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MATERNAL-FETAL MEDICINE

Development of prediction models for successful external cephalic version and delivery outcome

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Abstract

Objective To develop prediction models for the chance of successful external cephalic version (ECV) and delivery outcome.
Study design This is a single-center retrospective study including 350 pregnant women with a singleton non-cephalic pregnancy at or after 36 weeks of gestational age. We selected 22 factors for ECV prediction and 21 for delivery outcome after successful ECV prediction as candidate predictors. Multivariable logistic regression with a stepwise backward selection procedure was used to construct a prediction model for the chance of successful ECV and the other for the delivery outcome. The discrimination and calibration of the models were assessed and internal validation was done with bootstrapping.
Results ECV was successfully performed in 232 cases (66.3%) among 343 women. Eight predictive factors were identified to be associated with a successful ECV: Gestational week at ECV < 39 weeks, multiparous, BMI before pregnancy < 22 kg/m^3, palpable fetal head, breech engagement, larger AFI, larger BPD and posterior placenta. This model showed good calibration and good discrimination (c-statistic = 0.82, 95% CI 0.76–0.88). Six predictive factors were identified to be associated with vaginal delivery after successful ECV: age < 35, multiparous, BMI before pregnancy < 22 kg/m^3, anterior placenta, lateral placenta and none-front fetal spine position. This model showed fair discrimination (c-statistic = 0.79, 95% CI 0.72–0.85). However, its calibration was not so satisfactory especially when the predicted probability was low.
Conclusion We validated a prediction model for ECV and delivery outcome, showing that the model's overall performance is good. This can be used in clinical practice after external validation.

Keywords External cephalic version · Prediction model · Delivery outcome · Breech presentation

Introduction

The incidence of breech presentation is between 3 and 4% at term [1]. Breech delivery increases the incidence rate of perinatal morbidity and mortality and poses a challenge to obstetric management. Therefore, breech position is one of the most common indications for cesarean section. Although delivery by cesarean section is considered safe, it is associated with short and long-term consequences for maternal and neonatal health.

External cephalic version (ECV) is a safe and effective procedure to reduce the occurrence of breech presentations at term and consequently the cesarean delivery rate for this indication [2]. The reported chance for a successful ECV is highly variable, ranging from 35 to 86% depending on the selection of patients and the population studied [3, 4]. Several studies reported that even in the successful cases of ECV, the rate of intrapartum cesarean delivery and operative vaginal delivery (OVD) is higher than in cases with spontaneous cephalic presentation [5].

The uncertainty of ECV success rate combined with the unknown outcome of vaginal delivery after ECV leads to many difficulties in clinical consultation. Thus, we aim to develop prediction models using statistical inference for the

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chance of successful ECV and delivery outcomes. The models will be useful tools for counseling women considering an ECV.

Materials and methods

We conducted a retrospective cohort study using data collected from medical records of 350 consecutive cases of women who came to take an ECV attempt at Women's Hospital School of Medicine Zhejiang University between Apr 30, 2018, and Sep 20, 2019. All women presenting with a singleton non-cephalic pregnancy at or after 36 weeks of gestational age willing to accept ECV were included in the study. Exclude from the study were women with any contraindication to vaginal birth (e.g., placenta previa, placental abruption), any contraindication for ECV (scarred uterus others than transverse in the lower segment, known uterine anomalies, placental abruption in history or signs of placental abruption, severe preeclampsia or HELLP syndrome, ruptured membranes), severe oligohydramnios (deepest pool < 2 cm), fetal anomalies or non-reassuring fetal heart rate monitoring. After examining the data set, we found 7 pregnant women who came twice to take ECV, so we deleted the latter records. Finally, 343 cases were included in our ECV outcome analysis. Furthermore, all successful ECV cases were selected and after deleting 1 case of lost visit, 231 cases remained for delivery outcome analysis after ECV.

Our primary outcome was successful ECV, which means the fetus was in a cephalic position 30 min after the ECV and the secondary outcome was the route of delivery. The study was approved by the Ethics Review Committee of Women's Hospital School of Medicine Zhejiang University (IRB-20200239-R). Written informed consent was obtained from all the participants.

In the operating room before the procedure, a detailed ultrasound evaluation was performed to assess the fetal presentation, placental location, amniotic fluid volume, and the presence of the nuchal cord. Intravenous ritodrine was used as a tocolytic, administered through a continuous 100 μg infusion pump 30 min before ECV and continued throughout the procedure. The patient was placed in a supine position with legs slightly bent and abducted. Experienced obstetricians performed the ECV procedure without any analgesia. We preferred to begin with a forward roll and then attempt a backward roll if the forward roll fails. If ECV was unsuccessful after 10 min of attempts, we stopped and classified 'unsuccessful'. The FHR was monitored intermittently during the procedure and after the procedure a non-stress test (NST) was obtained for at least 60 min immediately and repeated before discharge.

Induction of labor was considered when there was an obstetric indication for termination of pregnancy. Delivery was induced before 42 + 0 weeks. According to the discretion of the obstetrician in charge, induction was performed based on obstetric or maternal indications. Oxytocin is generally used for patients with a Bishop score more than 6, while prostaglandin is used for those with a lower score.

Data analysis

Based on clinical reasoning and data accessibility, the following 22 factors were selected as candidate predictors for the ECV outcome prediction: maternal age, gestational week of ECV (gestational week for short), gravidity, parity, maternal height, body mass index (BMI) before pregnancy, BMI during ECV (BMI for short), the possibility of palpation of the fetal head, breech engagement, amniotic fluid index in cm (AFI), amniotic fluid depth in cm (SDP), estimated fetal weight (EFW), position of the fetal spine, placental location (anterior, posterior, lateral, fundal), number of loops of nuchal cord, fetal growth parameters (biparietal diameter, femur length, head circumference, abdominal circumference). EFW was calculated with the Hadlock formula [6]. For delivery outcome (vaginal delivery or cesarean section) prediction after successful ECV, the candidate factors were the same as above except for exclusion of possibility of palpation of fetal head. Gestational week of delivery was also analyzed for its association with the delivery outcome.

