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ORIGINAL RESEARCH

Prediction of uterine rupture in singleton pregnancies with one prior cesarean birth undergoing TOLAC: A cross-sectional study

Brittany J. Arkerson[1] | Giulia M. Muraca[2] | Nisha Thakur[3] | Ali Javinani[4] | Asma Khalil[5] | Rohan D'Souza[2] | Hiba J. Mustafa[1,6]

[1]Maternal-Fetal Medicine, Indiana University School of Medicine, Indianapolis, Indiana, USA

[2]Departments of Obstetrics and Gynecology and Health Research Methods, Evidence & Impact at McMaster University, Toronto, Ontario, Canada

[3]IU Luddy School of Informatics, Computing and Engineering, Indiana University, Indianapolis, Indiana, USA

[4]Maternal Fetal Care Center, Boston Children's Hospital, Boston, Massachusetts, USA

[5]Fetal Medicine Unit, St George's Hospital, St George's University of London, London, UK

[6]The Fetal Center at Riley Children's Health, Indianapolis, Indiana, USA

Correspondence
Hiba J. Mustafa, Division of Maternal-Fetal Medicine, Department of Obstetrics and Gynecology, Indiana University School of Medicine, Indianapolis, IN, USA.
Email: hmustafa@iu.edu; hiba.mustafa.md@gmail.com

Abstract

Introduction: Being able to counsel patients with one prior cesarean birth on the risk of uterine rupture with a trial of labor after cesarean, (TOLAC) is an important aspect of prenatal care. Despite uterine rupture being a catastrophic event, there is currently no successful, validated prediction model to predict its occurrence.

Material and Methods: This was a cross-sectional study using US national birth data between 2014 and 2021. The primary objective was to identify risk factors for uterine rupture during TOLAC and to generate a prediction model for uterine rupture among singleton gestations with one prior cesarean as their only prior birth. The secondary objective was to describe the maternal and neonatal morbidity associated with uterine rupture. The association of all candidate variables with uterine rupture was tested with uni- and multi-variable logistic regression analyses. We included term and preterm singleton pregnancies with one prior birth that was cesarean birth (CB) with cephalic presentation undergoing TOLAC. We excluded pregnancies with major structural anomalies and chromosomal abnormalities. The Receiver Operating Characteristics (ROC) Curve was generated. p value <0.001 was considered statistically significant.

Results: Of the 270 329 singleton pregnancies with one prior CB undergoing TOLAC during the study period, there were 957 cases of uterine rupture (3.54 cases per 1000). Factors associated with uterine rupture in multivariable models were an interpregnancy interval < 18 months vs the reference interval of 24–35 months (aOR 1.55; 95% CI, 1.19–2.02), induction of labor (aOR 2.31; 95% CI, 2.01–2.65), and augmentation of labor (aOR 1.94; 95% CI, 1.70–2.21). Factors associated with reduced rates of uterine rupture were maternal age < 20 years (aOR 0.33, 95% CI 0.15–0.74) and 20–24 years (aOR 0.79, 95% CI 0.64–0.97) vs the reference of 25–29 years and gestational age at delivery 32–36 weeks vs the reference of 37–41 weeks (aOR 0.55, 95%

Abbreviations: aOR, adjusted odds ratio; AUC, area under the curve; BMI, body mass index; CB, cesarean birth; CI, confidence interval; ICU, Intensive Care Unit; NICU, Neonatal Intensive Care Unit; OR, odds ratio; ROC, receiver operating characteristics; TOLAC, trial of labor after cesarean; US, United States; VBAC, vaginal birth after cesarean.

CI 0.38–0.79). Incorporating these factors into a predictive model for uterine rupture yielded an area under the receiver-operating curve of 0.66. Additionally, all analyzed maternal and neonatal morbidities were increased in the setting of uterine rupture compared to non-rupture.

Conclusions: Uterine rupture prediction models utilizing TOLAC characteristics have modest performance.

KEYWORDS
TOLAC, trial of labor after cesarean, uterine rupture

1 | INTRODUCTION

A trial of labor after cesarean (TOLAC) is an attempt to achieve a vaginal birth after cesarean (VBAC) with an overall success rate that is reported to be 60%–80%.[1,2] Evidence suggests that most patients with one prior low transverse cesarean birth (CB) are eligible candidates for TOLAC.[3] Counseling on the availability, risks, and benefits of TOLAC vs repeat CB is an important aspect of prenatal care for these patients.

VBAC is associated with fewer immediate maternal complications than elective repeat CB, and, for those who desire future fertility; VBAC may decrease the risk of consequences of multiple cesareans, such as abnormal placentation, bowel/bladder injury, and hysterectomy.[4–6] However, TOLAC is not without the potential for complications, particularly when TOLAC fails. One of the most feared complications is uterine rupture, which contributes most significantly to maternal and neonatal morbidity and mortality.[7,8]

TOLAC-associated uterine rupture rate in the setting of one prior low transverse CB is approximately 0.5%–0.96%.[1,2,9,10] Several studies have attempted to identify risk factors for uterine rupture during TOLAC.[11–14] However, while there is a well-validated prediction model to use prenatally to predict TOLAC success,[15] there is no validated tool to predict the risk of uterine rupture.

