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Full length article

Establishment and validation of a prediction model for vaginal delivery after cesarean and its pregnancy outcomes—Based on a prospective study

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ABSTRACT

Objective: To explore factors that can be used to predict successful vaginal births after cesarean (VBAC) and its outcome.
Methods: This is a prospective study involving women with a previous low-segment cesarean section, singleton pregnancy and cephalic presentation who desire for vaginal trial delivery. Delivery modes were observed and the pregnancy outcomes were followed up. The data were analyzed to identify the factors associated with the success of vaginal births after cesarean (VBAC). Then, there were elaborated the models, and their predictive capacity was determined by receiver-operator curve (ROC).
Results: The multivariate logistic regression showed Bishop's score and spontaneous labour independently influenced vaginal births after cesarean (VBAC) success. The prediction model is established and validated. The fitting degree and prediction accuracy of the model is good. The vaginal births after cesarean (VBAC) group had less postpartum hemorrhage (Median 270 ml vs. 300 ml, $P < 0.05$), a lower puerperal infection rate (1.62% vs 5.88%, $P < 0.01$), and shorter postpartum hospitalization (Median 2 days vs. 3 days, $P < 0.01$) than the trial of labor after cesarean (TOLAC)-failure groups. It also had less postpartum hemorrhage (Median 270 ml vs. 320 ml, $P < 0.01$), a lower puerperal infection rate (1.62% vs 6.23%, $P < 0.05$), and shorter postpartum hospitalization (Median 2 days vs. 3 days, $P < 0.01$) than the elective repeat cesarean section (ERCS) groups. The use of labor analgesia in the vaginal births after cesarean (VBAC) group had no effect on pregnancy outcomes.
Conclusion: The predictive factors are conducive to making rational choices about delivery mode and should improve pregnancy outcomes.

Introduction

In China, the cesarean section rate rose from 29% in 2008 to 35% in 2014 [1]. A survey of nine Asian countries in 2010 showed that China had the highest rate of cesarean section [2], which prompted the Chinese government to formulate a number of policies to reduce the rate of cesarean section. China's enactment of the two-child policy in 2016 increased the birth rate [3]; therefore, an increase in cesarean sections (C-sections) related to previous C-sections is expected. In recent years, the proportion of pregnant women seen in obstetric clinics with a scarred uterus has increased and choice of birth method after C-section has become a crucial issue.

Risks of ERCS include surgical complications, placenta previa, placenta increta, risks associated with multiple caesarean sections, increased risks of hysterectomy, and infant respiratory diseases [4–6]. Successful VBAC has the lowest risk, so more women are willing to accept VBAC because of the medical advances in this field and the advantages of mothers and children. A better understanding of a trial of labor after cesarean (TOLAC) is needed to reduce the C-section rate further and improve pregnancy outcomes and the distribution of medical resources. China's expertise in this field is in an early stage, although more hospitals have attempted TOLAC and recorded VBAC outcomes. The American Association of Obstetricians and Gynecologists developed strict VBAC guidelines [7] in 2010, and other countries have done the same [8], thereby encouraging pregnant women with a C-section history to attempt TOLAC when conditions permit [9]. VBAC rates vary (45.6–77.8%), depending on the samples and statistical methods used in studies [10,11].

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In different ways, ERCS and VBAC can bring a certain degree of additional morbidity and rare mortality to both maternal and perinatal infants. The risk of VBAC includes increased risk of emergency cesarean section (vbac failure), bleeding, blood transfusion, uterine rupture and endometritis, and increased risk of infant asphyxia or perinatal death [6,12,13]. But it is undeniable that the risk of successful VBAC is the lowest. Compared with elective repeat cesarean section (ERCS), a TOLAC can avoid secondary surgical trauma related to scarring of the uterus and reduce surgical complications, while it has a shorter recovery period and lower surgery costs. In addition, for women considering future pregnancies, VBAC reduces the risk of maternal outcomes associated with multiple cesarean deliveries (such as hysterectomy, intestinal or bladder injury, and abnormal placentation) [14]. However, uncertainty about TOLAC in the management of pregnancy and clinicians' liability have negatively affected VBAC rates. There were many studies in recent years investigating predictors for VBAC, some which are known in pregnancy and others at onset of labour. Unfortunately, none of the existing VBAC screening tools provide consistent ability to identify women who may achieve successful VBAC in China. The identification of factors affecting VBAC success and classification of TOLAC candidates into risk groups would help clinicians make accurate decisions [15] and personalize clinical treatment plans. This prospective study analyzed and identified factors that predict VBAC success. We also compared the advantages and disadvantages of VBAC and ERCS to assess the safety of VBAC and guide patients' and practitioners' decision-making.

Methods

Participant selection and settings

This prospective study investigated 3038 pregnant women after having C-sections when they delivered at the International Peace Maternal and Child Health Hospital affiliated with Shanghai Jiao Tong University Medical School. Samples were collected during a period of 17 months from August 2016 to December 2017. The pregnant women provided written informed consent to participate in this study. The study protocol was approved by The Ethics Committee of the International Peace Maternal and Child Health Hospital on 2/8/2016 (reference number (GKLW 2015-46).

