Prediction of vaginal birth after cesarean delivery in southeast China: A retrospective cohort study

Hua-Le Zhang  
Fujian provincial maternity and children's hospital  
https://orcid.org/0000-0003-4789-4016

Liang-Hui Zheng  
Fujian provincial maternity and children's hospital

Li-Chun Cheng  
Fujian provincial maternity and children's hospital

Zhao-Dong Liu  
Fujian provincial maternity and children's hospital

Lu Yu  
Fujian medical university

Qin Han  
Fujian provincial maternity and children's hospital

Geng-Yun Miao  
Fujian Medical University

jianying Yan (yanjy2019@fjmu.edu.cn)  
https://orcid.org/0000-0003-4289-3444

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Abstract

Objective To develop and validate a nomogram to better predict the vaginal birth after cesarean (VBAC) on the premise of clinical guide application. Methods We retrospectively identified hospitalised pregnant women who trial of labor after cesarean (TOLAC) between October 2015 and October 2017 using data from the Fujian Provincial Maternity and Children's Hospital. The inclusion criteria were as follows: Singleton pregnant women whose gestational age was above 37 weeks and underwent a primary cesarean section. Sociodemographic data and Clinical Characteristics were extracted. The samples were randomly divided into a training set and a validation set. Least absolute shrinkage and selection operator (LASSO) regression were used to select variables and construct of VBAC success rate in training set. The validation of the nomogram was performed using the concordance index (C-index), decision curve analysis (DCA), and calibration curves in the validation set. For comparison with published VBAC prediction models, the Grobman's model was used. Results Among the 708 pregnant women included according to inclusion criteria, 586 (82.77%) patients were successfully for VBAC. In multivariate logistic regression models, Maternal height (OR, 1.11; 95% CI, 1.04 to 1.19), maternal BMI at delivery (OR, 0.89; 95% CI, 0.79 to 1.00), fundal height (OR, 0.71; 95% CI, 0.58 to 0.88), cervix Bishop score (OR, 3.27; 95% CI, 2.49 to 4.45), maternal age at delivery (OR, 0.90; 95% CI, 0.82 to 0.98), gestational age (OR, 0.33; 95% CI, 0.17 to 0.62) and history of vaginal delivery (OR, 2.92; 95% CI, 1.42 to 6.48) were independently associated with successful VBAC. The predictive model was constructed showed better discrimination in the validation series than Grobman's model (c-index 0.906 VS 0.694, respectively). Decision curve analysis revealed that the new model resulted in a better clinical net benefit than the Grobman's model. Conclusions The promotion of VBAC is helpful to reduce the cesarean section rate in China. On the basis of following the clinical practice guidelines, the TOLAC prediction model helps to improve the success rate of VBAC and has a potential contribution to the reduction of secondary cesarean section.

Introduction

Reducing cesarean section rate has been a global consensus, however, the increase in cesarean delivery (CD) rate seems uncontrollable, and no signs that it is slowing down1. Statistical data demonstrated that the CD rate in china has increased by 20.8% from 2008 to 2014, and in certain regions CD rate is even higher2.

In the cesarean section caused by various reasons, the repeat cesarean delivery is the most important component, and after the implementation of the two-child policy the reduce repeat cesarean delivery will facing new challenges3-5. Since the 1970s, accumulated data have supported a trial of labor after cesarean (TOLAC) as a way to reduce cesarean section rates. Not only a high success VBAC ratio, but also low rates of adverse outcomes and more cost effective6 7. So professional organizations tendency patients and clinicians to attempt TOLAC. Clinical practice guidelines can be used to support evidence-based practice in such circumstances. For the tense doctor-patient relationships in china, Clinical practice guidelines can be used in different levels of hospitals to support evidence-based
practice in such circumstances. Among the many versions of clinical guidelines, Southeast China pays more attention to the practice of 2015RCOG guidelines, and the subsequent release of Chinese guidelines also take it as an important reference standard\textsuperscript{8,9}. However, TOLAC failure is associated with a greater perinatal risk than is elective repeated cesarean delivery without labor\textsuperscript{10}. To avoid doctor-patient disputes caused by the complications of TOLAC failure, Chinese medical staff prefer a sound plan, so it is important to distinguish whether TOLAC is successful or not before delivery. To date, there have been many studies of computational an individualized risk assessment for successful TOLAC\textsuperscript{11,12}. Moreover, some predict model development or validation for Chinese pregnancy women\textsuperscript{13-15}. However, predictive models based on local clinical guidelines as inclusion criteria of TOLAC are missing. Medical staffs in southeastern China are more likely to practice TOLAC, according to the admission criteria of clinical guidelines. Therefore, a prediction model based on this demand may help to improve TOLAC practice and reduce the CD rate.

