

# Determinants of failed trial of labor after one previous cesarean section: a retrospective cohort study from a tertiary hospital in Madinah, Saudi Arabia

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## Research Article

**Keywords:** trial of labor after cesarean, vaginal birth after cesarean, emergency cesarean section, parity, fetal weight, Firth regression, Saudi Arabia

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# Determinants of failed trial of labor after one previous cesarean section: a retrospective cohort study from a tertiary hospital in Madinah, Saudi Arabia

*Article type: Original research. Running title: Determinants of failed TOLAC in Madinah.*

## Abstract

**Background.** Trial of labor after cesarean (TOLAC) can spare women a repeat laparotomy, but many attempts end in emergency cesarean section (EMCS). Saudi data on predictors of failure are scarce.

**Methods.** Retrospective cohort at a tertiary hospital in Madinah (July–December 2025) including 117 women with one previous cesarean who underwent TOLAC. Women with vaginal birth after cesarean (VBAC) and EMCS were compared using chi-square or Fisher tests and Firth penalized logistic regression. An antenatal model used information available before labor; an explanatory model added birth-weight difference from the previous neonate, known only after delivery. Discrimination was assessed by the area under the curve (AUC).

**Results.** EMCS occurred in 65 women (55.6%). In the antenatal model, no previous vaginal birth (adjusted odds ratio [aOR] 8.54, 95% CI 3.45–23.54) and an unfavorable Bishop score (aOR 4.82, 1.99–12.54) increased the odds of failure; male fetal sex (aOR 0.31, 0.11–0.78) and height <155 cm (aOR 0.37, 0.14–0.94) lowered them (AUC 0.85; corrected 0.83). Birth weight >400 g above the previous neonate was the strongest postnatal correlate (aOR 20.78, 4.95–133.88; AUC 0.90). Para 1 women failed more often than multiparous women (66.1% vs 42.6%), but not after adjustment for previous vaginal birth. Failure was more frequent after a previous cesarean for failure to progress (67.9%) or other obstetric indications (78.9%) than for breech (40.9%).

**Conclusions.** More than half of TOLAC attempts failed. Previous vaginal birth and cervical favorability should anchor antenatal counseling; antenatal estimation of fetal weight relative to the previous birth warrants prospective evaluation.

**Keywords:** trial of labor after cesarean; vaginal birth after cesarean; emergency cesarean section; parity; fetal weight; Firth regression; Saudi Arabia

## Introduction

Cesarean section (CS) saves lives when vaginal birth is unsafe, yet its steady rise has become a global concern. Nationally representative data from 154 countries put the worldwide CS rate at 21.1% and project 28.5% by 2030 if current trends persist<sup>1</sup>. Saudi Arabia mirrors this pattern: 28.1% of births in 2024 were cesarean deliveries<sup>2</sup>. Each additional abdominal delivery adds cumulative surgical risk, and CS itself has been linked to long-term sequelae such as chronic pelvic pain<sup>3,4</sup>.

Trial of labor after cesarean (TOLAC) offers appropriately selected women a way to avoid a repeat operation. A successful trial ends in vaginal birth after cesarean (VBAC); a failed trial ends in emergency cesarean section (EMCS), which carries its own risks. Recent syntheses and cohort studies continue to compare TOLAC, VBAC and planned repeat CS across maternal and neonatal outcomes<sup>5-7</sup>, and TOLAC is now being extended to complex groups, including women with two previous cesareans, twin gestations and solid-organ transplant recipients<sup>8-11</sup>.

Success is shaped by many factors. A previous vaginal birth, parity, cervical readiness and the features of the earlier cesarean are the strongest and most consistent predictors<sup>12-16</sup>.

Induction of labor with an unfavorable cervix lowers the chance of vaginal delivery<sup>17,18</sup>, and recent calculators combine several of these characteristics rather than relying on any single one<sup>19,20</sup>. Decisions also depend on health literacy, clinician practice and local care pathways<sup>21-25</sup>, while uterine rupture remains the safety outcome that frames counseling<sup>26</sup>.

Fetal size relative to the previous baby is a less settled determinant. In women with prior labor dystocia and no previous vaginal birth, neither sonographic estimated fetal weight nor its difference from the earlier birth weight predicted TOLAC success<sup>27</sup>, and an estimated increase in fetal weight did not independently predict intrapartum cesarean after a previous vaginal birth<sup>28</sup>. Whether the actual difference between current and previous birth weight is

associated with failure after one cesarean, and whether any such signal is usable before labor, is unknown in Saudi populations. Saudi evidence on TOLAC is limited largely to induction outcomes<sup>29</sup>.

We therefore aimed (i) to identify determinants of failed TOLAC in a tertiary Madinah cohort, (ii) to separate predictors available before labor from variables known only after delivery, and (iii) to examine whether parity and the indication for the previous cesarean, particularly breech presentation, relate to the risk of EMCS.

## **Methods**

### **Design, setting and reporting**

This retrospective cohort study took place at Prince Mohammad Bin Abdulaziz Hospital, a tertiary center in Madinah, Saudi Arabia, between 1 July and 31 December 2025. Reporting follows the STROBE statement for cohort studies. Clinical and delivery records were abstracted into a structured dataset.

### **Participants and sample size**

Women with one previous lower-segment cesarean who were offered and underwent TOLAC were eligible. Of 244 women with a single previous cesarean assessed, 77 were excluded (64 did not meet the inclusion criteria and 13 had incomplete records), leaving 167 who were eligible for a trial of labor. Fifty chose elective repeat cesarean, so 117 women attempted TOLAC and formed the analytic cohort (Fig. 1). All consecutive eligible women in the study period were included; no a priori sample-size calculation was performed. Sample adequacy was therefore judged post hoc for the final models using the criterion of Riley et al.<sup>30</sup>, which requires  $n \geq P/[(S-1)\ln(1-R^2_{CS}/S)]$  for P predictors, target shrinkage  $S=0.90$  and Cox-Snell  $R^2$  ( $R^2_{CS}$ ) approximated from the Nagelkerke  $R^2$  and the observed outcome prevalence (55.6%).