It was up to the participants to decide whether to try vaginal delivery or not. Pregnant women willing to attempt a TOLAC were screened using the guidelines [7] developed by the American Society of Obstetricians and Gynecologists (ACOG) to determine their suitability for it. The TOLAC criteria consisted of a desire for a vaginal delivery and knowledge of the risks; submitting a consent form signed during pregnancy; history of only one C-sections with a transverse incision in the lower uterine segment; singleton birth with cephalic presentation; interdelivery interval after the C-section $\geq$18 months; continuous myometrial tissue of the uterine scar on ultrasound examination; and estimated neonatal birth weight <4000 g. TOLAC contraindications consisted of a confirmed classical, longitudinal, or T-shaped incision from the previous C-section; history of two or more uterine surgeries; history of uterine rupture or other incision-related complications; and causes of other contraindications of vaginal delivery. A total of 162 participants attempted TOLAC while 2876 underwent ERCS. Our hospital is a Grade-3 obstetrics and gynecology hospital with emergency surgical back-up resources for VBAC complications. It has a VBAC clinic to conduct prenatal assessments (including psychological status and pregnancy history) of pregnant women attempting TOLAC. A person assigned to all the participants conducted follow-ups. A pregnancy database containing uterine scarring was established in the outpatient clinic, and delivery-related data were retrieved from in-patient obstetrics and labor and delivery records.

Data collection and procedures

Variables affecting TOLAC success rates that meet our detailed criteria were isolated from several studies [16–19]. Variables selected for evaluation as confounders or effect modifiers included age, BMI (Body Mass Index), gravidity, parity, interdelivery interval after the last C-section, estimated fetal weight, and whether the previous C-section was performed during labor. Clinical data, such as gestational week at labor, thickness of the myometrium at the uterine scar, Bishop's score, premature rupture of membranes, analgesia, labor-inducing methods (such as oxytocin, artificial rupture of membranes, and cervical mechanical dilation) and spontaneous labor (with no induction) were also recorded. Correlations between the above variables were analyzed and their ability to predict VBAC rates to determine the factors most likely to predict the success of TOLAC were evaluated. Follow up of all participants to delivery was conducted. Data on pregnancy outcomes (e.g., postpartum hemorrhage, neonatal Apgar score, duration of labor and delivery, puerperal infection rate, and postpartum hospitalization duration) were compared between the VBAC and TOLAC-failure groups, the VBAC and ERCS groups, and the VBAC and a concurrent parturition group to examine the effects of vaginal delivery after C-section on pregnancy outcomes. The authors had access to information that could identify individual participants during or after data collection.

Ethical approval and informed consent

Approval was obtained from the institutional ethics committee, and signed written informed consent was obtained from all participants. The name of the ethics committee was Ethics Committee of International Peace Maternal and child health hospital. Date of approval was 2/8/2016 and reference number was (GKLW) 2015-46. The clinical trial registration numbers was "ChiCTR1800017712". The methods were carried out in accordance with the STROBE guidelines.

Statistical analyses

The statistics were analyzed using SPSS version 23.0. The K-S normality test was used to analyze the normality of continuous data. Normally distributed data are expressed as mean $\pm$ standard deviation; independent t-tests were used for subgroup comparisons. Data that were not normally distributed are presented as median and quartiles, and compared using the Mann-Whitney U test. Ordinal data were compared using the chi-square test. The receiver operating characteristic (ROC) curve was used to compare the contribution of each factor to predict VBAC, and the highest predictive value was determined using the Youden index. The effect of each influencing factor is expressed by the odds ratio and it's confidence interval (OR and 95%CI). Multivariate logistic regression model was employed to predict the probility of the successful VABC, and the regression equation was obtained. Hosmer-Lemeshow test was used to test the model fitting and overall prediction accuracy. All tests were bivariate with a significance level of 0.05.

Results

General findings

Of the 162 TOLAC patients, 141 were successful, and assigned to the VBAC group, and 21 TOLAC failures were assigned to the TOLAC-failure group. The flow chart was shown in Fig. 1. Partcipants' general

