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ARTICLE

Development of a Modified Score System as Prediction Model for Successful Vaginal Birth After Cesarean Delivery

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This study was designed to establish a modified prediction score system to improve the safety and success rate of vaginal birth after cesarean delivery (VBAC). We recruited 406 patients (between January 2012 and December 2016) and generated a modified score system in predicting the success rate of VBAC. All patients were required to sign informed consent forms. There were 87.2% of patients who had successful VBAC deliveries and 12.8% patients who had repeated cesarean sections. We conducted multivariable logistic regression and found seven variables that were associated with VBAC success, including previous primary indication of cesarean delivery (odds ratio (OR), 2.1; 95% confidence interval (CI), 1.4–3.0), previous vaginal birth history (OR, 2.5; 95% CI, 1.8–3.8), < 40 years of age (OR, 2.1; 95% CI, 1.2–3.3), < 20 kg weight gain (OR, 1.5; 95% CI, 1.2–2.3), no labor induction (OR, 1.9; 95% CI, 1.5–2.9), high score of pelvic/birth weight (OR, 1.4; 95% CI, 1.1–2.1), and Bishop score (OR, 1.3; 95% CI, 1.2–1.4). After adjustment for optimism, the area under the receiver operating characteristic curve (AUC-ROC) was 0.849 (95% CI, 0.78–0.89), and the modified VBAC score was positively correlated with the success rate of trial of labor after cesarean delivery (TOLAC). A valid and useful score system was established to predict VBAC success rate.

Study Highlights

WHAT IS THE CURRENT KNOWLEDGE ON THE TOPIC?
☑ Secondary CS is associated with increased short-term and long-term complications.
WHAT QUESTION DID THIS STUDY ADDRESS?
☑ To identify a valid model for women who opted for TOLAC so that the predicted success rate of TOLAC at admission time could be provided to encourage TOLAC.
WHAT DOES THIS STUDY ADD TO OUR KNOWLEDGE?
☑ We have proposed a model that can provide useful information to predict VBAC success rate at admission time for pregnant women who previously had a primary cesarean delivery.
HOW MIGHT THIS CHANGE CLINICAL PHARMACOLOGY OR TRANSLATIONAL SCIENCE?
☑ A model fitting in with pregnancy prediction after cesarean delivery will aid the obstetric medical personnel to estimate the feasibility of vaginal delivery, and also be of great importance for the enhancement in the confidence of pregnant women in selecting vaginal delivery.

Given that family planning policy has changed and the living standard has improved in China, the demand of women for having a second child has been going up recently. The high cesarean section (CS) rate in China made it increasingly significant to provide counseling to women regarding the possibility of trial of labor after cesarean delivery (TOLAC). Although the risk of maternal rupture and other adverse outcomes associated with TOLAC do exist, a large body of evidence shows that secondary CS is associated with increased short-term and long-term complications.[1] Previous studies have demonstrated that less morbidity is often associated with the success of vaginal birth after cesarean delivery (VBAC) compared with an elective repeat cesarean delivery,[2–4] and unsuccessful TOLAC may lead to higher morbidity. Therefore, VBAC may bring more benefits to both the child and the mother.

To ensure the success rate of TOLAC, predictive models have been developed to predict successful VBAC.[5–13] However, a more accurate prediction of the outcome of maternal VBAC may not only help clinicians assist patients in selecting delivery mode but also avoid complications. At the time of admission, an accurate prediction of successful VBAC may persuade more women to try TOLAC, thus reducing the risk of complications due to multiple cesarean deliveries.[14] Therefore, the main purpose of this study is to identify a valid model for women who opted for TOLAC,

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so that the predicted success rate of TOLAC at admission could be provided to encourage TOLAC. To this end, we enrolled patients (between January 2012 and December 2016) and generated a modified score system to predict the success rate of VBAC.