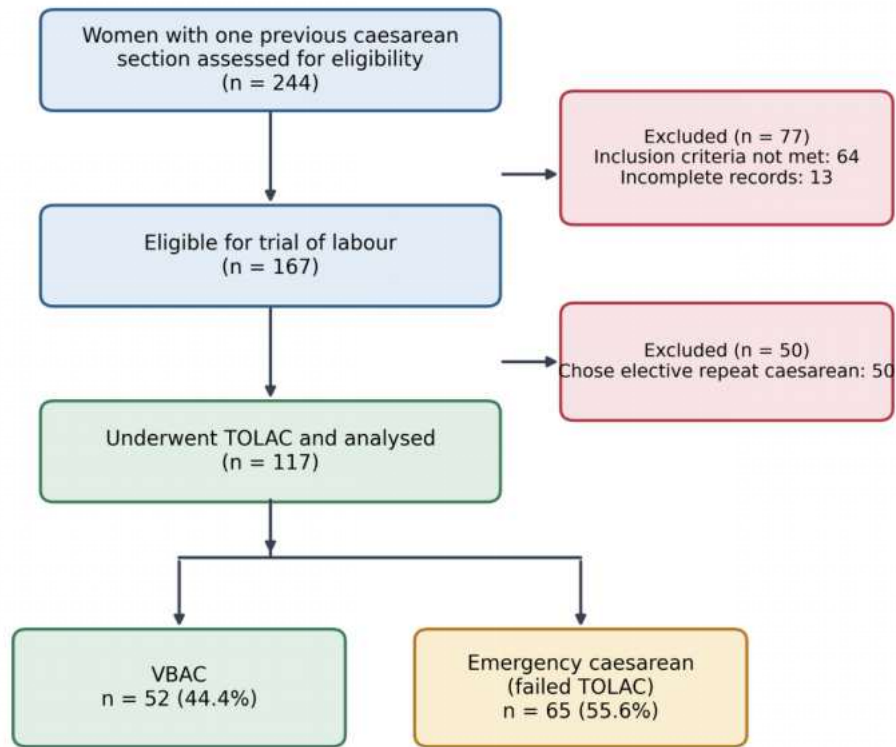


**Fig. 1** Participant flow diagram. TOLAC, trial of labor after cesarean; VBAC, vaginal birth after cesarean.

## Outcome and variables

The outcome was failed TOLAC, defined as intrapartum repeat cesarean (EMCS), compared with VBAC. Candidate variables, all dichotomized in the source dataset, were maternal age (>35 vs <35 years), height (<155 vs >155 cm), body mass index (>35 vs <35 kg/m<sup>2</sup>), previous vaginal birth, inter-delivery interval (<2 vs >2 years), previous cesarean for breech presentation, mechanical induction, Bishop score at admission (unfavorable vs favorable), epidural analgesia, birth weight >3.5 kg and <2.5 kg, gestation >40 weeks, fetal sex, any antenatal medical disorder, and birth weight >400 g above that of the previous neonate. Parity (para 1 vs para ≥2, as recorded in the dataset; one record entered as para 0 was grouped with para 1) and the indication for the previous cesarean (fetal distress, failure to progress, breech, other obstetric indications) were analyzed as additional exposures.

Variables were classified by when they become known. Antenatal variables are available before labor. Epidural analgesia is an intrapartum event that may follow, rather than precede,

labor progress, and was therefore treated as exploratory because only 13 women received it.

Birth-weight difference requires the current birth weight and was treated as a postnatal explanatory variable.

### **Statistical analysis**

Categorical variables are given as numbers and percentages and were compared between outcome groups with the Pearson chi-square test, or the Fisher exact test when any expected count was  $<5$ ; for multi-category variables with sparse cells, a Monte Carlo exact test (20,000 permutations) was used. Crude odds ratios (OR) with Woolf 95% confidence intervals (CI) are reported with a Haldane–Anscombe correction for zero cells. Because some exposures were sparse (only 2 of 30 women with a birth-weight gain  $>400$  g achieved VBAC; 2 of 13 women with epidural analgesia failed), Firth penalized-likelihood ORs with profile-likelihood CIs are also reported, and all multivariable models used Firth logistic regression to avoid separation and small-sample bias.

Univariable and multivariable results are presented separately. Variables with a univariable  $P < 0.25$  entered the multivariable models, excluding epidural analgesia (intrapartum). Model 1 (antenatal) used only variables known before labor. Model 2 (explanatory) added birth-weight difference and is not intended for counseling. Backward elimination removed the variable with the largest likelihood-ratio  $P$  value until all remaining variables had  $P < 0.10$ , which limited model size in relation to the 65 events. Discrimination was summarized by the AUC with DeLong 95% CI, and optimism was estimated by 1,000 bootstrap resamples with the final variable sets fixed. We also report the Nagelkerke  $R^2$ , Brier score, and sensitivity and specificity at a predicted probability of 0.5, and compared the AUC of the two models by bootstrap. Sensitivity analyses added epidural analgesia to Model 1 and replaced previous vaginal birth with parity. Complete-case analysis was used (inter-delivery interval missing in

3 women, age and parity in 1). Two-sided  $P < 0.05$  indicated statistical significance. Analyses used Python 3.12 (NumPy, pandas, SciPy, matplotlib) with an in-house Firth implementation.

## Ethical approval

The study followed the Declaration of Helsinki and was approved by the Institutional Review Board of King Abdullah International Medical Research Center (KAIMRC), approval number NRM26/003/2, on 29 April 2026. The committee waived individual informed consent because data were retrospective and de-identified.

## Results

### Cohort and outcome

Of the 117 women who underwent TOLAC, 65 (55.6%; 95% CI 46.5–64.2) required EMCS and 52 (44.4%) achieved VBAC (Fig. 1). Table 1 compares the characteristics of the two groups. Women with VBAC were more often parous (median para 2, IQR 1–4, vs 1, IQR 1–2; Mann–Whitney  $P = 0.003$ ), more often had a previous vaginal birth (76.9% vs 30.8%), and more often presented with a favorable cervix (63.5% vs 26.2%). A birth weight  $> 400$  g above the previous neonate was uncommon in the VBAC group (3.8%) but affected 43.1% of EMCS cases.