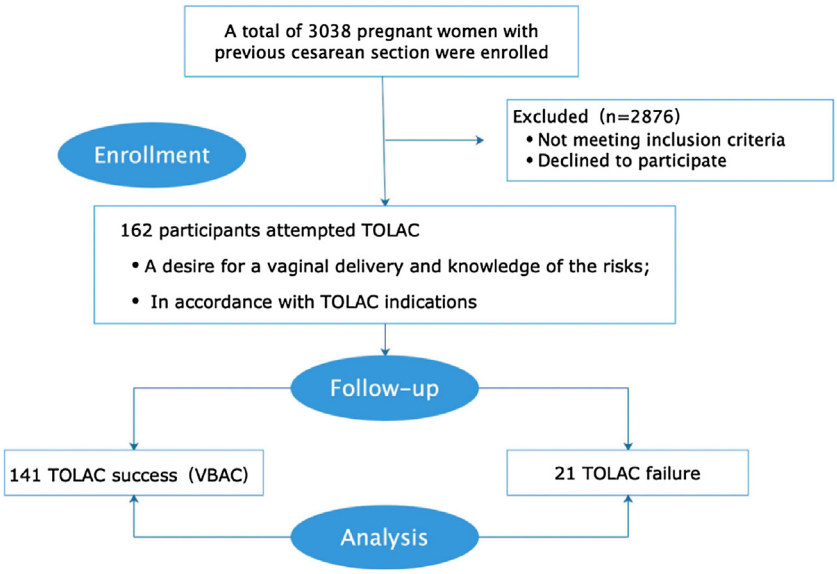

Fig. 1. Selection of cohort.
ERCS, elective repeat caesarean section; VBAC, vaginal birth after caesarean section; TOLAC, trial of labor after caesarean section.

and clinical characteristics were shown in Table 1. A total of 105 women in the TOLAC group received epidural anesthesia to have anodyne labor, and 57 did not. Thirty-seven women had premature rupture of membranes, and 125 did not; labor was induced in 52 cases (32.1%), with a success rate of 59.6%. In 52 women with induced labour, oxytocin was used in 18 cases (34.6%), artificial rupture of membranes in 25 cases (48.1%), and mechanical dilation of the cervix in 9 cases (17.3%). At the time of the previous C-section, 48 patients were already in labor, and 114 were not. Among the 162 participants, 141 (87.0%) had successful VBAC, and 21 (13.0%) had TOLAC failures. The most common cause of C-section in the TOLAC-failure group was fetal distress (61.9%). Other indicators included labor stagnation (19.1%), failed induction of labor (14.3%), and prenatal fever (4.7%). The only patient with a uterine rupture had a thickness of 3.6 mm in the lower uterine segment, and the interdelivery interval after the C-section was 54 months.

Univariate analysis of VBAC

Comparisons of the two groups indicated that Bishop's score, estimated fetal-weight, gestational week at labor, spontaneous labour during the current birth, and parturition status during the previous C-section were related to TOLAC outcomes ($P < 0.05$). Age, BMI, gravidity, parity, thickness of the myometrium in the uterine scar, interdelivery interval after the C-section, use of epidural anesthesia, and premature rupture of membranes were not related to TOLAC outcomes ($P > 0.05$).

Comparisons of the indicators predicting VBAC

The five significant indicators identified in the univariate analysis were used as indicators to predict VBAC success, as shown in the ROC curve in Fig. 2.

The value of the indices as VBAC predictors, in descending order were Bishop's score > spontaneous labour > gestational week at labor > estimated fetal-weight, and > parturition status during the previous C-section (Table 2). The VBAC success rate was higher when Bishop's score was higher than 6, gestational age at labor was < 39 weeks, the estimated fetal weight was < 3250 g, the previous cesarean C-section performed during labor, and there was spontaneous labour.

Table 1
Comparison of the VBAC group and the TOLAC-failure group.

	TOLAC (n = 162)	Success (n = 141)	Failure (n = 21)	Univariate analysis		
				P	OR	95%CI
Age (years)[a]	33.2 ± 4.1	33.2 ± 3.9	32.9 ± 4.5	0.798	0.979	0.875-1.095
BMI (kg/m^2)[a]	21.2 ± 2.2	21.2 ± 2.3	20.9 ± 1.9	0.630	0.986	0.801-1.214
Gravidity[b]	3 (2,3)	3(2,3)	3(2,3)	0.673	1.301	0.778-2.177
Parity[b]	1(1,1)	1(1,1)	1(1,1)	0.436	1.411	0.448-4.443
Myometrium thickness at the uterine scar (mm)[b]	3(2.5,3.4)	3(2.5,3.4)	3(2,3)	0.392	0.711	0.463-1.089
Interval after the previous C-section (months)[b]	64(48,96)	63.5(48,91)	72(48,108)	0.498	1.007	0.995-1.020
Bishop's score in parturient patients (points)[b]	5(5,9)	6(5,6)	4(3,5)	<0.001	0.431	0.294-0.632
Estimated fetal weight (g)[b]	3300(3300,3500)	3200(3000,3500)	3500(3400,3700)	0.001	1.240	1.116-1.379
Parturient gestational age[b] (weeks)	39.2(38.3,40.0)	39(38.1,39.6)	40(39.4,40.2)	<0.001	1.292	1.157-1.442
Anodyne labor rate(%)[c]	64.8%	66.7%	54.9%	0.201	0.870	0.345-2.189
Premature rupture of membranes rate(%)[c]	22.8%	24.8%	9.5%	0.119	0.326	0.072-1.479
Parturition rate during previous C-section(%)[c]	29.6%	33.3%	4.8%	0.007	1.397	1.231-1.586
Spontaneous labor rate(%)[c]	67.9%	78.0%	0	<0.001	1.871	1.471-2.379

Index: VBAC = vaginal birth after cesarean; TOLAC = trial of labor after cesarean; BMI = body mass index.
[a] Paired *t*-test with two independent samples was used.
[b] Non-parametric Mann-Whitney U test was used.
[c] Chi-square test was used.