Baseline characteristics were analyzed using descriptive statistics. Fetal growth parameters were presented as mean with standard deviance (SD) or median with interquartile (IQR). Frequency and proportion were presented for categorical and dichotomous variables. Univariable association was assessed between each candidate predictor and ECV outcome or delivery outcome after ECV by univariate binary logistic regression, resulting in odds ratios (ORs) with 95% confidence intervals (CIs) and corresponding p values. Factor with $p < 0.10$ was taken into consideration of model development and some of its groups with similar success rates (or ORs) were consolidated. The updated grouping would be used in subsequent model development.

Missing data of the qualified predictive variables were imputed because deleting them would lead to decreased statistical power and potentially biased results [7]. The multiple imputation process was repeated for 10 times by R package MICE. And then multiple logistic regression with the stepwise backward procedure was used to construct the prediction model of this study. The variable selection was repeated within each imputation set and a variable was included in the final model if it had been selected in 5 or more imputation sets (i.e., majority rule [8]). The final model was then fitted

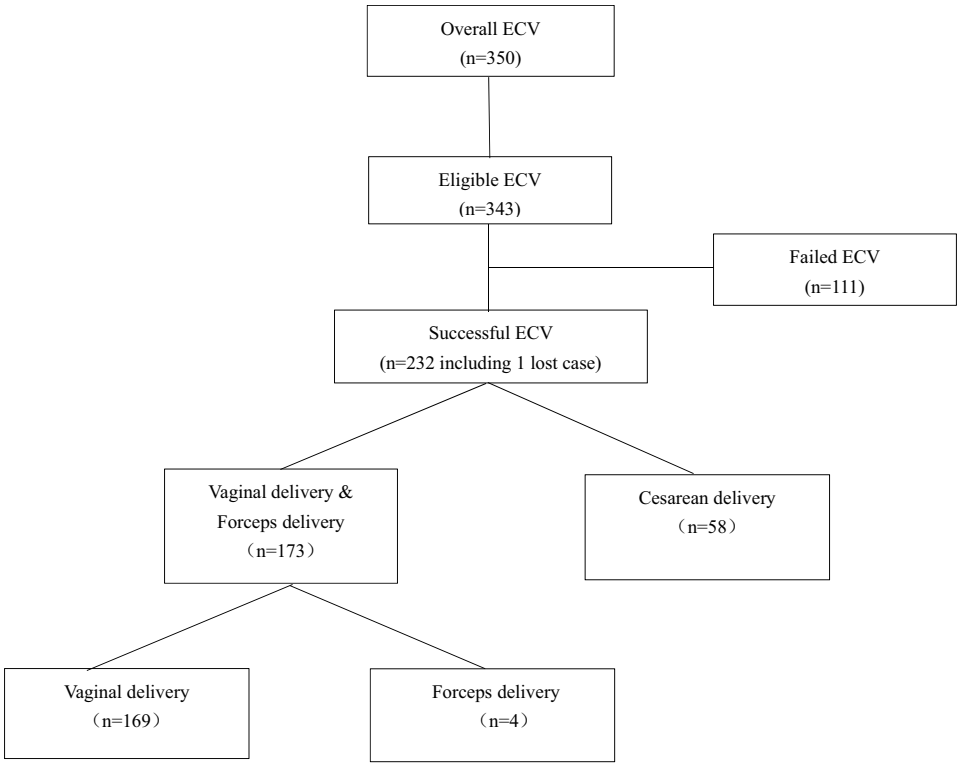

Fig. 1 Flow of patients through the study

within each imputation set and the intercept and regression coefficients were pooled. And the corresponding ORs with 95% CI were calculated by the value of coefficients and their standard error.

A key threat to the validity of the prediction is overfitting: the data under study are well described, but predictions are not valid for new subjects, which causes optimism about a model's performance in new subjects [9]. To reduce the overfitting or optimism, an internal validation was performed by bootstrapping (500 [9] times per imputation set) using a program in Harrell's book [10]. In each of these bootstrap samples, the same multivariable logistic regression was performed and the new model was applied to the original imputation set. As a result, optimism of c-statistic and the calibration slope was calculated, which was the difference between bootstrap performance and test performance, for every imputation set. Finally, the mean optimism of the 10 imputation sets was subtracted from their mean apparent performance, resulting in the validated performance of the imputation sets.

The discrimination and calibration of both prediction models were assessed in the original data. The discriminative ability was assessed by the ROC curve and its area under the curve (i.e., c-statistic) with 95% confidence interval. Besides, the maximum Jordan index was obtained, and the specificity, sensitivity, positive predictive value, and negative predictive value at this point were calculated. The calibration ability was assessed by the Hosmer–Lemeshow test with χ^2 value and corresponding p value obtained. $p > 0.05$ indicated that there was no statistically significant difference between the predicted value and the observed value, and the prediction model had a good calibration. In addition, a calibration curve was also drawn by Calster's method [11].

We used IBM SPSS statistics 20 for descriptive statistics, ROC curve drawing and area under ROC curve with 95% confidence interval calculation. Other data analysis was all performed in R version 3.6.3 (The R foundation for Statistical Computing, 2020, http://www.r-project.org/).

Results

Among 343 cases included in the ECV outcome analysis, 232 (67.6%) were successful. Exclude 1 lost case, 173 (74.9%) out of the 231 mothers-to-be with a successful ECV attempt gave birth via vaginal delivery, 58 (25.1%) had a cesarean section (Fig. 1) with certain indications shown in Table 1.