**Table 1** Characteristics of women by mode of delivery after TOLAC

| Characteristic               | VBAC (n=52) n (%) | EMCS (n=65) n (%) | P            |
|------------------------------|-------------------|-------------------|--------------|
| <b>Maternal age (n=116)</b>  |                   |                   | <b>1.000</b> |
| <35 years                    | 39 (75.0)         | 48 (75.0)         |              |
| >35 years                    | 13 (25.0)         | 16 (25.0)         |              |
| <b>Maternal height</b>       |                   |                   | <b>0.238</b> |
| >155 cm                      | 28 (53.8)         | 42 (64.6)         |              |
| <155 cm                      | 24 (46.2)         | 23 (35.4)         |              |
| <b>Maternal BMI</b>          |                   |                   | <b>0.351</b> |
| <35 kg/m <sup>2</sup>        | 45 (86.5)         | 52 (80.0)         |              |
| >35 kg/m <sup>2</sup>        | 7 (13.5)          | 13 (20.0)         |              |
| <b>Parity (para) (n=116)</b> |                   |                   | <b>0.011</b> |
| Para 1                       | 21 (40.4)         | 41 (64.1)         |              |

|                                                      |           |           |                  |
|------------------------------------------------------|-----------|-----------|------------------|
| Para $\geq 2$ (multipara)                            | 31 (59.6) | 23 (35.9) |                  |
| <b>Previous vaginal birth</b>                        |           |           | <b>&lt;0.001</b> |
| Yes                                                  | 40 (76.9) | 20 (30.8) |                  |
| No                                                   | 12 (23.1) | 45 (69.2) |                  |
| <b>Inter-delivery interval (n=114)</b>               |           |           | <b>0.061</b>     |
| >2 years                                             | 45 (90.0) | 49 (76.6) |                  |
| <2 years                                             | 5 (10.0)  | 15 (23.4) |                  |
| <b>Indication for previous CS</b>                    |           |           | <b>0.022</b>     |
| Fetal distress                                       | 26 (50.0) | 22 (33.8) |                  |
| Failure to progress (FTA)                            | 9 (17.3)  | 19 (29.2) |                  |
| Breech presentation                                  | 13 (25.0) | 9 (13.8)  |                  |
| Other obstetric indications                          | 4 (7.7)   | 15 (23.1) |                  |
| <b>Labour induction</b>                              |           |           | <b>0.363</b>     |
| None / spontaneous                                   | 37 (71.2) | 51 (78.5) |                  |
| Mechanical                                           | 15 (28.8) | 14 (21.5) |                  |
| <b>Bishop score at admission</b>                     |           |           | <b>&lt;0.001</b> |
| Favourable                                           | 33 (63.5) | 17 (26.2) |                  |
| Unfavourable                                         | 19 (36.5) | 48 (73.8) |                  |
| <b>Epidural analgesia</b>                            |           |           | <b>0.002</b>     |
| Not used                                             | 41 (78.8) | 63 (96.9) |                  |
| Used                                                 | 11 (21.2) | 2 (3.1)   |                  |
| <b>Fetal sex</b>                                     |           |           | <b>0.062</b>     |
| Female                                               | 19 (36.5) | 35 (53.8) |                  |
| Male                                                 | 33 (63.5) | 30 (46.2) |                  |
| <b>Birth-weight difference from previous neonate</b> |           |           | <b>&lt;0.001</b> |
| <400 g                                               | 50 (96.2) | 37 (56.9) |                  |
| >400 g                                               | 2 (3.8)   | 28 (43.1) |                  |
| <b>Birth weight (3.5 kg)</b>                         |           |           | <b>0.298</b>     |
| <3.5 kg                                              | 44 (84.6) | 50 (76.9) |                  |
| >3.5 kg                                              | 8 (15.4)  | 15 (23.1) |                  |
| <b>Birth weight (2.5 kg)</b>                         |           |           | <b>0.203</b>     |
| >2.5 kg                                              | 48 (92.3) | 55 (84.6) |                  |
| <2.5 kg                                              | 4 (7.7)   | 10 (15.4) |                  |
| <b>Gestational age</b>                               |           |           | <b>0.534</b>     |
| <40 weeks                                            | 34 (65.4) | 46 (70.8) |                  |
| >40 weeks                                            | 18 (34.6) | 19 (29.2) |                  |
| <b>Antenatal complications</b>                       |           |           | <b>0.001†</b>    |
| None                                                 | 37 (71.2) | 54 (83.1) |                  |
| GDM                                                  | 5 (9.6)   | 11 (16.9) |                  |
| Hypothyroidism                                       | 6 (11.5)  | 0 (0.0)   |                  |
| Other (asthma, cholestasis, APS, sickle trait)       | 4 (7.7)   | 0 (0.0)   |                  |

Values are n (%) of each outcome group with available data. P values: Pearson chi-square or Fisher exact test (Monte Carlo exact test for multi-category rows with sparse cells). †Any antenatal disorder vs none, P=0.123; all 10 women with hypothyroidism or another medical disorder achieved VBAC. EMCS, emergency cesarean section; GDM, gestational diabetes mellitus; VBAC, vaginal birth after cesarean.

## Univariable associations

Table 2 lists the univariable association of each characteristic with EMCS. Three variables were strongly associated with failure: birth weight >400 g above the previous neonate (EMCS 93.3% vs 42.5%; Firth OR 15.35, 95% CI 4.65–78.68), absence of a previous vaginal birth (78.9% vs 33.3%; OR 7.19, 3.24–16.87) and an unfavorable Bishop score (71.6% vs 34.0%; OR 4.76, 2.21–10.62), each P<0.001 (Fig. 2, Fig. 3). Epidural analgesia was associated with lower odds of EMCS (15.4% vs 60.6%; OR 0.14, 0.03–0.51; P=0.002), but this relationship is open to reverse causation (see Discussion). A short inter-delivery interval (<2 years; OR 2.59, 0.95–8.07; P=0.061) and male fetal sex (OR 0.50, 0.24–1.04; P=0.062) showed non-significant trends. Maternal age, height, body mass index, gestation >40 weeks, mechanical induction, birth weight >3.5 kg or <2.5 kg, antenatal medical disorder and a previous cesarean for breech showed no significant association (all P>0.12).