In this retrospective study, we aimed to build a personalized prediction model for successful TOLAC in a population with the admission criteria of clinical guidelines. Such a model can evaluate the feasibility of VBAC before delivery.

**Methods**

**Study setting and data source**

We conducted a retrospective observational study using data from the Fujian Provincial Maternity and Children's Hospital A tertiary hospital in southeastern China case register. Fujian Provincial Maternity and Children's Hospital is a specialized hospital serving nine prefecture-level cities, with an annual delivery volume of nearly 20,000. For this study, patients' data was later extracted from medical record databases using pre-defined data fields.

**Participants**

Inclusion and exclusion criteria were assessed by investigators based on China's clinical guidelines for VBAC\textsuperscript{9}. The inclusion criteria were as follows: women with a singleton pregnancy of cephalic presentation at 37 weeks or beyond who have had a single previous lower segment caesarean delivery. There is no indication of the previous cesarean section, and estimated the fetal weight is less than 4000 g. The ultrasound measurement suggested that the lower segment uterine scar was intact. Exclusion criteria: Women with two or more prior caesareans, classical cesarean scar or previous uterine rupture, and women who have other absolute contraindications to vaginal birth.

**Outcomes**

Primary outcome measure used success rate of trial of labor after cesarean (TOLAC). Secondary outcomes evaluated included maternal outcome features: uterine rupture, mortality, post-partum hemorrhage (estimated blood loss of more than 500 ml and 1000 ml for vaginal and cesarean deliveries,
respectively). Neonatal outcome features included: mortality, neonatal asphyxia (defined as 5-minute Apgar score $\leq 7$).

**Predictors**

Independent variables were extracted from medical record databases based on values recorded at the time of spontaneous production symptom. Extracted demographic information included age (on delivery date), maternal height, pre-gravid maternal weight, maternal weight at delivery, gravida, parity, abdominal, fundal height, Cervix Bishop score (Check the cervix when the onset of regular uterine contractions for two hours), history of vaginal delivery and gestational age.

**Statistical analysis**

We used R software (V3.6.2) in all drawings and statistical analyses with a significance level of 5%. Demographic and clinical characteristics were initially compared by outcome status using $t$ tests or $\chi^2$ tests as appropriate. Construction and validation of the nomogram:

In the design of the nomogram, we incorporated clinical features as predict predictors. Seventy percent ($n = 483$) were randomly assigned to the training cohort and the rest of thirty percent ($n = 225$) as the test cohort. We used the least absolute shrinkage and selection operator (LASSO) regression with 5-fold cross-validation to select the most useful predictive variables via 1se criteria for nomogram from the training cohort. Internal validation was first undertaken, with a concordance index (C-index) being estimated in the test cohort. Next, calibration curves were plotted to determine whether the predicted and observed probabilities for survival time were in concordance. Bootstrap resampling (1000 resamples) was used for this plot. Finally, the decision curve analysis (DCA) was used to evaluate the clinical usefulness of the nomograms. Our research also validates the Grobman's model$^{12}$ in the test cohort and compares it with our model.

**Patient and public involvement**

This retrospective study was approved by the local institutional review boards and ethical committees, and written informed consent wasn't required to cause unidentifiable patient information used only.