Predictors of successful ECV

Predictors related to the successful ECV were gestational week, gravidity, parity, BMI, BMI before pregnancy, palpation of the fetal head, breech engagement, AFI, anterior

Table 1 Indications of a cesarean section after successful ECV

Indications of cesarean section	Total $N=58$	%
Fetal distress	21	36.2
Relative cephalopelvic disproportion	10	17.2
Macrosomia	5	8.6
Malpresentation	5	8.6
Infection	4	6.9
Placenta abruption	4	6.9
Oligohydramnios	2	3.4
Failed labor induction	2	3.4
Secondary uterine atony	2	3.4
Nuchal cord	1	1.7
Others	2	3.4

placenta, posterior placenta, BPD (Table 1). The updated grouping was shown in Table 2.

In the multivariable analyses, the ECV outcome prediction model was developed according to the procedure mentioned above. Gestational week, parity, BMI before pregnancy, palpation of the fetal head, breech engagement, AFI, BPD and posterior placenta were found to be predictive of ECV outcome (Table 3). For this model, the predicted chance of successful ECV can be calculated using the following formula (0 for reference, 1 for the other except for AFI):

$$
\begin{aligned}
LP =& 10.1335 + 1.1773369 * \text{Parity} \\
&(0 \text{ for nulliparous, } 1 \text{ for multiparous}) \\
&+ 2.8676649 * \text{Palpation of head } (0 \text{ for unable, } 1 \text{ for able}) \\
&- 1.0933149 * \text{Breech engagement } (0 \text{ for no, } 1 \text{ for yes}) \\
&+ 1.4263758 * \text{AFI1 } 1 \text{ for} \geq 8.0 \text{ and; } 18.0, 0 \text{ for others} \\
&+ 2.7872484 * \text{AFI2 } (1 \text{ for} \geq 18.0, 0 \text{ for others}) \\
&+ 0.8341268 * \text{Posterior placenta } (0 \text{ for no, } 1 \text{ for yes}) \\
&+ 0.7382648 * \text{BPD} - 0.9656801 * \text{BMI before pregnancy} \\
&(0 \text{ for; } 22 \text{ kg/m}^3, 1 \text{ for} \geq 22 \text{ kg/m}^3) \text{ Predict;} \\
=& (1 + \exp(-LP))^{(-1)}
\end{aligned}
$$

The area under the ROC curve (c-statistics) is 0.823 (95% CI 0.764–0.881) which indicates a good discriminative ability of the model (Fig. 2). The maximum Youden index was 0.512. At this point, the sensitivity, specificity, positive predictive value, and negative predictive value were 66.7, 84.5, 89.5, 56.1%, respectively. The calibration plot of model suggested that the predictions by the model do not significantly deviate from the observed proportion as shown in Fig. 3. No statistically significant difference was suggested between the predicted probability and the observed proportion by Hosmer–Lemeshow test ($\chi^2=3.7106$, $p=0.8822$), which confirmed that the prediction model has moderate calibration ability.

The mean c-statistic was 0.815 for all imputation sets, which was very close to the c-statistic of the original data. As for the internal validation performed in the imputation sets, the mean optimism of c-statistic was 0.016. Subtracting this optimism estimation from the apparent performance of the imputation sets resulted in an optimism-adjusted discrimination of 0.80. The mean optimism of the slope was 0.129, which indicated an optimism-adjusted slope of 0.87 and a possible overfit up to 13% in an external population [12].

Predictors of delivery outcome after successful ECV

Predictors related to the delivery outcome after successful ECV were age, gravidity, parity, BMI, BMI before pregnancy, position of the fetal spine, anterior placenta, posterior placenta, lateral placenta, and number of loops of nuchal cord (Table 4). And the updated grouping was shown in Table 5. As for gestational week of delivery, it was indicated that pregnant women who gave birth relative early or relative late (<38 or ≥ 41 weeks) were more likely to have a cesarean section after a successful ECV while those who gave birth between 38 and 41 weeks were nearly 2 times more likely to have a vaginal delivery than the former (OR = 1.98, 95% CI: 0.94–4.14, $p=0.071$).

In the multivariable analyses, delivery outcome after successful ECV prediction model was developed according to the procedure mentioned above. Age, parity, BMI before pregnancy, anterior placenta, lateral placenta and position of the fetal spine were found to be predictive of ECV outcome (Table 6). For this model, the predicted chance of vaginal delivery can be calculated using the following formula (0 for reference, 1 for the other):

$$
\begin{aligned}
LP2 =& 1.5357370 - 1.2498236 * \text{Age} + 1.7086404 \\
&* \text{Parity} - 0.9728024 * \text{Anterior placenta} - 0.8248191 \\
&* \text{Lateral placenta} - 0.7956813 * \text{BMI before pregnancy} \\
&- 1.4876483 * \text{Position of the fetal spine} \\
\text{Predict1} =& (1 + \exp(-LP2))^{-1}
\end{aligned}
$$

The area under the ROC curve (c-statistic) was 0.786 (95% CI 0.724–0.848) which indicated a fair discriminative ability of the model (Fig. 4). The maximum Youden index was 0.466. At this point, the sensitivity, specificity, positive predictive value and negative predictive value were 65.5, 81.1, 91.7, 42.6%, respectively.

The calibration plot of the model suggested that the predictions by the model do not significantly deviate from the observed proportion when the predicted proportion

Table 2 Characteristics of the study population and the univariable associations between candidate predictors and successful ECV