**Table 2** Univariable analysis of factors associated with failed TOLAC (EMCS)

| Characteristic                                      | EMCS in exposed n/N (%) | EMCS in reference n/N (%) | Crude OR (95% CI)        | Firth OR (95% CI)        | P                |
|-----------------------------------------------------|-------------------------|---------------------------|--------------------------|--------------------------|------------------|
| <b>Maternal characteristics</b>                     |                         |                           |                          |                          |                  |
| Maternal age >35 y                                  | 16/29 (55.2)            | 48/87 (55.2)              | 1.00 (0.43–2.33)         | 1.00 (0.43–2.32)         | 1.000            |
| Maternal height <155 cm                             | 23/47 (48.9)            | 42/70 (60.0)              | 0.64 (0.30–1.35)         | 0.64 (0.31–1.34)         | 0.238            |
| BMI >35 kg/m <sup>2</sup>                           | 13/20 (65.0)            | 52/97 (53.6)              | 1.61 (0.59–4.38)         | 1.56 (0.60–4.33)         | 0.351            |
| <b>Obstetric history</b>                            |                         |                           |                          |                          |                  |
| <b>No previous vaginal birth</b>                    | <b>45/57 (78.9)</b>     | <b>20/60 (33.3)</b>       | <b>7.50 (3.26–17.25)</b> | <b>7.19 (3.24–16.87)</b> | <b>&lt;0.001</b> |
| <b>Para 1 (vs para ≥2)</b>                          | <b>41/62 (66.1)</b>     | <b>23/54 (42.6)</b>       | <b>2.63 (1.24–5.59)</b>  | <b>2.59 (1.24–5.53)</b>  | <b>0.011</b>     |
| Inter-delivery interval <2 y                        | 15/20 (75.0)            | 49/94 (52.1)              | 2.76 (0.93–8.19)         | 2.59 (0.95–8.07)         | 0.061            |
| Indication of previous cesarean (reference: breech) |                         |                           |                          |                          |                  |
| Fetal distress                                      | 22/48 (45.8)            | 9/22 (40.9)               | 1.22 (0.44–3.40)         | 1.21 (0.45–3.35)         | 0.700            |
| Failure to progress                                 | 19/28 (67.9)            | 9/22 (40.9)               | 3.05 (0.95–9.75)         | 2.92 (0.95–9.41)         | 0.057            |
| <b>Other obstetric indication</b>                   | <b>15/19 (78.9)</b>     | <b>9/22 (40.9)</b>        | <b>5.42 (1.35–21.80)</b> | <b>4.89 (1.36–20.38)</b> | <b>0.014</b>     |
| <b>Current pregnancy</b>                            |                         |                           |                          |                          |                  |
| <b>Unfavourable Bishop score</b>                    | <b>48/67 (71.6)</b>     | <b>17/50 (34.0)</b>       | <b>4.90 (2.22–10.81)</b> | <b>4.76 (2.21–10.62)</b> | <b>&lt;0.001</b> |
| Mechanical induction                                | 14/29 (48.3)            | 51/88 (58.0)              | 0.68 (0.29–1.57)         | 0.68 (0.29–1.57)         | 0.363            |
| Gestation >40 weeks                                 | 19/37 (51.4)            | 46/80 (57.5)              | 0.78 (0.36–1.71)         | 0.78 (0.36–1.70)         | 0.534            |
| Male fetal sex                                      | 30/63 (47.6)            | 35/54 (64.8)              | 0.49 (0.23–1.04)         | 0.50 (0.24–1.04)         | 0.062            |
| Antenatal medical disorder                          | 11/26 (42.3)            | 54/91 (59.3)              | 0.50 (0.21–1.22)         | 0.51 (0.21–1.21)         | 0.123            |
| Birth weight >3.5 kg                                | 15/23 (65.2)            | 50/94 (53.2)              | 1.65 (0.64–4.26)         | 1.61 (0.65–4.22)         | 0.298            |

|                                              |              |               |                           |                           |                  |
|----------------------------------------------|--------------|---------------|---------------------------|---------------------------|------------------|
| Birth weight <2.5 kg                         | 10/14 (71.4) | 55/103 (53.4) | 2.18 (0.64–7.41)          | 2.04 (0.66–7.26)          | 0.203            |
| <b>Intrapartum (exploratory)</b>             |              |               |                           |                           |                  |
| Epidural analgesia used                      | 2/13 (15.4)  | 63/104 (60.6) | <b>0.12 (0.02–0.56)</b>   | <b>0.14 (0.03–0.51)</b>   | <b>0.002</b>     |
| <b>Postnatal (known only after delivery)</b> |              |               |                           |                           |                  |
| Birth weight >400 g above previous neonate   | 28/30 (93.3) | 37/87 (42.5)  | <b>18.92 (4.24–84.47)</b> | <b>15.35 (4.65–78.68)</b> | <b>&lt;0.001</b> |

Percentages show the proportion of women who had EMCS within each category. For indication of previous cesarean the comparison group is previous breech (9/22 EMCS); the overall test across four indication groups gave  $P=0.022$ . P values are from the chi-square or Fisher exact test; bold rows indicate  $P<0.05$ . OR, odds ratio; CI, confidence interval.

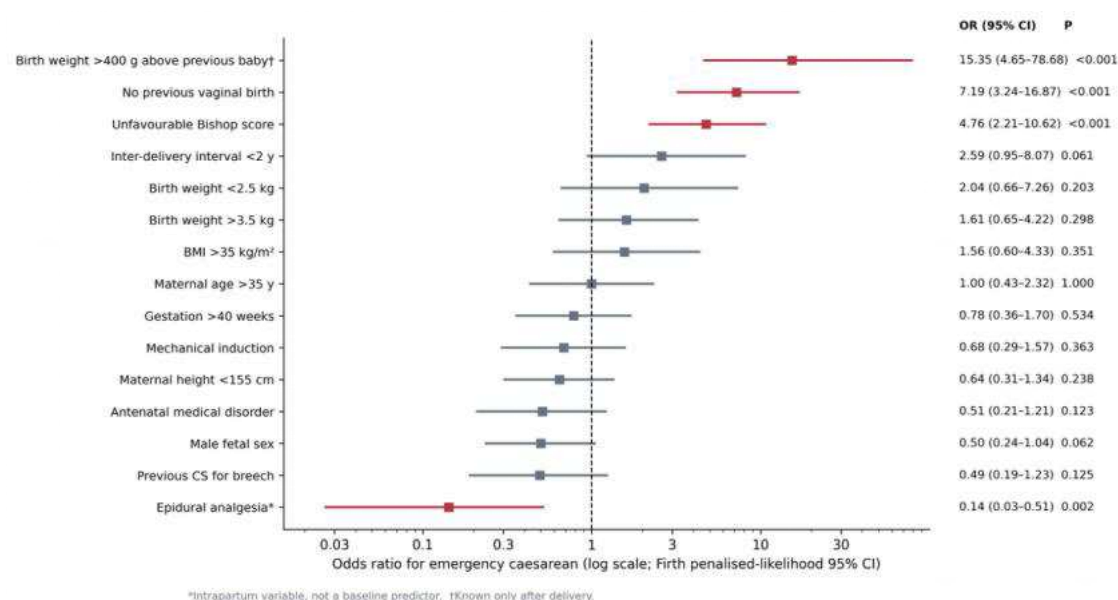


**Fig. 2** Forest plot of univariable (Firth) odds ratios for failed TOLAC. Red markers denote  $P<0.05$ . \*Intrapartum variable, not a baseline predictor. †Known only after delivery.