Thus, the primary aim of this study was to identify independent risk factors for uterine rupture among singleton gestation with a history of one prior CB undergoing TOLAC using large national data and to incorporate those risk factors into a predictive model. An additional aim of this study was to assess the relationship between uterine rupture and maternal and neonatal morbidity.

Key message

Short interpregnancy interval, induction, and augmentation of labor appear to be the strongest associations with uterine rupture. Uterine rupture prediction utilizing TOLAC characteristics has modest performance. Uterine rupture is associated with high maternal and neonatal morbidity.

2 | MATERIAL AND METHODS

2.1 | Study design

We performed a cross-sectional, US population-based study using data obtained from the natality dataset of the National Center for Health Statistics, Centers for Disease Control and Prevention from January 2014 to December 2021. The natality dataset includes paternal, maternal, prenatal, labor, and obstetric characteristics, as well as maternal/neonatal outcomes. It is derived from the national birth registry and uses the US Standard Certificate for live birth. This certificate is completed for every newborn upon delivery. As the natality dataset does not include any patient identifiers and records are anonymous, the study was exempt from ethics review and no patient consent was required.

2.2 | Inclusion and exclusion criteria

We included singleton pregnancies with cephalic presentation undergoing TOLAC in individuals with one prior birth that was a CB. We excluded pregnancies with major structural anomalies and chromosomal abnormalities.

2.3 | Predictors

From the available information in the natality dataset, we identified potential predictors as factors that were associated with uterine rupture by their significance in univariate analysis as well as correlation with a literature search on previously-documented risk factors for uterine rupture. After excluding variables with missingness >5% or highly correlated with other factors included, we selected the following variables: maternal age, interpregnancy interval, assisted reproductive technology, pre-pregnancy body mass index (BMI), pre-pregnancy diabetes mellitus, gestational diabetes, pre-pregnancy hypertension, hypertensive disorders of pregnancy, induction or augmentation of labor, and gestational age at TOLAC delivery. Methods for induction and augmentation of labor were not specified in the natality data set.

2.4 | Maternal and neonatal outcomes associated with uterine rupture

We assessed the frequency of maternal outcomes and neonatal outcomes in individuals who did and did not experience a uterine rupture. Maternal outcomes included transfusion, unplanned hysterectomy, and admission to the intensive care unit (ICU). Neonatal outcomes included 5-min Apgar score, assisted ventilation, admission to the neonatal intensive care unit (NICU), and seizures. Variables were selected based on their known clinical relevance to TOLAC.

2.5 | Statistical analyses

We used a forward selection approach to develop our predictive model by sequentially adding variables based on their significance in improving model fit, as assessed by the Akaike Information Criterion (AIC). Eleven predictors were entered into the logistic model: maternal age, BMI, interpregnancy interval, use of assisted reproductive technology, pre-existing diabetes, pre-existing hypertension, gestational diabetes, hypertensive disorders of pregnancy, induction of labor, augmentation of labor, and gestational age at delivery. Model performance was assessed using calibration and discrimination. We fitted a calibration plot and reported area under the receiver operating characteristic curve and 95% confidence interval (CI), sensitivity, specificity, and sample-level positive predicted value and negative predicted value to evaluate the ability of our model to classify outcomes correctly (Figure S1). The threshold for classifying those with and without uterine rupture was determined by maximizing Youden's index (the trade-off between sensitivity and specificity).[16] Internal validation was performed with bootstrap methods, and accuracy was reported.

We calculated crude rates and odds ratios (ORs) and 95% CIs for maternal and neonatal morbidity among deliveries with vs without uterine rupture. All statistical analyses and model development were conducted using SAS version 9.4 (Cary, NC).

3 | RESULTS

There were a total of 30 585 139 deliveries in the US between 2014 and 2021. Following exclusions, there were 1 531 035 singleton pregnancies with one prior CB. Of those, 270 329 (17.7%) underwent TOLAC, of which 180 002 (66.6%) had VBAC and 90 327 (33.4%) had failed TOLAC (Figure 1). Of the 270 329 singleton pregnancies with one prior CB undergoing TOLAC, there were 957 cases of uterine rupture (3.54 cases per 1000).

Of the 11 predictors entered into the logistic model, all remained in the final model based on the maximum likelihood ratio in the logistic regression. Following multivariate analysis, factors associated with higher risk of uterine rupture were < 18 months interpregnancy interval vs the reference interval of 24–35 months (aOR 1.55; 95% CI, 1.19–2.02), induction of labor (aOR 2.31; 95% CI, 2.01–2.65), and augmentation of labor (aOR 1.94; 95% CI, 1.70–2.21) (Table 1). Factors associated with reducing the risk of uterine rupture were maternal age < 20 years (aOR 0.33, 95% CI 0.15–0.74) and maternal