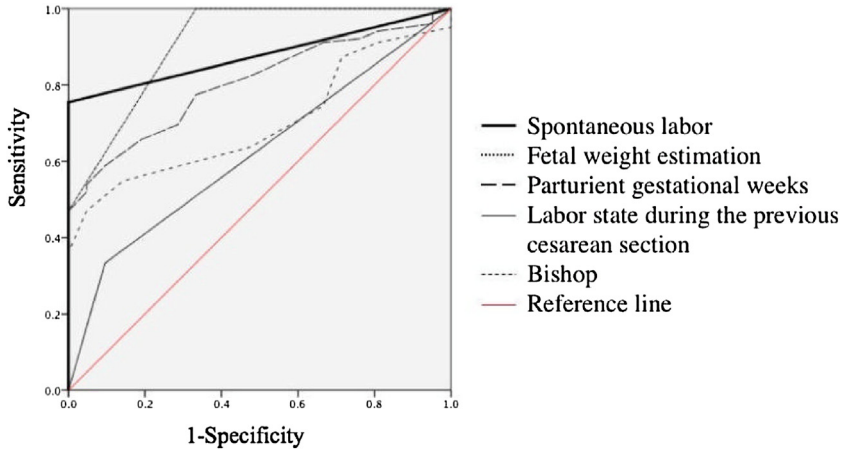

Fig. 2. ROC curve of indicators used to predict VBAC.
ROC = Receiver Operating Characteristic.

Table 2
Comparison of the area under the ROC curve of each indicator and their value in VBAC prediction.

	AUC	95% CI		P
		Lower limit	Upper limit	
Spontaneous labor	0.877	0.818	0.937	<0.001
Estimated fetal weight	0.699	0.602	0.795	0.004
Gestational age	0.803	0.721	0.885	<0.001
Parturition status during previous C-section	0.643	0.530	0.756	0.040
Bishop's score	0.912	0.842	0.981	<0.001

ROC = Receiver Operating Characteristic; AUC = Area Under the Curve; VBAC = vaginal birth after cesarean.

Table 3
Analysis of independent risk factors of VBAC through multivariate logistic regression.

	B	Standard error	Wald	P	OR	95 % CI	
						Lower limit	Upper limit
Estimated fetal weight	0.000	0.002	0.022	0.882	1.000	0.997	1.003
Parturient gestational age	−0.843	0.761	1.229	0.268	0.430	0.097	1.911
Parturition during previous C-section	−1.854	1.176	2.485	0.115	0.157	0.016	1.570
Bishop's score	2.342	0.949	6.088	0.014	10.405	1.619	66.878
Spontaneous labor	2.737	1.147	5.691	0.017	15.443	1.630	146.337
Constant	23.398	29.573	0.626	0.429			

Establishment and validation of VBAC prediction model

Multivariate, stepwise, backwards logistic regression was performed for the five indicators (Table 3). Only two indicators (Bishop's score and spontaneous labour) were significant independent predictors of VBAC. The expression of Logistic regression prediction equation is: $P = 1/[1 + 1/\exp(23.40 + 2.34 \times \text{Bishop's score} + 2.74 \times \text{spontaneous labour})]$ (Bishop's score ranged from 0 to 13; spontaneous labour:1 for existence and 2 for nonexistence). Through Hosmer-Lemeshow test, the fitting degree of the model is good (P = 0.959), the overall prediction accuracy of the model is 94.80%.

The nomogram obtained by logistic regression is shown in Fig. 3. The nomogram is used to locate the characteristics of each patient and find the number of points corresponding to the characteristics on the topmost point scale. For example, a patient's personality traits lead to a 60 total point, about a 80% chance of having a VBAC.

Pregnancy outcomes of women in the VBAC group

All participant were followed up to childbirth. Data on pregnancy outcomes, such as postpartum hemorrhage, Apgar score, birth process time, puerperal infection rate, and postpartum hospitalization duration were collected. The outcomes were compared between the VBAC and TOLAC-failure groups, and the VBAC and ERCS groups (Table 4). The VBAC group had fewer postpartum hemorrhages, a lower puerperal infection rate, and shorter postpartum hospitalization than the TOLAC-failure and ERCS groups. Apgar scores did not differ significantly between the groups.

Data on pregnancy outcomes from 13,054 parturient women with spontaneous deliveries during the same period were compared with those of the VBAC group (Table 5). There was no significant difference in postpartum hemorrhage, Apgar score, puerperal infection rate, or duration of postpartum hospitalization between the groups. However, the VBAC group's first, second, and total labor durations were shorter than those of the concurrent vaginal birth group.