METHODS

This retrospective cohort study was conducted at Cangzhou Central Hospital from January 2012 to December 2016. The hospital institutional review board approved this study. The size of our study was determined by the available cohort during the study period.
Inclusion criteria:

1. History of CS with previous transverse uterine incision, no new CS indication.
2. Pregnancy with one fetus.
3. The last CS was CS with transverse incision over 18 months ago.
4. No history of maternal rupture.
5. No history of repeated uterine injuries.
6. Gestational age between 35 and 40 weeks.
7. No complications associated with pregnancy and surgery.
8. Lower uterine segment scar continuous shown by ultrasound examination.
9. Signed patient consent forms.

Exclusion criteria:

1. T-cut CS, classical incision, or incision unknown in the last CS.
2. Cephalopelvic disproportion.
3. Had new indications for CS.
4. Suspicious uterine rupture.
5. Lower uterine tenderness.
6. Ultrasonic examination showed: (i) lower uterine with uneven thickness or scar defect; (ii) loss of muscle fiber at the lower uterine; (iii) umbilical cord prolapsed through urethra; or (iv) visible fetal movement.
7. Infection or uterine diverticulum in previous CS.
8. Exhibited complications associate with surgery and pregnancy.
9. Had more than one CS.
10. Pregnancy beyond 40 weeks.

Our final data analysis in this study included a total of 406 patients. Newborns with anomalies were excluded. To identify the patients, we used TOLAC request recorded by a nurse at admission coupled with a consent form signed by the patient. Demographic and obstetric data were collected using patient medical records. At the admission, we also recorded multiple variables, including gestational diabetes, pre-eclampsia or eclampsia, use of oxytocin, small-for-gestational-age neonate, indication for cesarean delivery, and mode of delivery. We used Rice pelvimeter to measure the pelvic area and conducted the first digital cervical examination at admission and calculated the Bishop score.[15] The patient was excluded from the study if the data for cervical examination were missing.

Statistical analysis

We used multivariable, stepwise, backward logistic regression to determine the association between each variable with VBAC success rate. For logistic regression, after the VBAC-associated variables were determined, we used a bootstrap inclusion fraction, which calculated the time percentage for each variable that could be retained as a significant predicting factor in the bootstrap resample for the model. In the bootstrap resample of the final model, variables with time percentage shorter than 50% were excluded. We focused on the predictors of VBAC success rates that were previously reported.[5–13] We assigned points to specific demographic and clinical characteristics. According to the coefficients of the regression model, weighting was also considered. We then calculated a modified VBAC score for each patient undergoing TOLAC. The modified VBAC score was then correlated with VBAC success chance. Finally, the receiver operating characteristic (ROC) curves were measured by calculating the corresponding area under the curve (AUC) and 95% confidence interval (CI). In order to randomly split samples into test and validation groups, bootstrapping was used to validate the established model internally. The acceptable level of discrimination was set as an AUC of at least 0.70 (95% CI, 0.66–0.75).

RESULTS

As shown in **Table 1**, the demographic characteristics for women undergoing TOLAC were described. In general, we found the rates for women who had gestational diabetes, pre-eclampsia, and small-for-gestational-age neonates were very low. Uterine rupture, discovered at 5–6 cm dilation, occurred in five women who underwent TOLAC during spontaneous labor. No hysterectomy was needed for any of the ruptures. No newborn died, and no apparent neurologic impairment was found in the newborns. In women who had a successful VBAC (n = 354), 9.0% (n = 32; 95% CI, 6.3–10.7) of them had third-or fourth-degree lacerations. In addition, 3.3% (n = 12; 95% CI, 1.0–2.5) of them had shoulder dystocia and 11.8% (n = 42; 95% CI, 8.7–11.9) of them had operative vaginal delivery.

We conducted multivariable logistic regression and found seven variables that were associated with VBAC success rate, including previous primary CS indication (odds ratio (OR) 2.1; 95% CI, 1.4–3.0), previous vaginal birth history (OR, 2.5; 95% CI ,1.8–3.8), age < 40 years old (OR, 2.1; 95% CI, 1.2–3.3), weight gain < 20 kg (OR, 1.5; 95% CI, 1.2–2.3), no labor induction (OR, 1.9; 95% CI, 1.5–2.9), high score of pelvic/birth weight (OR, 1.4; 95% CI, 1.1–2.1), and Bishop score (OR, 1.3; 95% CI, 1.2–1.4; **Table 2**).