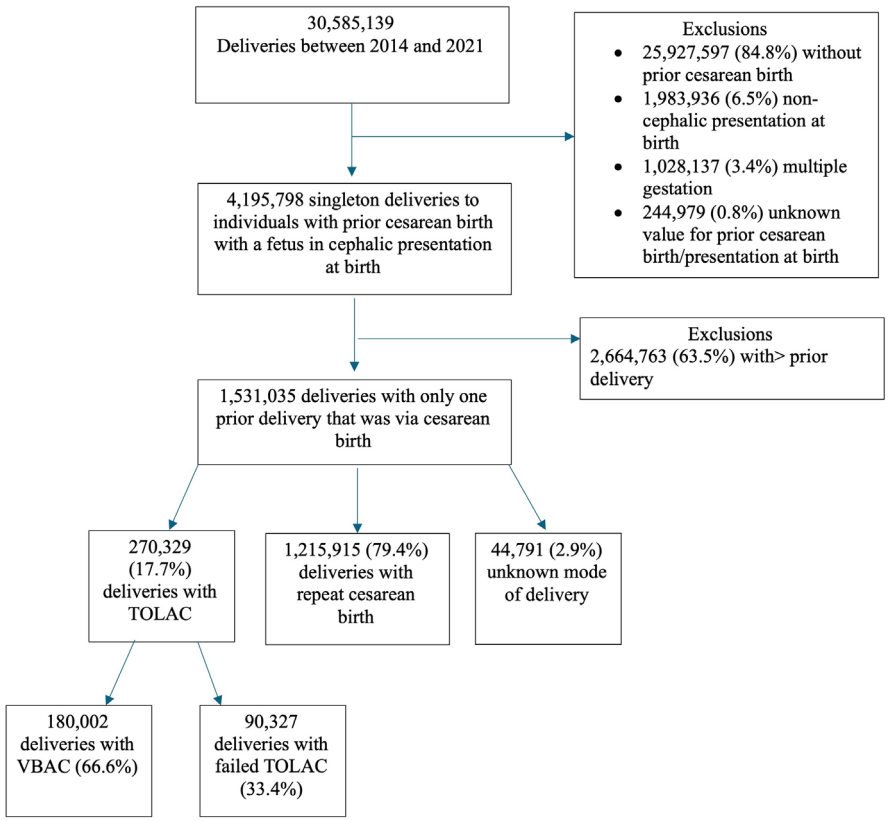

FIGURE 1 Population inclusion and exclusion flow diagram.

TABLE 1 Maternal and obstetric characteristics of singleton pregnancies with one prior cesarean birth undergoing TOLAC.

Characteristic	Cases of uterine rupture	Total	Uterine rupture rate per 1000	Odds ratio (95% CI)	Adjusted[a] odds ratio (95% CI)
All deliveries	957	270329	3.54	-	-
Maternal age					
<20	6	4455	1.35	0.37 (0.16–0.83)	0.33 (0.13–0.67)
20–24	144	46964	3.07	0.84 (0.69–1.02)	0.79 (0.64–0.97)
25–29	303	82937	3.65	Reference	Reference
30–34	335	90469	3.70	1.01 (0.87–1.18)	1.06 (0.90–1.24)
35–39	146	39936	3.66	1.00 (0.82–1.22)	1.08 (0.88–1.33)
≥40	23	5568	4.13	1.13 (0.74–1.73)	1.23 (0.78–1.85)
Body mass index (kg/m^2)					
Underweight (<18.5)	16	6475	2.47	0.65 (0.40–1.07)	0.71 (0.41–1.13)
Normal weight (18.5–24.9)	428	112733	3.80	Reference	Reference
Overweight (25.0–29.9)	247	73949	3.34	0.89 (0.75–1.03)	0.85 (0.73–0.99)
Obesity class I (30.0–34.9)	153	39273	3.90	1.03 (0.85–1.24)	0.98 (0.81–1.18)
Obesity class II (35.0–39.9)	56	18399	3.04	0.80 (0.61–1.06)	0.76 (0.57–1.00)
Obesity class III (≥40.0)	36	12539	2.87	0.76 (0.54–1.06)	0.71 (0.49–0.99)
Unknown/not stated	21	6961	3.02	0.79 (0.51–1.23)	0.83 (0.52–1.25)
Interpregnancy interval (months)					
<18	84	17286	4.86	1.39 (1.08–1.77)	1.57 (1.22–2.01)
18–23	149	36005	4.14	1.18 (0.96–1.44)	1.20 (0.98–1.47)
24–35	256	72871	3.51	Reference	Reference
36–47	151	41585	3.63	1.03 (0.85–1.26)	1.05 (0.85–1.28)
48–59	81	26350	3.07	0.88 (0.68–1.12)	0.88 (0.68–1.13)
60–71	52	17839	2.91	0.83 (0.62–1.12)	0.83 (0.61–1.11)
≥72	184	58393	3.15	0.90 (0.74–1.08)	0.87 (0.71–1.05)
Assisted reproductive technology					
Yes	11	1741	6.32	1.80 (0.99–3.27)	1.53 (0.79–2.67)
No	945	268374	3.52	Reference	Reference
Unknown	1	214	4.67	1.33 (0.19–9.49)	1.24 (0.07–5.53)
Pre-existing diabetes					
Yes	6	2449	2.45	0.69 (0.31–1.54)	0.68 (0.27–1.39)
No	951	267880	3.55	Reference	Reference
Pre-existing hypertension					
Yes	16	4237	3.78	1.07 (0.65–1.75)	1.00 (0.58–1.59)
No	941	266092	3.54	Reference	Reference
Gestational diabetes					
Yes	70	17371	4.03	1.15 (0.90–1.47)	1.08 (0.84–1.37)
No	887	252958	3.51	Reference	Reference
Hypertensive disorders of pregnancy					
Yes	68	13333	5.10	1.48 (1.15–1.89)	1.26 (0.97–1.62)
No	889	256996	3.46	Reference	Reference
Induction					
Yes	328	50726	6.47	2.27 (1.98–2.59)	2.31 (2.01–2.65)
No	629	219514	2.87	Reference	Reference
Unknown	0	89	0.00	-	-