Characteristic	Missing data	Total $n=343$	Successful ECV $n=232$	Failed ECV $n=111$	Univariable analysis		
					OR	95% CI	p
Patient characteristics							
Age							
< 28	0	72 (21.0)	47 (65.3)	25 (34.7)	Ref		
28 ~		77 (22.4)	46 (59.7)	31 (40.3)	0.80	0.41–1.54	0.49
30 ~		107 (31.2)	75 (70.1)	32 (29.9)	1.24	0.66–2.36	0.50
33 ~		87 (25.4)	64 (73.6)	23 (26.4)	1.48	0.75–2.92	0.26
Gestational week							
< 37	0	45 (13.1)	33 (73.3)	12 (26.7)	Ref		
37 ~		196 (57.1)	136 (69.4)	60 (30.6)	0.82	0.40–1.71	0.60
38 ~		85 (25.7)	55 (64.7)	30 (35.3)	0.67	0.30–1.48	0.32
39 ~		17 (5.2)	8 (47.1)	9 (52.9)	0.32	0.10–1.03	0.06
Gravidity							
1	0	139 (40.5)	86 (61.9)	53 (38.1)	Ref		
2		109 (31.8)	77 (70.6)	32 (29.4)	1.48	0.87–2.53	0.15
3		52 (15.2)	39 (75.0)	13 (25.0)	1.85	0.90–3.78	0.09
> 3		43 (12.5)	30 (69.8)	13 (30.2)	1.42	0.68–2.97	0.35
Parity							
Nulliparous	0	207 (60.3)	124 (59.9)	83 (40.1)	Ref		
Multiparous		136 (39.6)	108 (79.4)	28 (20.6)	2.58	1.57–4.26	< 0.001
Findings at clinical examination							
Height(cm)							
< 160	1	103 (30.1)	66 (64.1)	37 (35.9)	Ref		
160 ~		220 (64.3)	153 (69.5)	67 (30.5)	1.28	0.78–2.10	0.33
170 ~		19 (5.6)	12 (63.2)	7 (36.8)	0.96	0.35–2.65	0.94
BMI (kg/m^3)							
< 24	1	95 (27.8)	72 (75.8)	23 (24.2)	Ref		
24 ~		151 (44.2)	106 (70.2)	45 (29.8)	0.75	0.42–1.35	0.34
27 ~		96 (28.1)	53 (55.2)	43 (44.8)	0.39	0.21–0.73	< 0.01
BMI before pregnancy (kg/m^3)							
< 18	1	45 (13.2)	33 (73.3)	12 (26.7)	Ref		
18 ~		211 (61.7)	153 (72.5)	58 (27.5)	0.96	0.46–1.98	0.91
22 ~		86 (25.1)	45 (52.3)	41 (47.7)	0.40	0.18–0.88	0.02
Possibility of palpation of the fetal head							
Yes	0	327 (95.3)	230 (70.3)	97 (29.7)	16.60	3.70–74.42	< 0.001
No		16 (4.7)	2 (12.5)	14 (87.5)	Ref		
Breech engagement							
Yes	1[a]	40 (11.7)	16 (40.0)	24 (60.0)	0.27	0.14–0.53	< 0.001
No		302 (88.0)	215 (71.2)	87 (28.8)	Ref		
Ultrasonographic findings							
AFI (cm)							
< 8.0	131	27 (12.7)	9 (33.3)	18(66.7)	Ref		
8.0 ~		165 (77.8)	114 (69.1)	51 (30.9)	4.47	1.88–10.62	< 0.001
18.0 ~		20 (9.4)	18 (90.0)	2 (10.0)	18.00	3.40–95.20	< 0.001
SDP(cm)							
~ 3	214	99 (76.7)	68 (68.7)	31 (31.3)	Ref		
> 3		30 (23.3)	22 (73.3)	8(26.7)	1.25	0.50–3.13	0.63
EFW(g)							

Table 2 (continued)

Characteristic	Missing data	Total $n=343$	Successful ECV $n=232$	Failed ECV $n=111$	Univariable analysis		
					OR	95% CI	p
~3000	0	90 (26.2)	61 (67.8)	29 (32.2)	Ref		
>3000		253 (73.8)	171 (67.6)	82 (32.4)	0.99	0.60–1.66	0.97
Position of the fetal spine							
Left	15	180 (54.9)	117 (54.9)	63 (45.1)	Ref		
Front		16(4.9)	12 (75.0)	4 (25.0)	1.62	0.50–5.22	0.42
Right		126 (38.4)	90 (71.4)	36 (28.6)	1.35	0.82–2.20	0.24
Others[b]		6 (1.8)	5 (83.3)	1 (16.7)	2.69	0.31–23.55	0.37
Placental location							
Anterior							
No	1	199 (58.2)	145 (72.9)	54 (27.1)	Ref		
Yes		143 (41.8)	86 (60.1)	57 (39.9)	0.56	0.36–0.89	0.01
Posterior							
No	1	190 (55.6)	119 (62.6)	71 (37.4)	Ref		
Yes		152(44.4)	112 (73.7)	40 (26.3)	1.67	1.05–2.66	0.03
Lateral							
No	1	279 (81.6)	186 (66.7)	93(33.3)	Ref		
Yes		63 (18.4)	45 (68.3)	18(31.7)	1.25	0.69–2.28	0.47
Fundal							
No	2	276 (80.9)	188 (68.1)	88 (31.9)	Ref		
Yes		65 (19.1)	43 (71.4)	22 (28.6)	1.00	0.56–1.78	0.99
Number of loops of nuchal cord							
0	3	184 (54.1)	124 (67.4)	60 (32.6)	Ref		
1		124 (36.5)	87 (70.1)	37 (29.9)	1.14	0.70–1.86	0.61
2		32 (9.4)	19 (59.4)	13 (40.6)	0.71	0.33–1.53	0.38
BPD (cm)	3	9.2 (0.5)	–	–	1.97	1.11–3.49	0.02
FL (cm)	3	6.9 (0.4)	–	–	0.64	0.28–1.47	0.30
Head circumference (cm)	184	33.0 (1.8)	–	–	1.06	0.82–1.37	0.66
Abdominal circumference (cm)	196	33.0 ± 1.7	–	–	1.12	0.92–1.37	0.25

[a]Transverse lie

[b]Others include LSCA, Transverse lie and Unknown

was above 0.4 as shown in Fig. 5. However, when the predicted proportion was below 0.4, the possibility of vaginal delivery might be underestimated as was shown in the calibration plot, where further improvement was needed. No statistically significant difference was suggested between the predicted probability and the observed proportion by Hosmer–Lemeshow test ($\chi^2= 5.0851$, $p=0.7484$). Generally speaking, its calibration was not quite satisfactory and its application was limited, especially for those who have a low estimation of the probability of vaginal delivery-the decision whether or not to take an ECV could be very hard to make.