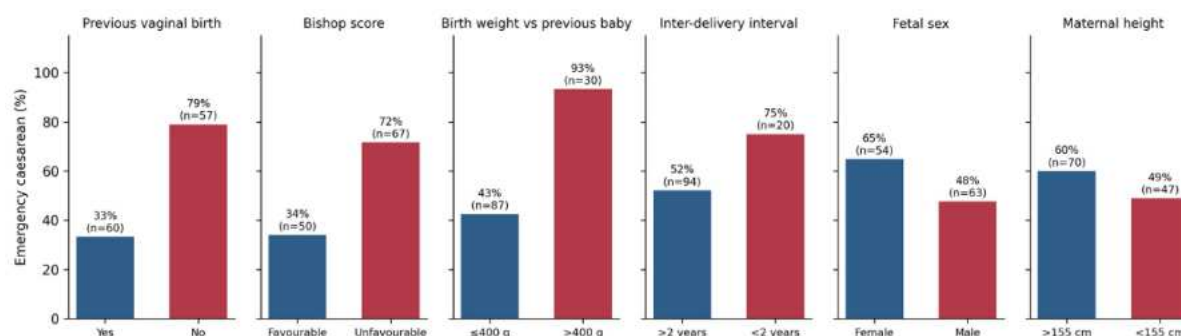


**Fig. 3** Proportion of women with EMCS across the strongest univariable factors.

### Parity and indication of the previous cesarean

Para 1 women were more likely to fail than multiparous women (EMCS 41/62, 66.1%, vs 23/54, 42.6%; OR 2.63, 95% CI 1.24–5.59;  $P=0.011$ ; Table 3, Fig. 4). Failure fell from 61% in para 2 to 20–33% in para 3 and above. This difference was explained by previous vaginal birth: when parity was added to a model containing previous vaginal birth and Bishop score,

multiparity was no longer associated with failure (aOR 0.84, 95% CI 0.32–2.31;  $P=0.72$ ), while absence of a previous vaginal birth remained strong (aOR 6.01, 2.30–17.06).

The indication for the previous cesarean differed significantly between outcome groups ( $P=0.022$ ). EMCS occurred in 45.8% after fetal distress, 67.9% after failure to progress, 40.9% after breech and 78.9% after other obstetric indications (placenta previa or abruption, polyhydramnios or oligohydramnios, and single cases of other conditions). Compared with breech, failure to progress (OR 3.05, 0.95–9.75;  $P=0.057$ ) and other obstetric indications (OR 5.42, 1.35–21.80;  $P=0.014$ ) carried higher odds, whereas fetal distress did not (OR 1.22;  $P=0.70$ ).

Previous breech presentation was not associated with failure overall (OR 0.49, 0.19–1.23;  $P=0.125$ ), and the confidence interval and  $P$  value are concordant. Among the 11 para 1 women with previous breech, 7 (63.6%) failed, versus 2 of 11 (18.2%) multiparous women with previous breech (Fisher  $P=0.080$ ). In para 1 women breech was not protective (63.6% vs 66.7% for other indications;  $P=1.00$ ); in multiparous women the point estimate favored breech (18.2% vs 48.8%; OR 0.23, 0.04–1.21;  $P=0.092$ ), but the test for interaction between parity and breech was not significant ( $P=0.26$ ). Previous vaginal birth again explained the contrast: among all 22 women with previous breech, EMCS occurred in 8 of 10 without and 1 of 12 with a previous vaginal birth (Fisher  $P=0.002$ ).

**Table 3** Failed TOLAC by parity and indication of the previous cesarean

| Comparison                                  | EMCS n/N (%)                | OR (95% CI)                 | P     |
|---------------------------------------------|-----------------------------|-----------------------------|-------|
| <b>Parity</b>                               |                             |                             |       |
| Para 1                                      | 41/62 (66.1)                | 1.00 (reference)            |       |
| Para $\geq 2$ (multipara)                   | 23/54 (42.6)                | 0.38 (0.18–0.81) $\ddagger$ | 0.011 |
| <b>Indication of previous cesarean</b>      |                             |                             |       |
| Fetal distress                              | 22/48 (45.8)                | 1.22 (0.44–3.40)            | 0.700 |
| Failure to progress                         | 19/28 (67.9)                | 3.05 (0.95–9.75)            | 0.057 |
| Breech (reference)                          | 9/22 (40.9)                 | 1.00 (reference)            |       |
| Other obstetric indication                  | 15/19 (78.9)                | 5.42 (1.35–21.80)           | 0.014 |
| <b>Previous breech by parity</b>            |                             |                             |       |
| Para 1: breech vs other indications         | 7/11 (63.6) vs 34/51 (66.7) | 0.88 (0.23–3.41)            | 1.000 |
| Para $\geq 2$ : breech vs other indications | 2/11 (18.2) vs 21/43 (48.8) | 0.23 (0.04–1.21)            | 0.092 |

$\ddagger$ Inverse of the para 1 vs para  $\geq 2$  odds ratio in Table 2 (2.63; 1.24–5.59).  $\S$ Crude odds ratio from the 2 $\times$ 2 table of 11 women per group; the interval is wide because of small numbers. Percentages and P values as in Table 2 (Fisher exact test for sparse cells). Parity as recorded in the dataset, with one para 0 record grouped with para 1.