TABLE 1 (Continued)

Characteristic	Cases of uterine rupture	Total	Uterine rupture rate per 1000	Odds ratio (95% CI)	Adjusted[a] odds ratio (95% CI)
Augmentation					
Yes	382	70440	5.42	1.89 (1.66–2.15)	1.94 (1.70–2.21)
No	575	199812	2.88	Reference	Reference
Unknown	0	77	0.00	-	-
Gestational age at delivery (weeks)					
<28	5	1423	3.51	0.96 (0.40–2.32)	1.24 (0.44–2.68)
28–31	6	1600	3.75	1.03 (0.46–2.30)	1.31 (0.52–2.67)
32–36	30	16569	1.81	0.50 (0.34–0.71)	0.55 (0.37–0.78)
37–41	909	249231	3.65	Reference	Reference
≥42	7	1397	5.01	1.38 (0.65–2.90)	1.11 (0.48–2.17)
Unknown	0	109	0.00	-	-

[a]Adjusted for maternal age, maternal pre-pregnancy BMI, interpregnancy interval, assisted reproductive technology, pre-existing diabetes, pre-existing hypertension, gestational diabetes, hypertensive disorders of pregnancy, payment source, labor induction, labor augmentation, and gestational age at delivery.

age 20–24 years (aOR 0.79, 95% CI 0.64–0.97) vs the reference of 25–29 years and gestational age at delivery 32–36 weeks vs the reference of 37–41 weeks (aOR 0.55, 95% CI 0.38–0.79) (Table 1).

We selected the optimal threshold to classify those with and without uterine rupture and evaluated the model performance in the training and bootstrapped data sets (Supplementary material, Table S1). The optimal threshold approximately equaled the incidence of the outcome in each set. The overall AUC was 0.66 (95% CI 0.64, 0.68; Figure 2). Using the optimal threshold, the sensitivity was 0.66, the specificity was 0.60, the positive predictive value was 0.006, and the negative predicted value was 99.8. The overall accuracy and AUC were approximately 0.6–0.7 in both the test and bootstrapped sample (Supplementary material, Table S1).

3.1 | Maternal and neonatal outcomes

Uterine rupture was associated with unplanned hysterectomy (OR 111.66, 95% CI 77.49–160.90), maternal transfusion (OR 28.50, 95% CI 23.41–34.69), and admission to the ICU (OR 35.74, 95% CI 26.75–47.75; Table 2). Neonates delivered in the setting of uterine rupture had higher odds of assisted ventilation (OR 7.99, 95% CI 6.94–9.21) and admission to the NICU (OR 4.45, 95% CI 3.86–5.12), among other negative outcomes (Table 2).

4 | DISCUSSION

In patients pursuing TOLAC in the setting of singleton gestation and one prior CB, factors that were associated with uterine rupture are <18-month interpregnancy interval, induction of labor, or augmentation of labor. Factors that decrease the risk of uterine rupture include younger maternal age and gestational age of 32–36 weeks at the time of delivery. Among pregnancies that experience uterine rupture, the risk of severe maternal and neonatal morbidity is significantly increased.

In the past decade, there have been a few attempts to develop models for uterine rupture during TOLAC. All of these studies were limited by sample size, given the rarity of this event, as well as the predictive factors, which did not yield strong, validated predictive models.[14,17,18] Our study included over 270000 patients undergoing TOLAC, yielding 957 cases of uterine rupture. Despite the larger sample size, our prediction model had a similar performance to these prior studies (AUC 0.66).

In our study, an interpregnancy interval of <18 months was associated with an increased risk of uterine rupture compared to the reference interval of 24–35 months. Historically, inter-delivery intervals of <18 months have been associated with increased rates of uterine rupture during TOLAC, with an interval of less than 6 months being particularly significant.[19,20] Scientifically, this corresponds with what is known about scar healing and tissue remodeling.