The mean c-statistic was 0.777 for all imputation sets, which was very close to the c-statistic of the original data. As for the internal validation performed in the imputation sets, the mean optimism of c-statistic was 0.028. Subtracting this optimism estimation from the apparent performance of the imputation sets resulted in optimism-adjusted discrimination of 0.749. The mean optimism of the slope was 0.158, which indicated an optimism-adjusted slope of 0.84 and a possible overfit up to 16% in an external population [12].

Discussion

The aim of this study was to identify predictors of successful ECV and delivery outcomes. The total success rate of ECV during the study period was about 67%. Overall, the success rate was higher compared to the previous studies [13, 14]. The relatively high success rate can be attributed to the

Table 3 Univariable associations between potential predictors and successful ECV

Characteristic	Missing data	Total $n=343$	Successful ECV $n=232$	Failed ECV $n=111$	Univariable analysis		
					OR	95% CI	p
Patient characteristics							
Gestational week							
< 39	0	326 (94.8)	224 (68.7)	102 (31.3)	Ref		
39 ~		17 (5.2)	8 (47.1)	9 (52.9)	0.40	0.15–1.08	0.07
Gravidity							
1	0	139 (40.5)	86 (61.9)	53 (38.1)	Ref		
2 ~		204 (49.5)	146 (71.6)	58 (28.4)	1.55	0.98–2.45	0.06
Parity							
Nulliparous	0	207 (60.3)	124 (59.9)	83 (40.1)	Ref		
Multiparous		136 (39.6)	108 (79.4)	28 (20.6)	2.58	1.57–4.26	< 0.001
Findings at clinical examination							
BMI (kg/m^3)							
< 27	1	246 (71.9)	178 (72.4)	68 (27.6)	Ref		
27 ~		96 (28.1)	53 (55.2)	43 (44.8)	0.47	0.29–0.77	< 0.01
BMI before pregnancy (kg/m^3)							
< 22	1	256 (74.9)	186 (72.7)	70 (27.3)	Ref		
22 ~		86 (25.1)	45 (52.3)	41 (47.7)	0.41	0.25–0.68	< 0.001
Possibility of palpation of the fetal head							
Yes	0	327 (95.3)	230 (70.3)	97 (29.7)	16.60	3.70–74.42	< 0.001
No		16 (4.7)	2 (12.5)	14 (87.5)	Ref		
Breech engagement							
Yes	1[a]	40 (11.7)	16 (40.0)	24 (60.0)	0.27	0.14–0.53	< 0.001
No		302 (88.0)	215 (71.2)	87 (28.8)	ref		
Ultrasonographic findings							
AFI (cm)							
< 8.0	131	27 (12.7)	9 (33.3)	18 (66.7)	Ref		
8.0 ~		165 (77.8)	114 (69.1)	51 (30.9)	4.47	1.88–10.62	< 0.001
18.0 ~		20 (9.4)	18 (90.0)	2 (10.0)	18.00	3.40–95.20	< 0.001
Placental location							
Anterior							
No	1	199 (58.2)	145 (72.9)	54 (27.1)	Ref		
Yes		143 (41.8)	86 (60.1)	57 (39.9)	0.56	0.36–0.89	0.01
Posterior							
No	1	190 (55.6)	119 (62.6)	71 (37.4)	Ref		
Yes		152 (44.4)	112 (73.7)	40 (26.3)	1.67	1.05–2.66	0.03
BPD(cm)	3	9.2 (0.5)	–	–	1.97	1.11–3.49	0.02

[a]Transverse lie

[b]Others include LSCA, Transverse lie and Unknown

characteristics of our study population, such as a relatively high proportion of multipara (48%) and lower BMI levels (25.4). Here, we conducted a retrospective study to explore the factors associated with successful ECV attempts and to develop prediction models for successful ECV and delivery outcomes. The results of univariate analyses revealed that gestational week, gravidity, parity, BMI, BMI before pregnancy, palpation of the fetal head, breech engagement, AFI, anterior placenta, type of breech, BPD play an important prognostic role in successful ECV and indicated that age, gravidity, parity, BMI, BMI before pregnancy, position of the fetal spine, anterior placenta, posterior placenta, lateral placenta, number of loops of umbilical cord around