The modified scoring system to predict VBAC success was based on the relative weight of significant variables and ORs in the final regression model. A score was assigned to each variable (**Table 3**). **Figure 1** shows the ROC curve of the final model (black). After adjustment for optimism, the AUC was 0.849 (95% CI, 0.78–0.89). On the other hand, when the pelvic/birth weight score was not included in the final VBAC score, the AUC after adjustment for optimism was 0.769 (95% CI, 0.71–0.84; **Figure 1**, grey). As shown in **Table 4**, the TOLAC success rate was correlated with the

Table 1 Demographic characteristics of women undergoing trial of labor after cesarean delivery

Demographic characteristic	Successful VBAC (*n* = 354)	Failed VBAC (*n* = 52)	*P* value
Maternal age (year)	27.9 ± 4.8	35.5 ± 4.7	0.043
Gestational age at delivery (week)	38.7 ± 1.8	38.6 ± 1.7	0.62
Weight gain during pregnancy			<0.001
< 15 kg	18 (5.1)	5 (9.6)	
15–20 kg	318 (89.8)	22 (42.3)	
> 20 kg	18 (5.1)	25 (48.1)	
Marital status			0.37
Married	330 (93.2)	49 (94.2)	
Single	12 (3.4)	1 (1.9)	
Divorced or separated	6 (1.7)	1 (1.9)	
Unknown	6 (1.7)	1 (1.9)	
History of vaginal delivery	138 (38.9)	10 (19.2)	<0.001
Previous indication for primary cesarean delivery	36 (10.1)	14 (26.9)	<0.001
Induction of labor	78 (22.0)	39 (75.0)	0.022
Maternal pre-eclampsia or eclampsia	12 (3.4)	2 (3.8)	0.66
Maternal gestational diabetes	18 (5.1)	3 (5.7)	0.29
Small-for-gestational-age neonate	12 (3.4)	2 (3.8)	0.79
Pelvic measurement (cm)			
Sacral shame external diameter	19.4 ± 1.5	17.6 ± 1.6	0.040
Diagonal conjugate	13.2 ± 0.7	11.4 ± 0.8	0.047
Transverse outlet	9.5 ± 0.2	7.8 ± 0.4	0.038
Posterior sagittal diameter of pelvic outlet	17.8 ± 1.5	14.9 ± 1.6	0.026
Anteroposterior diameter of pelvic outlet	12.5 ± 0.8	10.3 ± 0.6	0.037
Estimated prenatal fetal weight (g)	3,158 ± 469	3,753 ± 517	0.045

VBAC, vaginal birth after cesarean delivery.

modified VBAC score. Specifically, we showed that when a modified VBAC score was < 10, the patient had < 50% likelihood to have successful TOLAC. However, when a modified VBAC score was > 17, the patient had > 85% likelihood to have successful TOLAC.

DISCUSSION

In the present study, > 87% (354/406) of patients had successful VBAC. Most of these patients had spontaneous vaginal delivery. The successful rate in our study seemed slightly higher than reported from other studies, showing a range of 60.0–80.0% success rate of VBAC.[16,17] Our study also found that women with prior vaginal delivery had higher chance for successful VBAC than women who previously did not have vaginal delivery. Similar to our results, previous studies have shown that previous vaginal delivery is the strongest predictor for VBAC success.[18,19] In addition, we found that VBAC failure was connected with higher maternal age, and pregnancy weight gain critically contributed to the VBAC success rate. Specifically, increased failure rate of VBAC was seen in women who had gained over 20 kg weight. In contrast to previous studies, the success rate of VBAC was not affected by gestational age in our study. Finally, one of the important findings in our study is that high pelvic/birth weight score was also associated with high success rate of VBAC. Hence, our prediction model was the first to include pelvic/birth weight score.