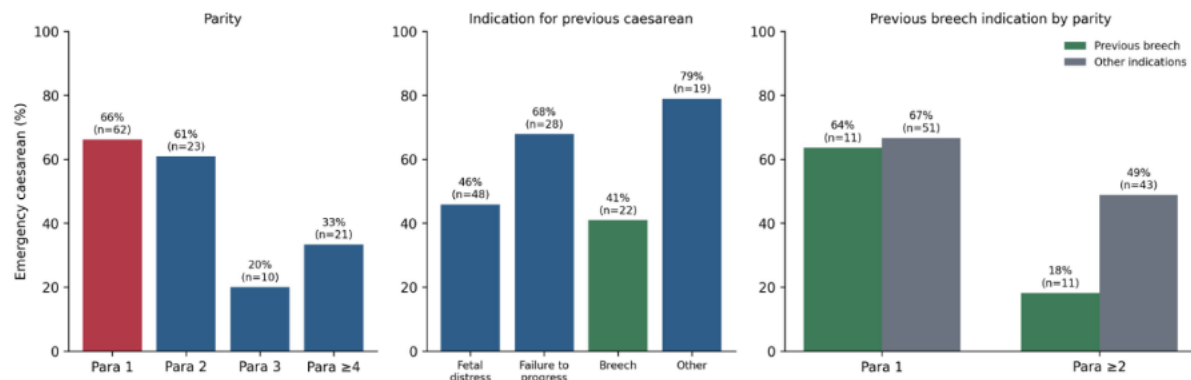


**Fig. 4** Proportion of women with EMCS by parity, by indication of the previous caesarean, and by previous breech indication within parity groups.

### Multivariable analysis

Seven variables entered Model 1 (previous vaginal birth, Bishop score, inter-delivery interval, previous breech, fetal sex, antenatal medical disorder and height; 64 events in 114 women with complete data, 9.1 events per variable). Backward elimination removed previous breech ( $P=0.67$ ), antenatal disorder ( $P=0.29$ ) and inter-delivery interval ( $P=0.14$ ). The final model ( $n=117$ , 65 events, 16.3 events per variable) retained four variables (Table 4, Fig. 5). Absence of a previous vaginal birth (aOR 8.54, 95% CI 3.45–23.54) and an unfavorable Bishop score (aOR 4.82, 1.99–12.54) increased the odds of EMCS, while male fetal sex (aOR 0.31, 0.11–0.78) and height  $<155$  cm (aOR 0.37, 0.14–0.94) were associated with lower odds. Mechanical induction, which had a protective estimate in an earlier analysis, did not meet the entry threshold (univariable  $P=0.36$ ).

Model 2 added birth-weight difference. Eight variables entered (8.0 events per variable); previous breech ( $P=0.80$ ), height ( $P=0.27$ ) and inter-delivery interval ( $P=0.12$ ) were removed. The final model retained five variables. A birth weight  $>400$  g above the previous neonate was the strongest correlate of failure (aOR 20.78, 95% CI 4.95–133.88;  $P<0.001$ ), with previous vaginal birth (aOR 8.13, 3.06–24.30) and Bishop score (aOR 5.16, 1.92–15.62)

remaining independent. Male fetal sex (aOR 0.42, 0.15–1.13;  $P=0.086$ ) and antenatal medical disorder (aOR 0.29, 0.07–1.04;  $P=0.058$ ) were borderline. Conventional maximum-likelihood estimation gave similar estimates for Model 1 (aORs 9.76, 5.29, 0.29 and 0.35) but a larger and less stable estimate for birth-weight difference in Model 2 (aOR 31.05, 5.18–186.22), illustrating the sparse-data inflation that Firth estimation reduces.

**Table 4** Multivariable Firth logistic regression for failed TOLAC (EMCS)

| Variable                                    | Model 1: aOR<br>(95% CI) | P      | Model 2: aOR<br>(95% CI) | P      |
|---------------------------------------------|--------------------------|--------|--------------------------|--------|
| No previous vaginal birth                   | 8.54 (3.45–23.54)        | <0.001 | 8.13 (3.06–24.30)        | <0.001 |
| Unfavorable Bishop score                    | 4.82 (1.99–12.54)        | <0.001 | 5.16 (1.92–15.62)        | <0.001 |
| Male fetal sex                              | 0.31 (0.11–0.78)         | 0.013  | 0.42 (0.15–1.13)         | 0.086  |
| Maternal height <155 cm                     | 0.37 (0.14–0.94)         | 0.037  | –                        | –      |
| Antenatal medical disorder                  | –                        | –      | 0.29 (0.07–1.04)         | 0.058  |
| Birth weight >400 g above previous neonate¶ | –                        | –      | 20.78 (4.95–133.88)      | <0.001 |

Model 1: antenatal predictors (n=117, 65 events). Model 2: explanatory model including a postnatal variable, not for prospective counseling (n=117, 65 events). ¶Known only after delivery. Dashes indicate variables removed by backward elimination or not eligible. P values are penalized-likelihood ratio tests. aOR, adjusted odds ratio.

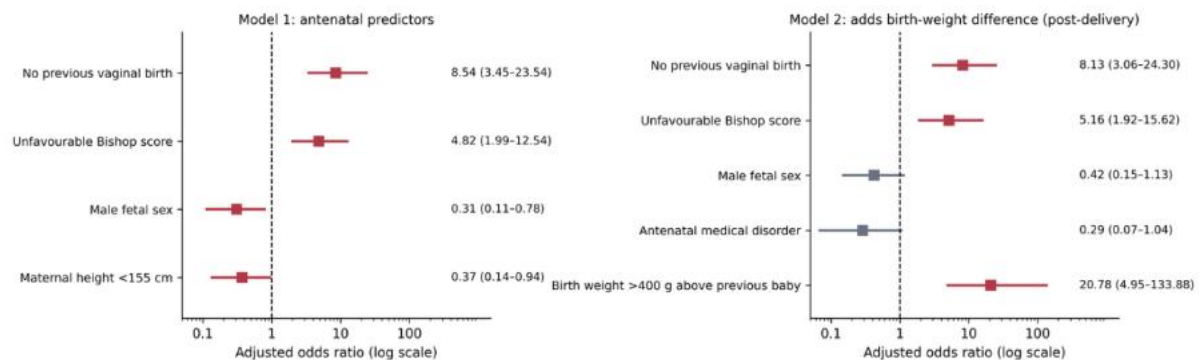


**Fig. 5** Forest plots of adjusted odds ratios for Model 1 (antenatal) and Model 2 (explanatory, includes a postnatal variable). Red markers denote  $P<0.05$ .