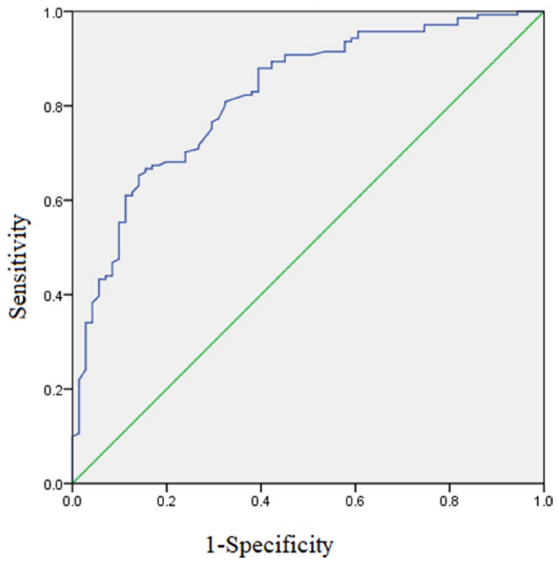

Fig. 2 ROC curve of ECV outcome prediction model

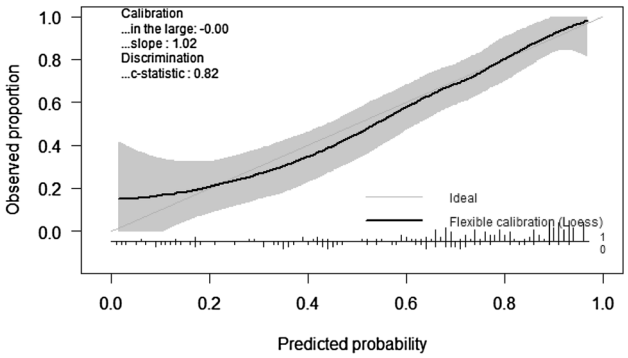

Fig. 3 Calibration plot of the ECV outcome prediction model

neck should be considered as factors influencing delivery outcome. In the model of predicting delivery outcome after successful ECV, the anterior and lateral placenta are the negative factors for the success of vaginal delivery (OR < 1, Table 7). We speculate that the external cephalic version operation may exert force on the anterior or lateral placenta, which increases the risk of forming potential subplacental hematoma or hidden placental abruption. Consequently, the incidence of fetal distress or placental abruption is increased during delivery, reducing the success rate of vaginal delivery. In addition, it may be that the anterior and lateral placenta affects the rotation and descent of the fetal body with the change of position of the fetal head in the birth canal.

In this study, we developed and internally validated prediction models for the successful ECV procedure and delivery outcome. Our research has some advantages:

Table 4 Multivariable associations for ECV outcome prediction model

predictor	β	OR	95% CI	p
Intercept	− 10.284			0.004
Gestational week				
< 39	Ref			
≥ 39	− 1.102	0.33	0.10–1.09	0.069
Parity				
Nulliparous	Ref			
Multiparous	1.189	3.28	1.74–6.19	< 0.001
BMI before pregnancy (kg/m^3)				
< 22	Ref			
22 ~	− 0.963	0.38	0.21–0.70	0.002
Palpation of head				
No	Ref			
Yes	2.912	18.39	3.73–90.76	< 0.001
Breech engagement				
No	Ref			
Yes	− 1.174	0.31	0.14–0.70	0.005
AFI (cm)				
< 8.0	Ref			
≥ 8.0 and < 18.0	1.371	3.94	1.56–9.93	0.004
≥ 18.0	2.752	15.68	2.32–105.96	0.006
Posterior placenta				
No	Ref			
Yes	0.838	2.31	1.27–4.19	0.006
BPD (cm)	0.771	2.16	1.04–4.51	0.041

(1) To the best of our knowledge, this is the first concurrent study to predict both ECV success and delivery outcome. Combined with the results of the two prediction

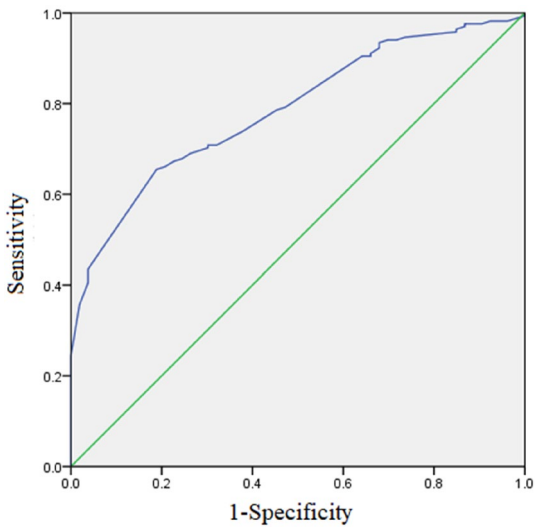

Fig. 4 ROC curve of delivery outcome prediction model

Table 5 Characteristics of the study population and the univariable associations between candidate predictors and vaginal delivery

Characteristic	Missing data	Total $n=231$	Natural childbirth $n=173$	Cesarean section $n=58$	Univariate analysis		
					OR	95% CI	p
Patient characteristics							
Age							
< 35	0	192 (83.1)	149 (77.6)	43 (22.4)	Ref		
35 ~		33 (14.2)	21 (63.6)	12 (36.4)	0.51	0.23–1.11	0.089
> 40		6 (2.6)	3 (50.0)	3 (50.0)	0.28	0.06–1.48	0.137
Gestational week at ECV							
< 37	0	32 (12.8)	25 (78.1)	7 (21.9)	Ref		
37 ~		136 (58.9)	98 (72.1)	38 (27.9)	0.72	0.29–1.81	0.487
38 ~		55 (23.8)	44 (80.0)	11 (20.0)	1.12	0.39–3.26	0.835
39 ~		8 (3.5)	6 (75.0)	2 (25.0)	0.84	0.14–5.11	0.850
Gravidity							
1	0	85 (36.8)	58 (68.2)	27 (31.8)	Ref		
2		77 (33.3)	63 (81.8)	14 (18.2)	2.09	1.00–4.38	0.049
3		39 (16.9)	30 (76.9)	9 (23.1)	1.55	0.64–3.72	0.324
> 3		30 (13.0)	22 (73.3)	8 (26.7)	1.28	0.51–3.24	0.602
Parity							
Nulliparous	0	123 (53.2)	81 (65.9)	42 (34.1)	Ref		
Multiparous		108 (46.8)	92 (85.2)	16 (14.8)	2.98	1.56–5.70	< 0.001
Findings at clinical examination							
Height (cm)							
< 160	1	66 (28.7)	47 (71.2)	19 (28.8)	Ref		
160 ~		152 (66.1)	116 (76.3)	36 (23.7)	1.30	0.68–2.50	0.426
170 ~		12 (5.2)	10 (83.3)	2 (16.7)	2.02	0.40–10.10	0.391
BMI (kg/m^3)							
< 24	1	72 (31.3)	60 (83.3)	12 (16.7)	Ref		
24 ~		105 (45.7)	78 (74.3)	27 (25.7)	0.58	0.27–1.23	0.156
27 ~		53 (23.0)	35 (66.0)	18 (34.0)	0.39	0.17–0.90	0.028
BMI before pregnancy (kg/m^3)							
< 18	1	33 (14.3)	27 (81.8)	6 (18.2)	Ref		
18 ~		152 (66.1)	118 (77.6)	34 (22.4)	0.77	0.29–2.02	0.597
22 ~		45 (19.6)	28 (62.2)	17 (37.8)	0.37	0.13–1.07	0.066
Breech engagement							
Yes	1[a]	16 (7.0)	16 (100)	0 (0)	> 999.999	0-inf	0.987
No		214 (93.0)	157 (73.4)	57 (26.6)	Ref		
Ultrasonographic findings							
AFI (cm)							
< 8.0	91	9 (6.4)	6 (66.7)	3 (33.3)	Ref		
8.0 ~		113 (80.7)	82 (72.6)	31 (27.4)	1.32	0.31–5.62	0.705
18.0 ~		18 (12.9)	11 (61.1)	7 (38.9)	0.79	0.15–4.21	0.778
SDP(cm)							
~ 3	141	68 (75.6)	56 (82.4)	12 (17.6)	Ref		
> 3		22 (24.4)	17 (77.3)	5 (22.7)	0.73	0.22–2.46	0.598
EFW(g)							
~ 3000	0	61 (26.4)	46 (75.4)	15 (24.6)	Ref		
> 3000		170 (73.6)	127 (74.7)	43 (25.3)	0.96	0.49–1.90	0.913
Position of the fetal spine							