Effects of labor analgesia on labor and pregnancy outcomes of the VBAC group

A total of 94 patients (66.7%) in the VBAC group received epidural anesthesia for analgesia and 47 delivered without

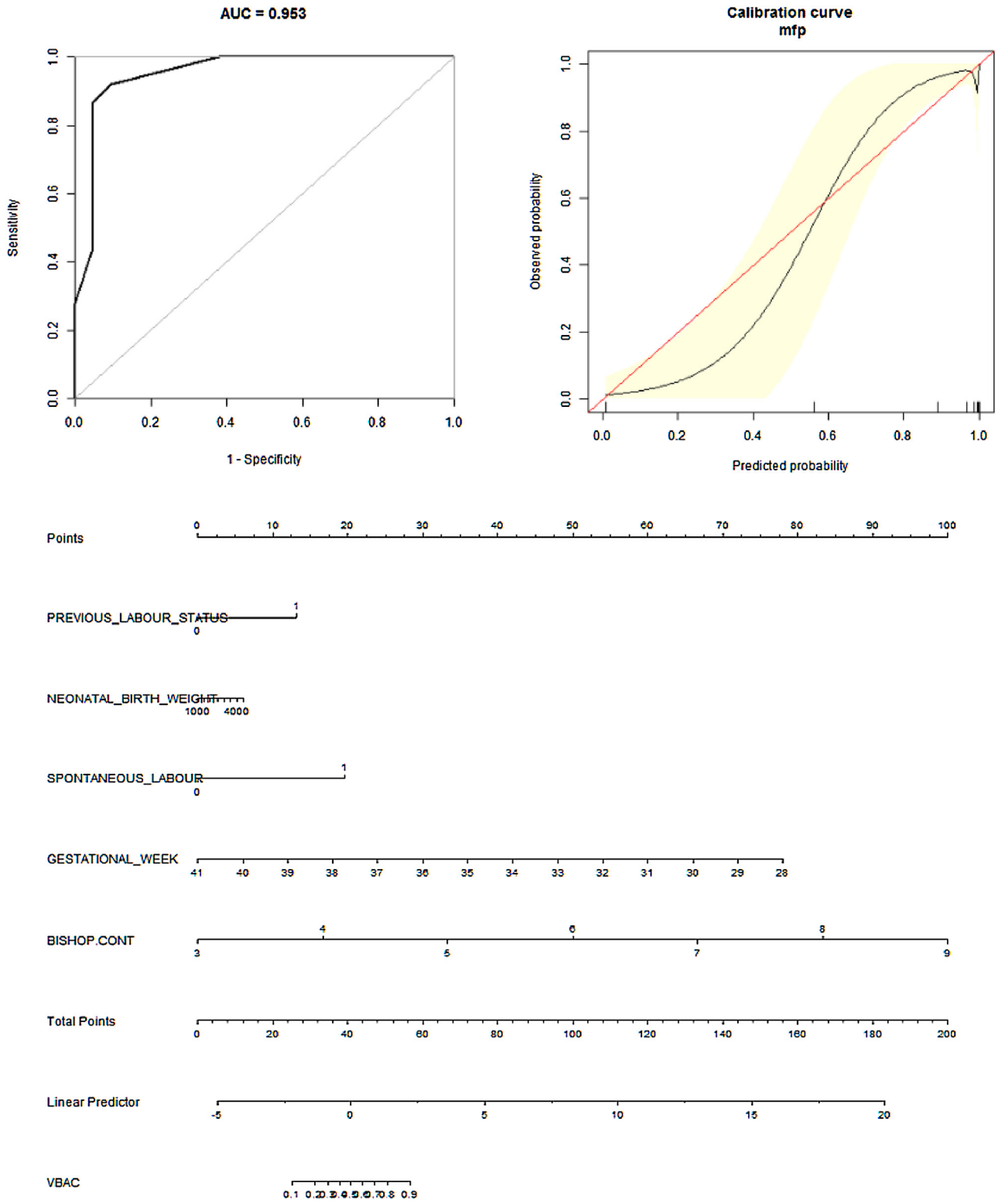

Fig. 3. Predictive graphic nomogram for probability of vaginal birth after caesarean delivery resulting from a trial of labor.

analgesia. Compared with non-analgesic delivery, the use of analgesia in VBAC group had no effect on postpartum hemorrhage, Apgar score, puerperal infection rate, or duration of postpartum hospitalization ($P > 0.05$).

Discussion

In our study, we found that factors related to VBAC success included Bishop's score, estimated fetal weight, gestational week

Table 4
Comparison of pregnancy outcomes between the VBAC group, TOLAC-failure group and ERCS group.

	VBAC group(n = 141)	TOLAC-failure group (n = 21)	ERCS group(n = 2876)	P^1	P^2
Postpartum hemorrhage (ml)	270(250, 310)	300(290,320)	320(250,430)	0.029	0.001
Apgar score (points)	10(10, 10)	10(10,10)	10(10,10)	0.838	0.729
Puerperal infection rate (%)	1.62%	5.88%	6.23%	0.006	0.036
Postpartum hospitalization duration (days)	2(2,2)	3(3,4)	3(3,3)	<0.001	0.001

VBAC = vaginal birth after cesarean; TOLAC = trial of labor after cesarean; ERCS = elective repeat cesarean section.
P^1: Comparison between VBAC group and TOLAC-failure group.
P^2: Comparison between VBAC group and ERCS group.