**Results**

**Sample characteristics of the cohort**

During the observation period of 5951 pregnant women with a history of previous CS were identified. Of these, 1191 had a Vaginal delivery plan after 36 weeks of pregnancy, and these comprised the sample for the candidate. Cases that were not medically indicated during vaginal delivery due to patients or family members were excluded. At last, 708 pregnant women were included in the final analysis based on the inclusion and exclusion criteria. **Table 1** present Clinical characteristic of the training($n=483$) and validation($n=225$) cohorts were no statistical differences. Mean maternal age at delivery was 31.28(SD: ...
3.64) years and median gestation of the delivery was 39 weeks (IQR: 38.29-39.86). None of the pregnant women had preeclampsia or gestational hypertension during pregnancy. An overall TOLAC success rate of 82.8% was found in the cohorts. 39 (5.5%) of those women undergoing TOLAC were diagnosed with postpartum hemorrhage, 2(0.28%) women had a uterine rupture, and only one (0.14%) new-born had neonatal asphyxia. No maternal death and hysterectomy was noted. The reasons for TOLAC failure were abnormal stage of labour (34.4%), fetal monitoring change (33.6%), sharp lower abdominal pain (14.8%), fever or abnormal bleeding (9.8%) and other (7.4%).

Table 1 Clinical characteristics of the training and validation cohorts
| Characteristics                      | Whole cohort (n=708) | Training cohorts (n=483) | Validation cohorts (n=225) | P* |
|--------------------------------------|----------------------|--------------------------|---------------------------|----|
| Maternal height (mean (SD))          | 1.60 (0.05)          | 159.80 (4.87)            | 159.27 (5.00)             | 0.180 |
| Pre-gravid maternal weight (mean (SD)) | 53.27 (7.19)        | 53.43 (7.43)             | 52.93 (6.64)              | 0.383 |
| Maternal weight at delivery (mean (SD)) | 66.74 (7.84)        | 67.07 (8.03)             | 66.02 (7.37)              | 0.095 |
| Pre-gravid maternal BMI (median [IQR]) | 20.62 [19.15, 22.42] | 20.57 [19.07, 22.48]    | 20.78 [19.33, 22.06]      | 0.703 |
| Maternal BMI at delivery (median [IQR]) | 26.16 [24.36, 27.88] | 26.20 [24.34, 27.96]    | 26.02 [24.50, 27.50]      | 0.392 |
| Abdominal (mean (SD))                | 98.37 (5.05)         | 98.44 (5.23)             | 98.21 (4.62)              | 0.582 |
| Fundal height (mean (SD))            | 33.87 (1.50)         | 33.91 (1.57)             | 33.78 (1.31)              | 0.253 |
| Cervix Bishop score (median [IQR])    | 7.00 [7.00, 8.00]    | 7.00 [7.00, 8.00]        | 7.00 [7.00, 8.00]         | 0.909 |
| Maternal age at delivery (mean (SD)) | 31.28 (3.64)         | 31.23 (3.58)             | 31.39 (3.78)              | 0.574 |
| Gestation (median [IQR])             | 39.00 [38.29, 39.86] | 1.00 [0.00, 1.00]        | 1.00 [0.00, 1.00]         | 0.334 |
| Cesarean section interval time (median [IQR]) | 5.00 [3.00, 7.00]    | 5.00 [3.00, 6.50]        | 4.00 [3.00, 7.00]         | 0.942 |
| History of vaginal delivery (%)      | NO 473 (66.8)        | 319 (66.0)               | 154 (68.4)                | 0.585 |
|                                      | YES 235 (33.2)       | 164 (34.0)               | 71 (31.6)                 |    |
| Rupture of membrane s (%)            | NO 473 (66.8)        | 332 (68.7)               | 141 (62.7)                | 0.131 |
|                                      | YES 235 (33.2)       | 151 (31.3)               | 84 (37.3)                 |    |
| Success of TOLAC (%)                 | NO 122 (17.2)        | 86 (17.8)                | 36 (16.0)                 | 0.627 |
|                                      | YES 586 (82.8)       | 397 (82.2)               | 189 (84.0)                |    |

* t test or χ² test; Mann-Whitney U test was applied for Non-normally distributed data.  
IQR, interquartile range; BMI, Body Mass Index; SD, standard deviation.

Predictors of TOLAC success
Univariate analysis showed that maternal height, maternal BMI, parity, fundal height, the cervix bishop score, duration time of labour, maternal age, history of vaginal delivery and rupture of membranes were associated with the success rate of TOLAC (table 2).