Table 5 (continued)

Characteristic	Missing data	Total $n=231$	Natural childbirth $n=173$	Cesarean section $n=58$	Univariate analysis		
					OR	95% CI	p
Left	8	116 (50.2)	90 (77.6)	26 (22.4)	Ref		
Front		12 (5.4)	6 (50.0)	6 (50.0)	0.29	0.09–0.97	0.045
Right		90 (40.4)	68 (75.6)	22 (24.4)	0.89	0.47–1.71	0.732
Others[b]		5 (2.2)	5 (100)	0 (0)	> 999.999	0-inf	0.989
Placental location							
Anterior							
No	1	144 (62.3)	116 (80.6)	28 (19.4)	Ref		
Yes		86 (37.2)	56 (65.1)	30 (34.9)	0.45	0.25–0.83	0.010
Posterior							
No	1	119 (51.7)	82 (68.9)	37 (31.1)	Ref		
Yes		111 (48.3)	90 (81.1)	21 (18.9)	1.93	1.05–3.57	0.035
Lateral							
No	1	185 (80.4)	143 (77.3)	42 (22.7)	Ref		
Yes		45 (19.6)	29 (64.4)	16 (35.6)	0.53	0.26–1.07	0.078
Fundal							
No	1	187 (81.3)	136 (73.5)	49 (26.5)	Ref		
Yes		43 (18.7)	34 (79.1)	9 (20.9)	1.34	0.60–3.00	0.474
Number of loops of nuchal cord							
0	2	123 (53.7)	98 (79.7)	25 (20.3)	Ref		
1		87 (38.0)	60 (69.0)	27 (31.0)	0.57	0.30–1.07	0.078
2		19 (8.3)	14 (73.7)	5 (26.3)	0.71	0.24–2.17	0.553
BPD (cm)	2	9.2 (0.6)	–	–	1.31	0.63–2.73	0.462
FL (cm)	2	6.9 (0.4)	–	–	0.70	0.23–2.12	0.525
Head circumference (cm)	127	32.9 ± 1.2	–	–	1.21	0.83–1.77	0.317
Abdominal circumference (cm)	138	33.1 ± 1.7	–	–	1.07	0.82–1.41	0.618
Others							
Gestational week of delivery							
<38 or ≥ 41 weeks	0	38 (16.4)	24 (63.2)	14 (36.8)	Ref		
Others		193 (83.6)	149 (77.2)	44 (22.8)	1.98	0.94–4.14	0.071

[a]Transverse lie

[b]Others include LSCA, Transverse lie and Unknown

models, we can provide unbiased and meaningful information. (2) Our study is the highest AUC (0.82; 95% CI 0.76–0.88) achieved by the developed prediction of ECV success compared to the c-statics of (0.78; 95% CI 0.75–0.81) of the study of Velzel et al. [15] and (0.66; 95% CI 0.60–0.72) of the study by Marcella et al. [16]. (3) This study provides detailed information regarding the predictors of successful ECV and delivery outcome in a single-center according to a standardized approach. All data were recorded using standardized data collection forms. (4) We incorporated all possible relevant predictors in our prediction models, and all data collectible used in the model are easy to reach and easy to measure. Consequent, these two models can be easy to apply in clinical practice.

To counsel patients on the success rates of ECV and delivery outcomes better, we develop two prediction models to identify patients with a lower likelihood of success ECV and vaginal delivery. Several theoretical models have been developed in a number of studies [15–20]. Since we used a maximum of seven possible predictors in our models, we were able to make a more accurate successful ECV model (0.82; 95% CI 0.76–0.88).

Several studies reported that women after a successful ECV are at higher risk of cesarean section [21–23]. However, studies with contradictory findings are also available. According to some authors [24], cesarean delivery and operative vaginal delivery rates following successful ECV are not increased, even in patients

Table 6 Univariable associations between potential predictors and delivery outcomes