Table 5
Comparison of pregnancy outcomes between the VBAC group and the concurrent vaginal birth group.

	VBAC group (n = 141)	Concurrent vaginal birth group (n = 13,054)	P
Postpartum hemorrhage (ml)	270(250,310)	265(250,300)	0.311
Apgar score (points)	10(10,10)	10(10,10)	0.271
Duration of first labor (minutes)	294(240,405)	330(225,480)	0.003
Duration of second labor (minutes)	40(22,77)	54(29,125)	0.013
Duration of total labor (minutes)	320(270,450)	360(245,525)	0.027
Puerperal infection rate (%)	1.62%	1.47%	0.893
Postpartum hospitalization duration (days)	2(2,2)	2(2,2)	0.810

VBAC = vaginal birth after cesarean.

at labor, spontaneous labour, and whether the previous C-section was performed during labor. Age, BMI, gravida, parity, interdelivery interval after the previous C-section, thickness of the myometrium at the uterine scar, analgesia use, and premature rupture of membranes were not related to VBAC success. The multivariate logistic regression showed that Bishop's score and spontaneous labour independently influenced VBAC success. The VBAC group had fewer postpartum hemorrhages, a lower puerperal infection rate, and shorter postpartum hospitalization than both TOLAC-failure and ERCS groups. Compared with the concurrent vaginal birth group, the VBAC group had shorter labor duration and no difference in other pregnancy outcomes. Moreover, labor analgesia can be used in VBAC without affecting pregnancy outcomes or labor duration.

From 1996 to 2014, seven models were reported to predict TOLAC success with an accuracy rate of 67.8%–84.3% [20–23]. The VBAC rate in the present study was 87% and the high success rate may be related to our hospital's strict inclusion criteria for TOLAC selection, the establishment of a VBAC clinic, our comprehensive and systematic pre-delivery assessment, the provision of relevant information to patients, weight management during pregnancy, and strict monitoring of the trials.

Whether the maternal age can be used to predict VBAC success is controversial. Some studies have reported that negatively influence the likelihood of VBAC include increasing maternal age [24,25]. Yet, other studies [26] suggest that age does not affect VBAC success rates. China's recent two-child policy has sparked an increase in the proportion of older pregnant women who wish to reproduce after a C-section, which may lead to the fact that maternal age was not predicting VBAC success in this study.

Tessmer-Tuck et al. [27] reported that a BMI < 30 kg/m^2 independently influenced VBAC and Manzanares et al. [18] reported that a BMI > 25 kg/m^2 was a factor in TOLAC failure. But in this study, we found no effect of pregnancy BMI on VBAC. High BMI alone should not be considered as an absolute contraindication for TOLAC because it is only a factor in determining VBAC and obstetric morbidity in TOLAC settings. Women with a high BMI may be candidates for TOLAC, depending on their other characteristics (e.g., vaginal delivery), and their care should be individualized. Nevertheless, obese pregnant women should be more cautious about a TOLAC, and weight management should be incorporated into all patients' treatment plans.

In this study, our results suggest that the thickness of the lower segment of the uterus and the interdelivery interval after the previous C-section were not indicators for VBAC. Given only one uterine rupture case, we cannot conclude their value in predicting uterine rupture. Even so, as a precautionary measure to avoid uterine rupture, pregnant women should choose the mode of delivery and consider having surgery if the ultrasound indicates that the scar is too thin or discontinuity. We also found no effect of the interdelivery interval after the previous C-section on VBAC success in this study, possibly because the interdelivery intervals for the included cases were 18 months or longer, making statistical differences more difficult to detect. The results of studies on the effect of the length of the interval between the C-section and TOLAC on VBAC success are inconsistent [28,29]. In 2016, Chinese experts recommended a minimum period of 18 months after the previous cesarean section. Some also use magnetic resonance imaging and histopathology to observe healing of the uterine incision.

Bishop's score at labor was measured to standardize the timing of the cervix evaluations. The score at labor was a good predictor of VBAC. Maternal pelvis and fetal size may have important effects on VBAC success, which supports the importance of accurate estimation of fetal size [30]. The newborn's weight was closely related to the VBAC rate, and its cut-off value was 3250 g. The success rate of VBAC increased when the newborn's weight was less than 3250 g. Therefore, weight control among women attempting TOLAC is important during pregnancy to avoid excessive weight gain of the fetus.

In terms patients' previous histories, five women in the present study had a history of vaginal delivery, of which one was before the previous C-section and four were after the previous C-section; all were successful in the trial. This study's results suggest that being parturient during the previous C-section was closely related to the VBAC rate, indicating that previous parturition influences the trial's success. In a meta-analysis, Eden et al. [31] found that a history of vaginal delivery increased the VBAC rate 3–4 times and was related to a lower risk of uterine rupture. Other studies have shown that cervix expansion during the previous C-section was related to the subsequent trial's success rate [32]. Therefore, women with a history of parturition or vaginal delivery should have full access to TOLAC when they meet the TOLAC indications. Our results suggest that spontaneous labor without the use of a

labor induction method is one of the most favorable conditions for successful VBAC. Although there were no uterine ruptures among the women for whom labor was induced, its safety should be examined further given this study's low number of labor inductions.