Induction of labor has been shown in many studies to increase the risk of uterine rupture during TOLAC.[1,21–24] In particular, the use of prostaglandins for cervical ripening has been discouraged.[1,21] At present, it is unclear if the methods of induction and cervical ripening themselves increase the risk of rupture or if this risk is due to starting TOLAC with an unfavorable cervix. Data on risk related to the augmentation of labor is mixed. This is likely owed to the wide variance in oxytocin administration regarding maximum dose and titration methods. Moreover, a potential confounder to consider in those requiring induction or augmentation is the duration of labor, as longer labor and labor dystocia have been associated with an increased risk of uterine rupture.[25,26] Moreover, there is practice variation concerning candidacy for TOLAC as well as threshold for proceeding with cesarean birth in the setting of a trial of labor relating to fetal status, length of induction, etc. This practice heterogeneity is reflected within both US and international practices, likely impacting the rates of

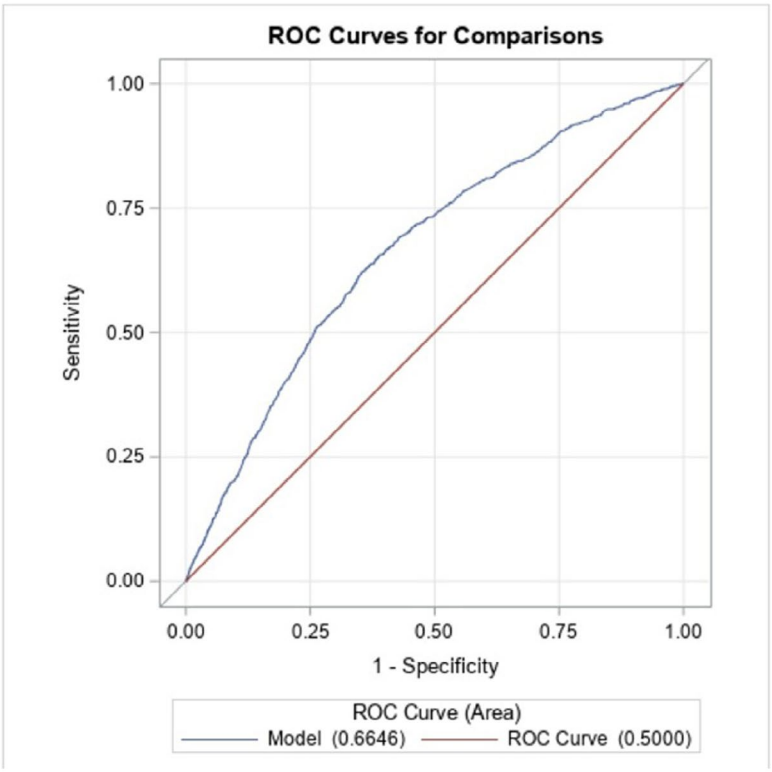

FIGURE 2 Area under the receiver operating characteristics curve for variables included in the prediction model.

ROC Association Statistics

ROC Model	Mann-Whitney				Somers' D	Gamma	Tau-a
	Area	Standard Error	95% Wald Confidence Limits				
Model	0.6646	0.00856	0.6478	0.6813	0.3291	0.3298	0.00232

uterine rupture and further complicating the ability to predict its occurrence.

Our study demonstrated that younger maternal age and gestational age of 32–36 weeks were factors that reduced the risk of uterine rupture. Patients <20 or 20–24 years old were both less likely to experience uterine rupture than the reference group of 25–29 years old. Additionally, gestational age 32–36 weeks was associated with decreased risk of uterine rupture compared to the reference group (37–41 weeks gestation). It is possible that this is due to smaller fetal size, and therefore less distention of the lower uterine segment. This could also be related to the number of spontaneous preterm births vs inductions in this gestational age window, though this was not specifically analyzed.

The results from the studied population suggest that BMI, use of assisted reproductive technology, pre-existing diabetes mellitus, gestational diabetes mellitus, and hypertensive disorders of pregnancy do not influence the risk of uterine rupture. While obesity complicates the management of cases of uterine rupture, it has not been consistently shown to increase the risk of uterine rupture during TOLAC.[27,28] Research regarding the impact of assisted reproductive technology on uterine rupture risk is not substantial. Diabetic disorders and hypertensive disorders of pregnancy have not been shown to impact uterine rupture rates in other studies as well.[29,30]

While the goal of TOLAC is to avoid the risks of repeat cesarean, it is important to simultaneously minimize exposure to significant risks during TOLAC. A uterine rupture is a catastrophic event; each of the negative, clinically relevant maternal and neonatal outcomes that we reviewed was, as expected, significantly increased in the setting of uterine rupture. And while uterine rupture is a rare event, the result is a significant increase in maternal and neonatal morbidity for those who experience it. This emphasizes the importance of developing a prediction model to aid in the counseling of patients considering TOLAC. Moreover, for those who do pursue TOLAC, close intrapartum monitoring is warranted with the goal of preventing uterine rupture.

This study has multiple strengths. Utilizing a national database over 8 years allowed for analysis of a large sample size, which is helpful in the investigation of a rare event such as uterine rupture. In such rare events, identifying statistically significant risk factors can be difficult when evaluating smaller populations. Additionally, using a national database allows for the inclusion of a diverse population, which makes these results more generalizable.