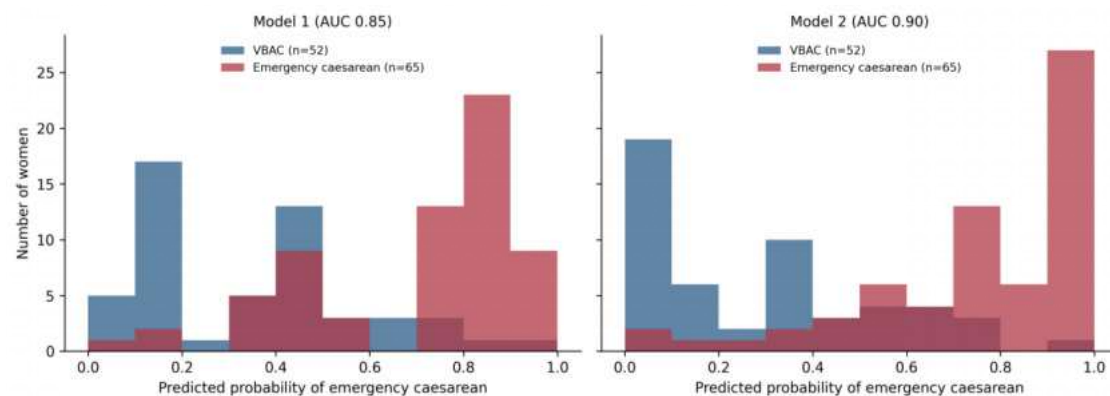
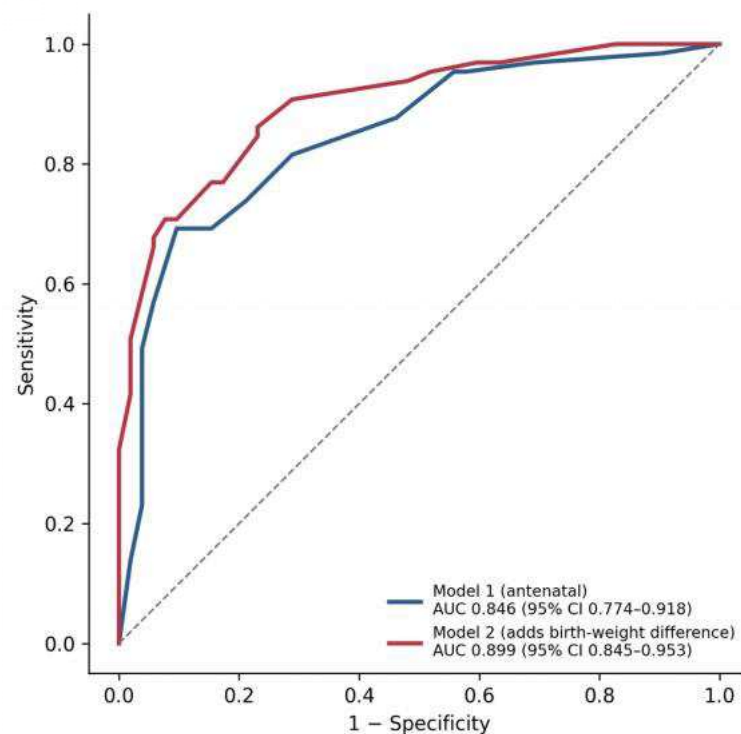
### Model performance and sensitivity analyses

Model 1 discriminated well (AUC 0.846, 95% CI 0.774–0.918; optimism-corrected 0.828), and Model 2 discriminated better (AUC 0.899, 0.845–0.953; optimism-corrected 0.883) (Table 5, Fig. 6, Fig. 7). The paired AUC gain from adding birth-weight difference was 0.052 (bootstrap 95% CI 0.003–0.102). A two-variable model of previous vaginal birth and Bishop score alone gave an AUC of 0.803 (0.726–0.880). Both final models exceeded the post hoc minimum sample size (87 women for Model 1, 75 for Model 2; observed 117).

**Table 5** Performance of the final models

| Measure                              | Model 1 (antenatal) | Model 2 (explanatory) |
|--------------------------------------|---------------------|-----------------------|
| AUC (95% CI)                         | 0.846 (0.774–0.918) | 0.899 (0.845–0.953)   |
| Optimism-corrected AUC               | 0.828               | 0.883                 |
| Nagelkerke R <sup>2</sup>            | 0.45                | 0.59                  |
| Brier score                          | 0.156               | 0.128                 |
| Sensitivity at cut-off 0.5           | 73.8%               | 86.2%                 |
| Specificity at cut-off 0.5           | 78.8%               | 76.9%                 |
| Minimum n required (Riley criterion) | 87                  | 75                    |

AUC, area under the receiver operating characteristic curve. Bootstrap optimism correction with 1,000 resamples and fixed final variable sets.

**Fig. 6** Distribution of predicted probability of EMCS by actual outcome for Model 1 and Model 2.**Fig. 7** Receiver operating characteristic curves of Model 1 and Model 2 with AUC and 95% CI.

In sensitivity analyses, adding epidural analgesia to Model 1 left the main estimates stable (previous vaginal birth aOR 7.83; Bishop score aOR 4.93) and gave an aOR of 0.12 (95% CI

0.02–0.60) for epidural use. Replacing previous vaginal birth with parity gave an aOR of 0.25 (0.10–0.59) for para  $\geq 2$ , equivalent to 4.03 (1.70–10.31) for para 1, but with lower discrimination (AUC 0.793, 0.709–0.877).

## Discussion

More than half of the women (55.6%) in this tertiary Saudi cohort who attempted TOLAC after one cesarean required an emergency repeat operation. Success rates vary widely between regions and health systems<sup>31,32</sup>, and the rate here is a reminder that case mix, selection and local practice shape outcomes<sup>22,23,33</sup>. Two antenatal findings dominated the analysis: absence of a previous vaginal birth and an unfavorable cervix. Together they gave an AUC of 0.80, and a four-variable antenatal model reached 0.85 (0.83 after optimism correction). These results agree with prediction work in other populations that places vaginal birth history and cervical status at the center of risk estimation<sup>12–16,19,20</sup>, and with evidence that induction on an unfavorable cervix often fails<sup>17,18</sup>.

The parity analysis answers a practical question. Para 1 women failed more often than multiparous women, but the contrast reflected previous vaginal birth rather than parity itself: once vaginal birth history was in the model, the multiparity effect vanished (aOR 0.84).

Parity is therefore a coarse proxy, and counseling should ask whether the woman has ever delivered vaginally. The dataset also contained multiparous women without a previous vaginal birth, all of whom failed (11 of 11), and para 1 women recorded with a previous vaginal birth. These combinations are logically unusual after a single cesarean and suggest that parity coding (for example, inclusion of pregnancy losses or the index cesarean) differs between records; parity findings should be read with this in mind.