The durations of the first, second, and both labors combined in the study's VBAC group were shorter than those in the concurrent vaginal birth group. These results are consistent with the report of Sondgeroth et al [33], which showed that stagnation of labor was a common cause of C-sections for TOLAC failure [17]. In this study, 19.1% of the women who switched to a C-section experienced stagnation of labor. Therefore, progress is a key factor for VBAC success, and continuous monitoring is crucial. TOLAC women who have labor stagnation should be re-evaluated to determine its causes. The use of labor analgesia had no effect on pregnancy outcomes for mother and fetus. Adequate pain relief can encourage more pregnant women to choose TOLAC. The American College of Obstetricians and Gynecologists (ACOG) guide [7] recommends that epidural block for analgesia is safe during TOLAC.

Strengths and limitations

Although retrospective studies have examined the effectiveness of the VBAC prediction model, prospective studies are scarce. The predictive value of each factor to VBAC success was established using univariate analysis, and the independent predictors were determined through multivariate analysis. The prediction model based on these analyses is more applicable to the Chinese population than some previous models. Through validation test, the fitting degree of the model is good and the overall prediction accuracy of the model is 94.80%. This study analyzed pregnancy outcomes and VBAC characteristics of success, emphasizing the unique advantages of VBAC. We also affirmed the important role of analgesia in TOLAC by analyzing the effect of epidural anesthesia on pregnancy outcomes.

The primary limitation of our study is possible selection bias due to the single-center study with a small sample size (5.6% TOLAC rate). The VBAC prediction model has not been widely used in clinical practice, and its accuracy and practicality should be verified in prospective studies with larger samples. This model can predict the likelihood of VBAC success at the population level, but its ability to predict risk at the individual level has not been established.

Conclusions

Our study found Bishop's score, estimated fetal weight, gestational week at labor, spontaneous labour, and previous C-section while in labor can be used as predictors of VBAC. Among them, Bishop's score and spontaneous labour independently influenced VBAC success. The prediction model based on the above factors can effectively predict the success rate of VBAC. Because of the optimistic pregnancy outcome of VBAC, we should encourage eligible women to choose trial delivery. Analgesia delivery can be provided as a humanized measure in VBAC. In future studies, we hope to establish a joint research group in China to develop a multi-center stratified study with a large sample to explore prediction models suitable for China's population.

Author contributions statement

G.W. put forward the concept and idea; L.J. designed the experiment; K.Y. and Z.W. summarized the data and conducted a statistical analysis; The essay was written by L.J. and H.Y.; G.W. proposed constructive amendments to the essay. All authors reviewed the manuscript.

Details of ethics approval

The manuscript contained a statement that the procedures of the study received ethics approval from the relevant regional or institutional ethics committee. The name of the ethics committee is Ethics Committee of International Peace Maternal and child health hospital. Date of approval is 2/8/2016 and reference number is (GKLW)2015-46.

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Declaration of Competing Interest

The authors report no conflict of interest.