However, this study does have limitations. This natality dataset only reflects births in the US, excluding the ability to apply the results to international settings, where candidacy for and management of TOLAC may differ. Though this database produced a large

TABLE 2 Maternal and neonatal outcomes of singleton pregnancies with one prior cesarean birth undergoing TOLAC.

Characteristic	Uterine rupture Yes	Uterine rupture No
All deliveries	957	269 372
Maternal outcomes		
Unplanned hysterectomy		
Yes	41	108
No	916	269 264
Rate per 1000	42.84	0.40
Odds ratio (95% CI)	111.66 (77.49–160.90)	Reference
Adjusted[a] odds ratio (95% CI)	109.28 (74.85–159.55)	Reference
Maternal transfusion		
Yes	123	1387
No	834	267 985
Rate per 1000	128.53	5.15
Odds ratio (95% CI)	28.50 (23.41–34.69)	Reference
Adjusted[a] odds ratio (95% CI)	24.98 (20.33–30.44)	Reference
Admission to ICU		
Yes	54	450
No	903	268 922
Rate per 1000	56.43	1.67
Odds ratio (95% CI)	35.74 (26.75–47.75)	Reference
Adjusted[a] odds ratio (95% CI)	34.95 (25.96–47.05)	Reference
Neonatal outcomes		
Apgar score <4 at 5-min		
Yes	95	1676
No	862	267 696
Rate per 1000	99.27	6.22
Odds ratio (95% CI)	17.61 (14.17–21.88)	Reference
Adjusted[a] odds ratio (95% CI)	26.13 (20.71–32.97)	Reference
Apgar score <7 at 5-min		
Yes	214	5759
No	743	263 613
Rate per 1000	223.62	21.38
Odds ratio (95% CI)	13.18 (11.30–15.38)	Reference
Adjusted[a] odds ratio (95% CI)	15.28 (13.01–17.94)	Reference
Assisted Ventilation		
Yes	270	12 610
No	687	256 762
Rate per 1000	282.13	46.81
Odds ratio (95% CI)	7.99 (6.94–9.21)	Reference
Adjusted[a] odds ratio (95% CI)	9.06 (7.82–10.50)	Reference
Assisted Ventilation >6 h		
Yes	77	3613
No	880	265 759
Rate per 1000	80.46	13.41
Odds ratio (95% CI)	6.43 (5.08–8.14)	Reference
Adjusted[a] odds ratio (95% CI)	8.63 (6.68–11.15)	Reference
Admission to NICU		
Yes	274	22 279
No	683	247 093
Rate per 1000	286.31	82.71
Odds ratio (95% CI)	4.45 (3.86–5.12)	Reference
Adjusted[a] odds ratio (95% CI)	6.04 (5.21–7.02)	Reference
Seizures		
Yes	24	116
No	933	269 256
Rate per 1000	25.08	0.43
Odds ratio (95% CI)	59.65 (38.26–93.01)	Reference
Adjusted[a] odds ratio (95% CI)	61.58 (38.88–97.52)	Reference
Birth Weight ≥ 4000 g		
Yes	111	22 749
No	846	246 623
Rate per 1000	115.99	84.45
Odds ratio (95% CI)	1.42 (1.17–1.74)	Reference
Adjusted[a] odds ratio (95% CI)	1.32 (1.07–1.62)	Reference

[a]Adjusted models included maternal age, pre-pregnancy BMI, interpregnancy interval, use of assisted reproduction, pre-existing or gestational diabetes, pre-existing or pregnancy-induced hypertension, payment source, induction, augmentation, and gestational age at delivery.

sample size, a limited set of maternal antepartum characteristics were available to be analyzed. Other studies have looked at possible antepartum factors such as prior uterine closure technique (single vs. double layer, locked vs unlocked),[31–33] gestational age at previous cesarean,[34,35] and sonographic thickness of the uterine scar.[12,36,37] While data on these potential risk factors is mixed, being able to evaluate these factors in a larger population could be more enlightening. However, given the data source for this study, these could not be assessed. While this study aimed to utilize TOLAC characteristics to better counsel patients, intrapartum details such as methods of induction or augmentation (i.e., rupture of membranes, oxytocin, and/or cervical ripening balloon), dosing, and time periods could help build a more robust prediction model. Additionally, the natality data set does not include information on whether the repeat cesarean

deliveries that occurred were elective or emergent, nor was the indication included other than stating it was a repeat procedure. This dataset also does not differentiate between cases of true uterine rupture and uterine dehiscence; thus, some dehiscences may have been classified as rupture, resulting in misclassification bias, less accurate associations, and underestimation of severe maternal and neonatal consequences due to true uterine rupture.[38] Moreover, this data set only includes live births, thus excluding cases of uterine rupture that result in fetal death. The result is a likely underestimation of the number of uterine ruptures and rupture-related complications. In summary, large sample size alone is insufficient to overcome the lack of specificity of the analyzed variables as compared to other large population-based TOLAC studies. (39) Additionally, this model has not yet been validated. However, the 2022 Natality Data has been released, and the authors plan on utilizing this for temporal validation of the model. An additional limitation is that birth certificate data has been shown to significantly underreport instances of severe maternal morbidity, including rates of uterine rupture, highlighting a reduction in the sensitivity of the birth certificate as a data source.[39] This may explain why the rates of uterine rupture (0.354%), maternal transfusion (12.9%), and maternal ICU admission (5.6%) were much lower than in the established literature.[1,9,10,40]

