit, indicating clinical utility in decision-making.)

duration were not included in our analysis. However, Bishop score emerged as a common predictor in both studies.

Danilack et al. developed a predictive model for cesarean delivery utilizing data from 17.370 term inductions without medical indications across fourteen hospitals in the United States between 2007 and 2012 (29). Their model incorporated eight clinical variables, including gestational age, maternal age, parity, obesity, race, excessive fetal growth, uterine fibroids, and history of herpes, and demonstrated robust discriminative performance, with an AUC of 0.82 in both internal and external validation cohorts. Conversely, our study examined 532 nulliparous women undergoing labor induction with slow-release dinoprostone and identified Bishop score and BMI as significant predictors via PMLE, resulting in a C-index of 0.661. Although Danilack's model was developed within a larger and more heterogeneous population, our cohort consisted of a more narrowly defined group of nulliparous women with unfavourable cervical conditions.

Zou et al. developed a nomogram to predict cesarean delivery following labor induction in term, nulliparous women in China (30). Their multivariable logistic regression model included nine clinical variables and achieved an AUC of 0.73 (95% CI: 0.70–0.75) in internal validation and 0.67 in external validation. In our study, internal validation using 1,000 bootstrap resamples yielded a C-index of 0.661. However, external validation was not possible due to the lack of an independent dataset. Unlike Zou's model, which identified estimated fetal weight as a significant predictor, this variable was not independently associated with cesarean delivery in our analysis.

One of the strengths of this study is the development of a specific predictive model for cesarean delivery in a homogeneous population of nulliparous women with unfavorable cervices. The inclusion of widely used and easily accessible clinical variables enhances the model's potential applicability in future research settings. Model performance and utility were comprehensively evaluated using calibration analysis and DCA. While not yet ready for direct clinical use, the resulting nomogram may offer a preliminary framework to support individualized risk assessment strategies for future prospective studies.

By estimating cesarean risk prior to induction, the model may help inform research efforts to develop risk-based labor management approaches. Identifying individuals at low or high predicted risk could guide future hypotheses regarding optimal decision-making, potentially reducing adverse outcomes in appropriate patient populations.

However, the study also has several limitations. First, its retrospective and single-center design may limit the generalizability of the findings. Second, although internal validation was performed using 1000 bootstrap resamples with bias correction, no external or prospective validation cohort was available. Therefore, the model's performance in other populations remains to be confirmed. Third, the model was not implemented in clinical practice during the study period; hence, we could not assess whether or how the nomogram would influence provider or patient decision-making. Additionally, the exact duration of induction could not be recorded individually for all participants and was thus not included in the model. Although all patients received dinoprostone for up to 24 hours as per protocol, this missing detail may have reduced the model's explanatory power.

In conclusion, this study presents a practical nomogram to predict the risk of cesarean delivery in nulliparous women undergoing labor induction with an unfavorable cervix. The model identified higher BMI and lower Bishop score as independent factors associated with an increased risk of cesarean delivery in this population. Although the model demonstrated moderate discriminatory ability and good internal calibration, it requires prospective external validation before being considered for clinical implementation. Nonetheless, it may serve as a basis for future efforts to personalize induction strategies and improve risk assessment during the decision-making process.

Declarations

Ethics Approval and Consent to Participate: This study was approved by the Clinical Research Ethics Committee of Gaziantep City Hospital on February 19, 2025 (Approval No: 151/2025). A comprehensive review of the patients' medical records was conducted to gather clinical data, patient characteristics, and follow-up information. Due to the retrospective design of the study, the requirement for informed consent was waived by the ethics committee.

Competing Interests: The authors declare that they have no competing interests.

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Availability of Data and Materials: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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