For the development of nomogram, we incorporated clinical characteristics as prognostic features. All these parameters were reduced to the most useful potential predictors for the success rate of TOLAC in the training cohort, in the LASSO logistic regression model. Nomogram to predict success rate of TOLAC was developed using the results from the LASSO logistic regression model (figure 1). Maternal height, maternal BMI at delivery, fundal height, the cervix Bishop score, maternal age at delivery, gestation great than 39 weeks and history of vaginal delivery were independent predictors for TOLAC (figure 2 and table 3).

**Nomogram validation and compare**

The predictive accuracy for the success rate of TOLAC as measured by C-index was 0.89 in the internal validation. The calibration plot for the probability of success of TOLAC showed a good correlation between the actual observed outcome and the prediction by the nomogram (figure 3a). Calibration curves were plotted to describe the performance of the newly-developed nomogram and Grobman's model in the test cohort, respectively (figure 3b and 3c). Among the patients predicted to be included in the standard according to clinical guidelines, from the data in Figure 3, the newly-developed nomogram model is superior to the Grobman's model in both the correlation and c-index (c-index: 0.90 vs 0.69, respectively).

**Decision curve analysis**

Figure 3d illustrates the decision curves for newly-developed nomogram model and Grobman's model to predict the rate of TOLAC in patients with new model were useful between threshold probabilities of 60–90%, and the calibration curves also shows that the actual vaginal delivery success rate is higher in this interval.

**Table 2: Sample characteristics by TOLAC status**
| Characteristics                        | Failure of TOLAC (n=12) | Success of TOLAC (n=58) | P*     |
|---------------------------------------|-------------------------|--------------------------|--------|
| Maternal height (mean (SD))           | 1.58 (0.05)             | 1.60 (0.05)              | <0.001 |
| Pre-gravid maternal weight (mean (SD))| 53.55 (7.56)            | 53.21 (7.11)             | 0.635  |
| Maternal weight at delivery (mean (SD))| 67.64 (7.98)            | 66.55 (7.80)             | 0.164  |
| Pre-gravid maternal BMI (median [IQR])| 21.23 [19.71, 22.95]    | 20.57 [19.04, 22.26]     | 0.013  |
| Maternal BMI at delivery (median [IQR])| 27.10 [25.24, 28.78]    | 26.00 [24.20, 27.60]     | <0.001 |
| Parity (median [IQR])                 | 1.00 [1.00, 2.00]       | 1.00 [1.00, 3.00]        | <0.001 |
| Abdominal (mean (SD))                 | 98.56 (5.26)            | 98.33 (5.00)             | 0.639  |
| Fundal height (mean (SD))             | 34.32 (1.60)            | 33.78 (1.46)             | <0.001 |
| Cervix Bishop score (median [IQR])    | 6.00 [4.00, 6.00]       | 8.00 [7.00, 8.00]        | <0.001 |
| Duration time of labor (median [IQR]) | 7.00 [4.00, 10.75]      | 5.57 [4.10, 8.30]        | 0.044  |
| Maternal age at delivery (mean (SD))  | 31.87 (3.57)            | 31.16 (3.64)             | 0.049  |
| Gestation (median [IQR])              | 39.00 [38.00, 40.00]    | 39.00 [38.29, 39.86]     | 0.177  |
| Cesarean section interval time (median [IQR]) | 5.00 [3.00, 7.00]      | 5.00 [3.00, 7.00]        | 0.28   |
| History of vaginal delivery (%)       | NO                      |                           |        |
|                                       | 104 (85.2)              | 369 (63.0)               | <0.001 |
|                                       | YES                     | 18 (14.8)                |        |
|                                       |                         | 217 (37.0)               |        |
| PROM (%)                              | NO                      |                           |        |
|                                       | 96 (78.7)               | 377 (64.3)               | 0.003  |
|                                       | YES                     | 26 (21.3)                |        |
|                                       |                         | 209 (35.7)               |        |

*t test or χ² test; Mann-Whitney U test was applied for Non-normally distributed data.