5 | CONCLUSION

Factors that were associated with uterine rupture were interpregnancy interval <18 months, induction, and augmentation of labor, while younger maternal age and gestational age 32–36 weeks were associated with decreased risk. Incorporating these factors into a TOLAC prediction model has modest performance. However, the data reinforces that uterine rupture is a rare but catastrophic event that increases rates of severe maternal morbidity and mortality. Thus, further research is imperative to develop more robust prediction models for uterine rupture in TOLAC to help individualize care and continue to improve TOLAC safety.

AUTHOR CONTRIBUTIONS

Brittany J. Arkerson: Writing—original draft; writing—review and editing. Giulia M. Muraca: Statistical analysis. Nisha Thakur: CDC data preparation. Ali Javinani: Methodology. Asma Khalil: Expert review of methods, results, and manuscript. Rohan D'Souza: Expert review of methods, results, and manuscript. Hiba J. Mustafa: Study, design, methods, results, and manuscript review.

CONFLICT OF INTEREST STATEMENT

No conflicts of interest declared for any author.

ETHICS STATEMENT

This study was exempt from ethics committee or IRB review, as the de-identified CDC database that was utilized for data analysis is publicly available and no patient contact or consent were required.

ORCID

Brittany J. Arkerson https://orcid.org/0000-0002-7557-8179

REFERENCES

1. Landon MB, Hauth JC, Leveno KJ, et al. Maternal and perinatal outcomes associated with a trial of labor after prior cesarean delivery. *N Engl J Med*. 2004;351:2581-2589.
2. Macones GA, Peipert J, Nelson DB, et al. Maternal complications with vaginal birth after cesarean delivery: a multicenter study. *Am J Obstet Gynecol*. 2005;193:1656-1662.
3. ACOG Practice Bulletin No. 205: vaginal birth after cesarean delivery. *Obstet Gynecol*. 2019;133:e110-e127.
4. Curtin SC, Gregory KD, Korst LM, Uddin SF. Maternal Morbidity for Vaginal and Cesarean Deliveries, According to Previous Cesarean History: New Data From the Birth Certificate, 2013. *Natl Vital Stat Rep*. 2015;64:1-13.
5. Silver RM, Landon MB, Rouse DJ, et al. Maternal morbidity associated with multiple repeat cesarean deliveries. *Obstet Gynecol*. 2006;107:1226-1232.
6. Nisenblat V, Barak S, Griness OB, Degani S, Ohel G, Gonen R. Maternal complications associated with multiple cesarean deliveries. *Obstet Gynecol*. 2006;108:21-26.
7. Habak PJ, Kole M. Vaginal birth after cesarean delivery. *StatPearls [Internet]*. StatPearls Publishing; 2023 [cited 2023 Nov 29] Available from: http://www.ncbi.nlm.nih.gov/books/NBK507844/
8. Togioka BM, Tonismae T. Uterine Rupture. *StatPearls [Internet]*. StatPearls Publishing; 2023 [cited 2023 Nov 29]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK559209/
9. Flamm BL, Newman LA, Thomas SJ, Fallon D, Yoshida MM. Vaginal birth after cesarean delivery: results of a 5-year multicenter collaborative study. *Obstet Gynecol*. 1990;76:750-754.
10. Amikam U, Hochberg A, Segal R, et al. Perinatal outcomes following uterine rupture during a trial of labor after cesarean: a 12-year single-center experience. *Int J Gynecol Obstet*. 2024;165:237-243.
11. Landon MB. Predicting uterine rupture in women undergoing trial of labor after prior cesarean delivery. *Semin Perinatol*. 2010;34:267-271.
12. Kok N, Wiersma IC, Opmeer BC, de Graaf IM, Mol BW, Pajkrt E. Sonographic measurement of lower uterine segment thickness to predict uterine rupture during a trial of labor in women with previous cesarean section: a meta-analysis. *Ultrasound Obstet Gynecol*. 2013;42:132-139.
13. Tanos V, Toney ZA. Uterine scar rupture - prediction, prevention, diagnosis, and management. *Best Pract Res Clin Obstet Gynaecol*. 2019;59:115-131.
14. Stanhope T, El-Nashar S, Garrett A, et al. 821: prediction of uterine rupture or dehiscence during trial of labor after cesarean delivery: a cohort study. *Am J Obstet Gynecol*. 2013;208:S343-S344.
15. Grobman WA, Lai Y, Landon MB, et al. Development of a nomogram for prediction of vaginal birth after cesarean delivery. *Obstet Gynecol*. 2007;109:806-812.
16. Perkins NJ, Schisterman EF. The Youden index and the optimal cut-point corrected for measurement error. *Biom J Biom Z*. 2005;47:428-441.
17. Macones GA, Cahill AG, Stamilio DM, Odibo A, Peipert J, Stevens EJ. Can uterine rupture in patients attempting vaginal birth after cesarean delivery be predicted? *Am J Obstet Gynecol*. 2006;195:1148-1152.
18. Grobman WA, Lai Y, Landon MB, et al. Prediction of uterine rupture associated with attempted vaginal birth after cesarean delivery. *Am J Obstet Gynecol*. 2008;199:30.e1-30.e5.
19. Stamilio DM, DeFranco E, Paré E, et al. Short interpregnancy interval: risk of uterine rupture and complications of vaginal birth after cesarean delivery. *Obstet Gynecol*. 2007;110:1075-1082.