To calculate ORs and 95% CIs, we used univariate and multiple stepwise logistic regressions. We found seven variables were independently associated with VBAC success, including: no previous indication for primary cesarean delivery, prior vaginal birth, weight gain < 20 kg, age < 40 years, high pelvic/birth weight score, Bishop score, and no induction of labor. Based on these findings, our study generated a scoring system that can be used to predict the probabilities for VBAC success with reasonable accuracy. We further developed the score based on the relative weight of these variables and the success rate of these variables in prediction of VBAC success. We assigned a score to each of these seven variables, and the highest score indicates the highest probability. When the total value of score increases, the probabilities for having a VBAC success increase. Patients

Table 2 Pelvic/birth weight score

Sacral shame external diameter (cm)	Diagonal conjugate (cm)	Transverse outlet (cm)	Posterior sagittal diameter of pelvic outlet (cm)	Anteroposterior diameter of pelvic outlet (cm)	Score
> 19.5	> 13.5	> 9	> 18	> 12	6
18.5–19.5	12–13.5	8–9	15.5–18	11–12	5
18	11.5	7.5	15	10.5	4
17.5	11	7	14	10	3
17	10.5	6.5	13	9.5	2
16.5	10	6	12	9	1

Estimated prenatal fetal weight (g)	Score
2,500 ± 250	4
3,000 ± 250	3
3,500 ± 250	2
4,000 ± 250	1

Table 3 Modified VBAC score system

Factor		Score
Maternal age	< 40	1
	> 40	0
Prior vaginal delivery	Before and after CS	4
	After CS	2
	Before CS	1
	No	0
Pelvic/birth weight score (see **Table 2**)	10	4
	9	2
	8	1
	No more than 7	0
Induction of labor	No	10
	Yes	0
Bishop score	10–13	4
	5–9	2
	0–4	1
	No more than 3	0
Weight gain	< 15 kg	2
	15–20 kg	1
	More than 20 kg	0
Previous indication for primary cesarean delivery	Breech delivery; twins; gestational hypertension	3
	Placenta previa, abruption; premature birth; premature rupture of fetal membranes	2
	Fetal distress; cephalopelvic disproportion; stagnant labor; umbilical cord abnormalities	1
Total		31

CS, caesarian section; VBAC, vaginal birth after cesarean delivery.

Table 4 Chance of successful VBAC based on calculated VBAC score

Modified VBAC score	No. of participants	Chance of successful VBAC (CI)	Actual VBAC success rate
6	7 (1.7)	19.3 (11.4–29.3)	20.1
7	11 (2.7)	24.5 (16.6–34.0)	39.0
8	21 (5.2)	32.5 (36.1–46.7)	42.5
9	32 (7.9)	40.5 (31.5–49.7)	45.4
10	45 (11.1)	48.1 (49.7–56.6)	54.2
11	67 (16.5)	57.8 (51.2–64.6)	58.4
12	85 (20.9)	65.7 (61.2–69.7)	65.4
13	58 (14.3)	71.2 (68.8–75.7)	72.7
14	39 (9.6)	77.5 (74.7–80.1)	71.3
15	20 (4.9)	81.8 (79.2–83.9)	80.9
16	12 (2.9)	84.5 (82.6–86.9)	84.3
17	6 (1.5)	87.1 (84.9–89.2)	86.4
18	3 (0.7)	88.9 (86.1–90.5)	91.9

CI, confidence interval; VBAC, vaginal birth after cesarean delivery. Data are *n* (%), (95% CI), or %.

with a score of 6 have a probability of 20.1% for a successful VBAC. Patients with a score of 18 have a probability of 91.9% for a successful VBAC. Interestingly, when the pelvic/birth weight score was not included in the VBAC score, the AUC was reduced in the ROC analysis, suggesting