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References

[1] Li HT, Luo S, Trasande L, Hellerstein S, Kang C, Li JX, et al. Geographic variations and temporal trends in cesarean delivery rates in China, 2008—2014. JAMA 2017;317(1):69.
[2] Lumbiganon P, Laopaiboon M, Gülmezoglu AM, Souza JP, Taneepanichskul S, Pang R, et al. Method of delivery and pregnancy outcomes in Asia: the WHO global survey on maternal and perinatal health 2007–08. Lancet 2010;375 (9713):490–9.
[3] Zeng Y, Hesketh T. The effects of China's universal two-child policy. Lancet 2016;388(10054):1930–8.
[4] Cheng YW, Eden KB, Marshall N, Pereira L, Caughey AB, Guise JM. Delivery after prior cesarean: maternal morbidity and mortality. Clin Perinatol 2011;38 (2):297–309.
[5] ACOG Committee. Opinion No. 559: cesarean delivery on maternal request. Obstet Gynecol 2013;121(4):904–7.
[6] Dodd JM, Crowther CA, Huertas E, Guise J, Horey D. Planned elective repeat caesarean section versus planned vaginal birth for women with a previous caesarean birth. Cochrane Database Syst Rev 2013;12:.
[7] ACO Obstetricians. ACOG Practice bulletin no. 115: vaginal birth after previous cesarean delivery. Obstet Gynecol 2010;116:450–63.
[8] Hauk L. Practice guidelines: planning for labor and vaginal birth after cesarean delivery: guidelines from the AAFP. Am Fam Phys 2015;91(3):197–8.
[9] SOGC Clinical Practice Guidelines. Guidelines for vaginal birth after previous caesarean birth. Number 155 (replaces Guideline Number 147), February 2005. Int J Gynaecol Obstet 2005;89:319–31.
[10] Moeed Saman M. Improving VBAC rates: the combined impact of two management strategies. Aust N Z J Obstet Gynaecol 2014;54(6):601–2.
[11] Lea B, Mary B, Lena D, Sabine M, Claudia H. Vaginal birth after cesarean in German out-of-Hospital settings: maternal and neonatal outcomes of women with their second child. Birth 2014;41(4):309–15.
[12] Bellows P, Shah U, Hawley L, Drexler K, Gandhi M, Sangihaghpeykar H, et al. Evaluation of outcomes associated with trial of labor after cesarean delivery after a change in clinical practice guidelines in an academic hospital. J Matern Fetal Neonatal Med 2017;30(17):2092–6.
[13] Crowther CA, Dodd JM, Hiller JE, Haslam RR, Robinson JS. Planned vaginal birth or elective repeat caesarean: patient preference restricted cohort with nested randomised trial. PLoS Med 2012;9(3) e1001192.
[14] 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(4):1–13.
[15] Smith GCS, White IR, Pell JP, Dobbie R. Predicting cesarean section and uterine rupture among women attempting vaginal birth after prior cesarean section. PLoS Med 2005;2(9):e252.
[16] Knight HE, Gurol-Urganci I, Jh VDM, Mahmood T, Richmond D, Dougall A, et al. Vaginal birth after caesarean section: a cohort study investigating factors associated with its uptake and success. Bjog Int J Obstet Gynaecol 2014;121:183.
[17] Mcpherson JA, Strauss RA, Stamilio DM. Nonreassuring fetal status during trial of labor after cesarean. Am J Obstet Gynecol 2014;211(4) 408.e1–408.e8.
[18] Manzanares S, Ruiz-Duran S, Pinto A, Pineda A, Puertas A. An integrated model with classification criteria to predict vaginal delivery success after cesarean section. J Matern Neonatal Med 2018;1–7.

[19] Viteri O, Chauhan S, Mendez-tabueroa H, Hammad I, Roberts R, Sibai B. 267: interdelivery interval length and obstetric outcomes during trial of labor after cesarean. Am J Obstet Gynecol 2015;212(1):S146.
[20] Metz TD, Stoddard GJ, Henry E, Jackson M, Holmgren C, Esplin S. Simple, validated vaginal birth after cesarean delivery prediction model for use at the time of admission. Obstet Gynecol 2013;122:571–8.
[21] Grobman WA, Lai Y, Landon MB, Spong C, Leveno K, Rouse D, et al. Does information availableat admission for delivery improve prediction of vaginal birth after cesar-ean? Am J Perinatol 2009;26:693–701.
[22] Van Calster B, Vickers AJ. Calibration of risk prediction models: impact on decision-analytic performance. Med Decis Mak 2015;35:162–9.
[23] Chaillet N, Bujold E, Dubé E, Grobman WA. Validation of a prediction model for vaginal birth after caesarean. J Obstet Gynaecol Can 2013;35:119–24.
[24] American College of Obstetricians and Gynecologists. ACOG Practice Bulletin No. 115: vaginal birth after previous cesarean delivery. Obstet Gynecol 2010;116:450–63.
[25] Eden KB, McDonagh M, Denman MA, Marshall N, Guise JM. New insights on vaginal birth after cesarean: can it be predicted? Obstet Gynecol 2010;116 (4):967–81.
[26] Ashwal E, Wertheimer A, Aviram A, Wiznitzer A, Yogev Y, Hiersch L. Prediction of successful trial of labor after cesarean—the benefit of prior vaginal delivery. J Matern Neonatal Med 2015;1–25.
[27] Tessmer-Tuck JA, El-Nashar SA, Racek AR, Lohse CM, Famuyide AO, Wick MJ. Predicting vaginal birth after cesarean section: a cohort study. Gynecol Obstet Invest 2014;77(2):121–6.
[28] Royal College of Obstetricians and Gynaecologists (RCOG). Greentop guideline: birth after previous caesarean birth. Clinical Green Top Guidelines 45. London: RCOG; 2007.
[29] Bujold E, Gauthier RJ. Risk of uterine rupture associated with an interdelivery interval between 18 and 24 months. Obstet Gynecol 2010;115(5):1003.
[30] Fagerberg MC, Maršál K, Källén K. Predicting the chance of vaginal delivery after one cesarean section: validation and elaboration of a published prediction model. Eur J Obstet Gynecol 2015;188:88–94.
[31] Eden KB, Mcdonagh M, Denman MA, Marshall N, Guise JM. New insights on vaginal birth after cesarean: can it be predicted? Obstet Gynecol 2010;116 (4):967.
[32] Goodlin RC. Correlation between maximum cervical dilatation at cesarean delivery and subsequent vaginal birth after cesarean delivery. Obstet Gynecol 1997;90(2):316.
[33] Sondgeroth KE, Stout MJ, Graseck AS, Roehl KA, Macones GA, Cahill AG. Progress of induced labor in trial of labor after cesarean delivery. Am J Obstet Gynecol 2015;213: 420.e421–420.e425.