Table 3: predictors for the nomogram of TOLAC success rate
### Discussion

Prior studies have noted the importance of encouraging TOLAC in reducing the CD rate and improving maternal and child outcomes\(^6\). Several reports have shown that using the Generalizing Grobman’s model to predict the success rate of TOLAC in the Chinese population also has a strong clinical predictive power\(^13\)\(^15\). However, the inclusion population of these studies lacks uniform standards. Given the vigorous promotion of clinical guidelines for obstetrics in China in recent years to reduce medical disputes and improve healthcare quality, it is very important to select patients to be predicted based on clinical guidelines, since the prediction models should be applied only to patient populations selected with similar inclusion and exclusion criteria and clinical management\(^16\). The target of the project was to identify the factors that influence the success rate of TOLAC and to develop a predictive model during the implementation of clinical guidelines. Based on the external verification of the widely used Grobman’s model, through the improvement of the Grobman’s model, the corresponding features before delivery were added, the predictive model of this study shows a good prediction ability.

While a clear trend of benefit from the successful vaginal delivery among those trials of labor after cesarean, it should be noted that VBAC failure increases many risks, such as bleeding, blood transfusions, uterine rupture and endometritis, and infant asphyxia or perinatal death\(^8\)\(^17\)\(^18\). Due to the complex physician-patient relationship and the increase in work-related stress, Obstetricians prefer a more conservative approach during TOLAC to avoid medical disputes. When longer labor course or changes in fetal heart rate occur during TOLAC, doctors are more active to take repeat cesarean section to avoid the adverse consequences of uterine rupture or neonatal asphyxia. For this reason, as the results show, the incidence of adverse clinical outcomes such as uterine rupture and neonatal asphyxia is lower than the related literature. However, this strategy also reduces the success rate of TOLAC accordingly.
In this study, the risk model described has several advantages in its discrimination and calibration compared to Grobman’s model, by increasing and selecting the predictor variable near delivery.

The inclusion and exclusion criteria of this study were based on recent clinical guidelines, and the pre-delivery variables were increased by modifying the Grobman’s model. These results are in accord with recent studies indicating maternal BMI at delivery, history of vaginal delivery and maternal age at delivery are relevant or independent risk factors for the success of TOLAC\textsuperscript{12,19-22}. Among these factors, history of vaginal delivery can be used to predict TOLAC success was not in dispute\textsuperscript{23}. Even if the proportion of older pregnant women increased affected by China’s recent two-child policy, we still find that maternal age is correlated with the success of TOLAC. Given the differences in BMI between different races\textsuperscript{24}, maternal BMI as a continuous variable included in the model. The results of LASSO screening showed that maternal pre-pregnancy weight is not an independent risk factor for TOLAC’s success, and the maternal weight at delivery has a correlation with the success rate.

Bishop’s score is a relatively subjective indicator, for standardization, we looked up the cervical bishop’s score two hours after regular uterine contractions, and checked the results of midwives and obstetricians at the same time, and averaged them. We found a positive correlation between Bishop’s score and success of TOLAC. This finding is consistent with that of Francis(2005) who declare that risk of cesarean delivery related to an unfavourable Bishop score at admission\textsuperscript{25}. Similarly, several studies confirms that the Bishop’s score at delivery affects the success rate of TOLAC\textsuperscript{17,26}. The OR of Bishop’s score in this investigation were higher and have relatively narrow confidence intervals compared to those of other studies and have(OR, 3.27; 95% CI, 2.49 to 4.55). It is possible that previously reported models may underestimate the role of standardized cervical evaluation.

Maternal pelvis shape and fetal weight are the determining factor for the success of TOLAC\textsuperscript{13,21}, however, both of them are hard to estimate, in general. A strong relationship between maternal pelvis shape and their height has been reported in the literature\textsuperscript{27}. Corresponding to this result, in this study pregnant women with higher heights seem to have a greater chance of TOLAC success. Hence, it could conceivably be hypothesised that maternal height is an independent factor that influences the success of TOLAC. Determine fetal weight by ultrasound scan is difficult to obtain high accuracy, and easily affected by the experience of ultrasound doctors\textsuperscript{28}. In addition, ultrasound scan is difficult to standardize the estimated weight between different hospitals, so we chose the fundal height and maternal abdominal as the indicators to included in the model, and noted fundal height showed a negative correlation with TOLAC success.