Previous breech presentation did not independently predict failure (OR 0.49, P=0.125), and no confidence interval excluded unity at that P value, which resolves the inconsistency raised during review. In para 1 women, a previous breech cesarean was followed by failure in

63.6%, similar to other indications, whereas multiparous women with breech fared better (18.2%). That gradient disappears when previous vaginal birth is considered, because breech women with no vaginal birth failed in 8 of 10 cases and those with one in 1 of 12. A non-recurring indication does not, by itself, guarantee success in a woman who has never delivered vaginally, and a history of breech cesarean is not benign for later deliveries<sup>34</sup>. The number of women in these strata is small, and the interaction test was not significant, so these figures are descriptive.

The indication for the previous cesarean mattered more. Failure was more frequent after failure to progress (67.9%) and after other obstetric indications (78.9%) than after breech (40.9%) or fetal distress (45.8%). Labor dystocia is the indication most likely to recur, and prior work has found that sonographic fetal weight characteristics add little to prediction in women with prior dystocia who have never delivered vaginally<sup>27</sup>. The “other” category was heterogeneous (placenta previa or abruption and abnormal liquor volume predominated), and the estimates are imprecise; they support a detailed review of operative notes rather than a binary breech-versus-other approach.

Birth-weight difference showed the strongest association (aOR 20.78) but is knowable only after birth, as the editor observed, so Model 2 should be read as explanatory. The wide interval (4.95–133.88) reflects sparse data, since only 2 of 30 women with a gain above 400 g achieved VBAC, and Firth estimation was used to temper this. Absolute birth weight above 3.5 kg was not significant (OR 1.61), in line with studies showing that selected women with macrosomic neonates can succeed<sup>35</sup>; it is the change relative to the previous baby, in a uterus that has already delivered a smaller infant by cesarean, that appears informative. A usable antenatal analogue would require ultrasound estimation of fetal weight combined with clinical examination before the trial, compared with the previous birth weight. This is plausible but unproven: in a large cohort with a previous vaginal birth, an estimated increase

in weight did not independently predict cesarean<sup>28</sup>, and in women with prior dystocia the sonographic estimate did not predict TOLAC success<sup>27</sup>. Our data motivate, but do not validate, a prospective study of estimated weight difference as a counseling variable. Several secondary findings need cautious reading. Epidural analgesia was strongly linked to VBAC, but only 13 women received it, and the analgesia recorded in the dataset partly reflects the route of delivery: all 10 women with spinal anesthesia and the one under general anesthesia had EMCS, whereas Entonox was recorded only among women who delivered vaginally. Epidural use is also more likely in women who progress. This is reverse causation, not a protective effect, and larger cohorts have found no harm from epidural analgesia on TOLAC success<sup>36</sup>. Male fetal sex and short stature were associated with lower odds of EMCS, but neither has a convincing mechanism, the sex effect weakened in Model 2, and both are best regarded as hypothesis-generating. Our earlier suggestion that mechanical induction was protective did not survive correction of the model, and age showed no association (OR 1.00), so no explanation for younger women is needed. Finally, antenatal medical disorders were associated with fewer failures only because all 10 women with hypothyroidism or other disorders achieved VBAC, whereas those with gestational diabetes had EMCS in 11 of 16 cases; the numbers do not allow inference. A short inter-delivery interval showed a non-significant trend (OR 2.59, P=0.061) in only 20 women; most literature concerns uterine rupture rather than failure<sup>37</sup>, and the question needs larger samples. The findings fit a shared decision-making framework. Women weigh clinical numbers alongside their own priorities<sup>21,38</sup>, and counseling is best built on a few robust factors, previous vaginal birth and cervical status, with the earlier cesarean indication added from the operative record. Calculators can support this conversation but should not replace judgment<sup>19,20</sup>.

## **Strengths and limitations**

Strengths include complete outcome ascertainment in a defined single-center cohort, separation of antenatal from postnatal predictors, penalized estimation suited to sparse data, a limit on model size relative to events, and bootstrap correction for optimism. The study also has limitations. It is retrospective, single-center and modest in size, so confidence intervals are wide and the findings cannot be generalized without replication. All predictors were pre-dichotomized, which discards information (for example continuous Bishop score, estimated fetal weight, exact interval in months), and the indication categories and parity coding are imperfect. Variables were selected using the same data used for estimation, and the bootstrap corrects only part of the resulting optimism; there was no external validation and calibration was summarized only by the Brier score. Residual confounding by labor management and clinician decisions is possible, the cohort excludes women who chose elective repeat cesarean, and the sample-size adequacy was assessed post hoc.

## **Conclusions**

In this Madinah cohort, absence of a previous vaginal birth and an unfavorable cervix were the main antenatal determinants of failed TOLAC, and a model built on antenatal data discriminated well. Para 1 status carried excess risk only through the lack of a previous vaginal birth. Failure to progress and other obstetric indications at the previous cesarean predicted more failure than breech. A birth weight >400 g above the previous neonate was strongly associated with failure but is a postnatal finding; prospective evaluation of estimated fetal weight relative to the previous birth is the logical next step. Multicenter Saudi studies with continuous predictors and external validation are needed before any prediction tool is used in practice.

## Declarations

**Ethics approval and consent to participate.** Approved by the Institutional Review Board of King Abdullah International Medical Research Center (KAIMRC), approval number NRM26/003/2, dated 29 April 2026. The study complied with the Declaration of Helsinki. Individual informed consent was waived because the data were retrospective and de-identified.

**Consent for publication.** Not applicable.

**Availability of data and materials.** The dataset analyzed in this study is available from the corresponding author on reasonable request.

**Competing interests.** The authors declare that they have no competing interests.

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**Authors' contributions.** Dr Ferdus Alshangiti conceived the study as first author, Nadia Naureen(corresponding author) conceived the study, contributed to the statistical analysis and manuscript writing. Farah Asghar contributed to manuscript writing & the statistical analysis. Shaeema Qaiser utilized AI assisted tools to re-run the statistical analyses from the study dataset, generate figures and assist with drafting and language editing. The authors verified the analyses and text and take full responsibility for the content. Sadia Naureen contributed to the statistical analysis as well. Dr Fatima Abdulkarim, Dr Raghad Alghabban and Mohammad Khalid collected the data. Dr Mona Al Airan and Shaeema Q proofread the manuscript. All authors read and approved the final manuscript.

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