20. Shipp TD, Zelop CM, Repke JT, Cohen A, Lieberman E. Interdelivery interval and risk of symptomatic uterine rupture. *Obstet Gynecol*. 2001;97:175-177.
21. Lydon-Rochelle M, Holt VL, Easterling TR, Martin DP. Risk of uterine rupture during labor among women with a prior cesarean delivery. *N Engl J Med*. 2001;345:3-8.
22. Grobman WA, Gilbert S, Landon MB, et al. Outcomes of induction of labor after one prior cesarean. *Obstet Gynecol*. 2007;109:262-269.
23. Ravasia DJ, Wood SL, Pollard JK. Uterine rupture during induced trial of labor among women with previous cesarean delivery. *Am J Obstet Gynecol*. 2000;183:1176-1179.
24. Zelop CM. Uterine rupture during a trial of labor after previous cesarean delivery. *Clin Perinatol*. 2011;38:277-284.
25. Hesselman S, Lampa E, Wikman A, et al. Time matters—a Swedish cohort study of labor duration and risk of uterine rupture. *Acta Obstet Gynecol Scand*. 2021;100:1902-1909.
26. Vachon-Marceau C, Demers S, Goyet M, et al. Labor dystocia and the risk of uterine rupture in women with prior cesarean. *Am J Perinatol*. 2016;33:577-583.
27. Hibbard JU, Gilbert S, Landon MB, et al. Trial of labor or repeat cesarean delivery in women with morbid obesity and previous cesarean delivery. *Obstet Gynecol*. 2006;108:125-133.
28. Studsgaard A, Skorstengaard M, Glavind J, Hvidman L, Uldbjerg N. Trial of labor compared to repeat cesarean section in women with no other risk factors than a prior cesarean delivery. *Acta Obstet Gynecol Scand*. 2013;92:1256-1263.
29. Srinivas SK, Stamilio DM, Stevens EJ, Peipert JF, Odibo AO, Macones GA. Safety and success of vaginal birth after cesarean delivery in patients with preeclampsia. *Am J Perinatol*. 2006;23:145-152.
30. Levin G, Tsur A, Tenenbaum L, Mor N, Zamir M, Meyer R. Prediction of successful vaginal birth after cesarean in women with diabetic disorders and no prior vaginal delivery. *Int J Gynecol Obstet*. 2022;157:165-172.
31. Bujold E, Goyet M, Marcoux S, et al. The role of uterine closure in the risk of uterine rupture. *Obstet Gynecol*. 2010;116:43-50.
32. Hudic I, Bujold E, Fatusic Z, Roberge S, Mandzic A, Fatusic J. Risk of uterine rupture following locked vs unlocked single-layer closure. *Mediev Archaeol*. 2012;66:412-414.
33. Roberge S, Bujold E. 685: single versus double layer closure and risk of uterine rupture: systematic review and meta-analysis. *Am J Obstet Gynecol*. 2009;201:S247.
34. Mantel Ä, Ajne G, Wollmann CL, Stephansson O. Previous preterm cesarean delivery and risk of uterine rupture in subsequent trial of labor—a national cohort study. *Am J Obstet Gynecol*. 2021;224:380.e1-380. e13.
35. Sciscione AC, Landon MB, Leveno KJ, et al. Previous preterm cesarean delivery and risk of subsequent uterine rupture. *Obstet Gynecol*. 2008;111:648-653.
36. Bujold E, Jastrow N, Simoneau J, Brunet S, Gauthier RJ. Prediction of complete uterine rupture by sonographic evaluation of the lower uterine segment. *Am J Obstet Gynecol*. 2009;201:320.e1-320.e6.
37. Swift BE, Shah PS, Farine D. Sonographic lower uterine segment thickness after prior cesarean section to predict uterine rupture: a systematic review and meta-analysis. *Acta Obstet Gynecol Scand*. 2019;98:830-841.
38. Al-Zirqi I, Daltveit AK, Forsén L, Stray-Pedersen B, Vangen S. Risk factors for complete uterine rupture. *Am J Obstet Gynecol*. 2017;216:165.e1-165.e8.
39. Luke B, Brown MB, Liu CL, Diop H, Stern JE. Validation of severe maternal morbidity on the US certificate of live birth. *Epidemiology*. 2018;29:e31-e32.
40. Amikam U, Hochberg A, Abramov S, Lavie A, Yogev Y, Hiersch L. Risk factors for maternal complications following uterine rupture: a 12-year single-center experience. *Arch Gynecol Obstet*. 2024;309:1863-1871.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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