It has been suggested that Using pregnancy at 40 weeks as the cut-off point to develop a prediction model\textsuperscript{29,30}. However, for reference the clinical guidelines, in the present study we used a cutoff of 39 weeks for delivered gestational weeks. However, for reference the clinical guidelines, in the present study we used a cutoff of 39 weeks for delivered gestational weeks. Interestingly, the similar results were
observed for using these difference cut-off values: the later of gestational weeks, the lower the success rate of TOLAC.

Although studies have implicated the hysterotomy scar can predict the success of TOLAC\textsuperscript{31}--\textsuperscript{32} we did not evaluate performance on the hysterotomy scar. Due to this examination is difficult to standardize and is not conducive to further promotion to the primary hospital because of the difference in the experience of ultrasound doctors and examination methods. Recent evidence also suggests that the prediction model based on the sonographic assessment of a hysterotomy scar demonstrated poor accuracy for the prediction of successful VBAC\textsuperscript{32}.

Finally, this study had several limitations, including those inherent to the study design, particularly those dependent on retrospective recall of medical services received. Although we screened all vaginal trial cases during the study period, some patients refusal TOLAC and select repeat cesareans. Secondly, the sample size limited includes more clinical factors to prediction models for improvement of accuracy. Third, since this study is a single center study in Southeast China, additional researches should be conducted to amend and verify the predict model for fully promoted in China.

**Conclusion**

In Southeast China, the TOLAC ratio is still low (20%), this study set out to develop a model for predict the success rate of TOLAC. The key strengths of this study are its inclusion and exclusion criteria consistent with clinical guidelines. Our data confirm safety of TOLAC in accordance with clinical guidelines. These findings may help obstetrician of southeast China to predict the success rate of TOLAC and have a number of practical implications. However, to further confirm and broader variety of applications the present model, it may be necessary to generalize the models. Further prospective research and multicentre clinical trials should be carried out to verify and refine the model.

**Abbreviations**

TOLAC: Trial of Labor After Cesarean; VBAC: Vaginal Birth After Cesarean; BMI: Body Mass Index; CS: Caesarean Section; CD: Cesarean Delivery; IQR, interquartile range; SD, standard deviation; LASSO: Least Absolute Shrinkage and Selection Operator; OR: Odds Ratio; CI: confidence interval;

**Declarations**

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Availability of data and materials

Data were anonymized and no patient identifying information was included for preserve patient confidentiality. All data to evaluate the conclusions in the paper available for scientific purposes if needed.

Authors’ contributions

HLZ and JYY conceptualised the study. LCC, ZDL and LY contributed to data acquisition. HLZ and LHZ designed the analyses, QH and GYM performed the analyses. HLZ and LHZ drafted the manuscript. All authors revised the manuscript for important intellectual content.

Ethics approval and consent to participate

Ethical approval for this study was granted by the ethics committee of Fujian Provincial Maternity and Children's Hospital. Permission to access the anonymized (de-identified) data was granted by the Fujian Provincial Maternity and Children's Hospital Database steering committee.

Consent for publication

All data was anonymised so individual consent for publication was not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

1. Department of Obstetrics and Gynecology, Fujian Provincial Maternity and Children's Hospital, Affiliated Hospital of Fujian Medical University

2. Fujian Medical University

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**Figures**
Figure 1

Feature selection using the least absolute shrinkage and selection operator (LASSO) logistic regression model. (a) LASSO coefficient profiles of the 13 features for success rate of TOLAC. (b) Tuning parameter (lamda) selection in the LASSO model used 5-fold cross-validation via minimum criteria for success rate of TOLAC.

Figure 2

Nomogram of success rate of TOLAC.
Figure 3

Calibration curves of the nomogram in training cohort and validation cohorts of TOLAC. (a) Prediction of success rate of TOLAC in training cohort of TOLAC. (b) prediction of success rate of TOLAC used Grobman's model in validation (test) cohort of TOLAC. (c) Calibration curves for Success probability of TOLAC nomogram construction (Bootstrap = 1000 repetitions) in validation (test) cohort of TOLAC. (d). Decision curve analysis for two method.