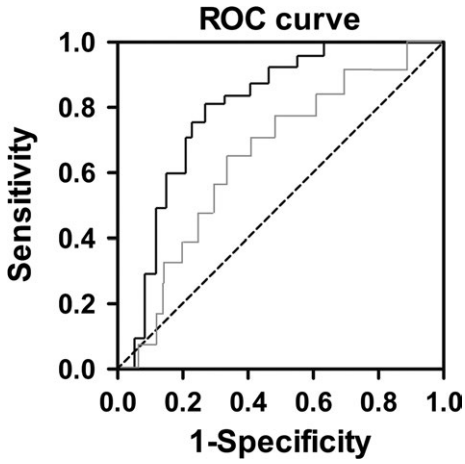

Figure 1 Receiver operating characteristic curve (ROC) for validation of vaginal birth after cesarean score. Black line: the area under the curve was 0.849 (95% confidence interval (CI), 0.78–0.89). Grey line: when not including the pelvic/birth weight score in the final vaginal birth after cesarean delivery score, the area under the curve was 0.769 (95% CI, 0.71–0.84).

prediction was decreased in the current model at each combination of specificity and sensitivity.

Previous studies have reported to develop several VBAC prediction models.[5–13] On the other hand, these prediction models usually do not include variables that are available at admission time or are not established based on regression models. A similar study has reported a scoring system dependent on five factors that are connected with VBAC success. Their factors included previous VBAC, lower gestational age at the time of the first CS, abnormal presentation as indication for first CS, cervical dilation, and gestational age ≤ 41 weeks.[8] For application at admission time, the most recently published nomogram included several other variables, such as ethnicity.[9,20] Additionally, the Grobman *et al.*,[13] model includes more factors and is complicated.[13] They generated a predictive nomogram model, which included variables that allow the determination of a patient-specific probability for VBAC success at the first prenatal visit. The Grobman *et al.*,[13] model is built on a multivariable logistic regression. This model includes variables, such as ethnicity, index of body mass, maternal age, previous vaginal delivery, potentially recurrent indication for the cesarean delivery, and the occurrence of VBAC. Because Han Chinese is the majority population in China, we did not include ethnicity in our analysis. However, compared with these models, our model includes a comprehensive pelvic/birth weight score, pelvic measurements and estimated prenatal fetal weight, and accounts for induction of labor. Published studies showed that labor induction may decrease the chance of successful VBAC.[21] Our results are consistent with those of Grobman *et al.*[13] and support the theory that collected data available at admission can increase the prediction power for a successful VBAC.

Finally, using VBAC prediction model in the clinic still faces major challenge. The predicted success rate for individual women alone cannot inform the decision for them. A successful chance estimation could be of great importance

in encouraging women who have less willingness to undergo TOLAC or facilitate the decision making for women who are willing to undergo TOLAC. Indeed, suggesting TOLAC to any inclined woman is supported by current recommendations. Hence, application of the VBAC prediction model in the clinic and success rate prediction for individuals may not be used by the provider to restrict options of women when the score is low. Instead, a high success rate score should be actively used to promote TOLAC. Indeed, the Obstetrics and Gynecology branch of the Chinese Medical Association recently issued a consensus on VBAC management in 2016. A model that could fit in with pregnancy prediction after caesarean delivery will aid the obstetric medical personnel to estimate the feasibility of vaginal delivery and will also be of great importance for the enhancement in the confidence of pregnant women in selecting vaginal delivery.

CONCLUSION

One big limitation of our study is its retrospective nature. Medical records by staff were critical for our study. Additionally, a highly homogeneous (mostly Han Chinese, married) obstetric population is used for this study, and this highly homogeneous obstetric population is possible to enhance our model performance, particularly when compared with previous models. Hence, it might be limited to generalize our model to highly heterogeneous and high-risk populations. Similar with other available models predicting success rates of VBAC, many other factors were not included in our prediction model. These factors include labor management, patient preference, and physician counseling. In fact, an elective repeat cesarean delivery is still often selected by many women who are likely considered as good candidates for TOLAC. Hence, our studies in the future would be necessary to investigate which factors have the highest impact on women to decline or accept TOLAC (e.g., desired family size, patient information, previous labor experiences, cost effect, or hospital sitting). In summary, we have proposed a model that can provide useful information to predict VBAC success rate at admission time for pregnant women who previously had a primary cesarean delivery. However, a future perspective study incorporating a larger sample size is needed to validate this prediction model in clinical settings.

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