Characteristic	Missing data	Total $n=231$	Natural childbirth $n=173$	Cesarean section $n=58$	Univariate analysis		
					OR	95% CI	p
Patient characteristics							
Age							
< 35	0	192 (83.1)	149 (77.6)	43 (22.4)	Ref		
35 ~		39 (16.8)	24 (61.5)	15 (38.5)	0.46	0.22–0.96	0.038
Gravidity							
1 or > 3	0	115 (49.8)	80 (69.6)	35 (30.4)	Ref		
2 or 3		116 (50.2)	93 (80.2)	23 (19.8)	1.77	0.97–3.24	0.065
Parity							
Nulliparous	0	123 (53.2)	81 (65.9)	42 (34.1)	Ref		
Multiparous		108 (46.8)	92 (85.2)	16 (14.8)	2.98	1.56–5.70	< 0.001
Findings at clinical examination							
BMI (kg/m^3)							
< 24	1	72 (31.3)	60 (83.3)	12 (16.7)	Ref		
24 ~		105 (45.7)	78 (74.3)	27 (25.7)	0.58	0.27–1.23	0.156
27 ~		53 (23.0)	35 (66.0)	18 (34.0)	0.39	0.17–0.90	0.028
BMI before pregnancy (kg/m^3)							
< 22	1	185 (80.4)	145 (78.4)	40 (21.6)	Ref		
22 ~		45 (19.6)	28 (62.2)	17 (37.8)	0.45	0.23–0.91	0.027
Ultrasonographic findings							
Position of the fetal spine							
None-Front[a]	8	211 (94.6)	163 (77.3)	48 (22.7)	Ref		
Front		12 (5.4)	6 (50.0)	6 (50.0)	0.29	0.09–0.95	0.042
Placental location							
Anterior							
No	1	144 (62.3)	116 (80.6)	28 (19.4)	Ref		
Yes		86 (37.2)	56 (65.1)	30 (34.9)	0.45	0.25–0.83	0.010
Posterior							
No	1	119 (51.7)	82 (68.9)	37 (31.1)	Ref		
Yes		111 (48.3)	90 (81.1)	21 (18.9)	1.93	1.05–3.57	0.035
Lateral							
No	1	185 (80.4)	143 (77.3)	42 (22.7)	Ref		
Yes		45 (19.6)	29 (64.4)	16 (35.6)	0.53	0.26–1.07	0.078
Number of loops of nuchal cord							
0	2	123 (53.7)	98 (79.7)	25 (20.3)	Ref		
1		87 (38.0)	60 (69.0)	27 (31.0)	0.57	0.30–1.07	0.078
2		19 (8.3)	14 (73.7)	5 (26.3)	0.71	0.24–2.17	0.553

*None-Front contains Left, Right, Others (LSCA, Transverse lie and Unknown)

with a prior cesarean delivery. This brings with it some potential biases and knowledge gaps. Thus, it is of great clinical value to predict the final delivery outcome of breech external inversion surgery before and after full-term. Compared to the c-statics of (0.728) of the delivery outcome prediction study of Jorge et al. [25], our performance was better (0.749; 95% CI 0.677–0.822).

Several limitations are still present in our study. First, we did not externally validate our model. In further work, we plan to perform external validation to corroborate our model. Second, to maximally reduce the medical costs, our procedure did not routinely use regional analgesia during ECV. Although, administration of neuraxial analgesia can significantly increase the success rate of ECV among women with malpresentation at term or late preterm [26].

Table 7 Multivariable associations for delivery outcome prediction model

Predictor	β	OR	95% CI	p
Intercept	1.536			< 0.001
Age				
< 35	Ref			
35 ~	− 1.250	0.29	0.16–0.50	< 0.001
Parity				
Nulliparous	Ref			
Multiparous	1.709	5.52	2.50–12.19	< 0.001
BMI before pregnancy (kg/m^3)				
< 22	Ref			
22 ~	− 0.796	0.45	0.21–0.99	0.048
Position of the fetal spine				
None-Front[a]	Ref			
Front	− 1.488	0.23	0.06–0.85	0.029
Anterior				
No	Ref			
Yes	− 0.9728	0.38	0.19–0.74	0.005
Lateral				
No	Ref			
Yes	− 0.8248	0.44	0.20–0.96	0.039

*None-Front contains Left, Right, Others (LSCA, Transverse lie and Unknown)

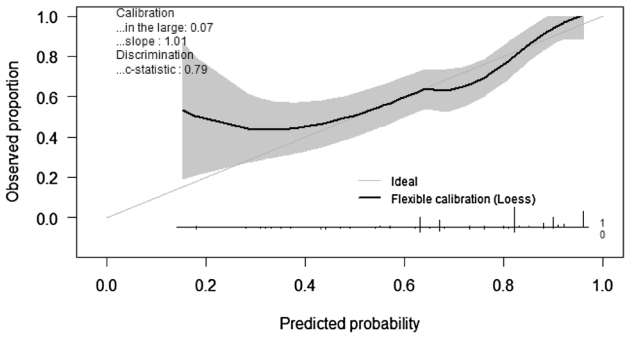

Fig. 5 Calibration plot of the delivery outcome prediction model

Conclusion

We used a maximum of seven possible predictors in our models to make a more accurate successful ECV model, and concurrent study to predict delivery outcome after a successful ECV. Two models have good performance in forecasting accuracy. We believe that our model is more useful and effective in clinical consultation. From a clinical perspective, the prediction models in our study can help clinicians to use as a decision-making tool and provide an explanation for informed decision making. This can facilitate shared decision-making between the clinicians and pregnant women on the appropriate course of action.

Author's contributions Guarantor of integrity of entire study Jian Xu. Study concepts Jian Xu, Qiong Luo, Guangdi Chen. Study design Qiong Luo Literature research Tian Dong Clinical studies Tian Dong, Baihui Zhao Data acquisition Tian Dong, Ying Jiang, Yuan Chen. Data analysis/interpretation Tian Dong, Xinjie Chen, Min Lv, Yuqun Pu. Statistical analysis Xinjie Chen. Manuscript preparation. Tian Dong Manuscript definition of intellectual content. Tian Dong. Manuscript editing Tian Dong. Manuscript revision/review. Jian Xu, Qiong Luo. Manuscript final version approval Jian Xu, Qiong Luo. All the authors have accepted responsibility for the entire content of this submitted manuscript and approved submission.

Declarations

Conflict of interest We declare that we have no conflict of interest.

Ethical approval Ethical approval was obtained for the pilot trial. (The Ethics Review Committee of Women's Hospital School of Medicine Zhejiang University, reference number: IRB-20200239-R)

Informed Consent All subjects gave informed written consent permitting participation.

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