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A nomogram to predict shoulder dystocia in patients during labor: a retrospective cohort study

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Abstract

Background

Shoulder dystocia (SD) is defined as a delivery complication in which, following delivery of the fetal head, the anterior fetal shoulder becomes impacted behind the maternal pubic symphysis, preventing vaginal delivery despite application of gentle axial traction. It represents a mechanical obstruction arising from fetopelvic disproportion. To date, no validated predictive model exists for identifying pregnant individuals at elevated risk of shoulder dystocia. This study aims to develop and validate a clinical prediction model by systematically screening candidate risk factors, performing multivariate logistic regression analysis, and identifying independent predictors of shoulder dystocia. The resulting model is intended for integration into antenatal risk assessment protocols to support timely intervention, thereby reducing the incidence of shoulder dystocia and improving maternal and neonatal outcomes.

Materials and Methods

A total of 800 vaginal deliveries—including 160 cases complicated by shoulder dystocia and 640 uncomplicated cases—were randomly allocated to a model development cohort (n = 560) and a validation cohort (n = 240) in a 7:3 ratio. Using the model development cohort, a predictive logistic regression model for shoulder dystocia during vaginal delivery was constructed. Following variable selection via Least Absolute Shrinkage and Selection Operator (LASSO) regression, nine candidate variables significantly associated with shoulder dystocia were identified; subsequently, multivariate logistic regression was employed to refine the model and identify six independent predictors. The final model's discrimination and calibration were rigorously evaluated in the independent validation cohort.

Results

Compared with parturients without shoulder dystocia, six independent risk factors are significantly associated with an increased incidence of shoulder dystocia: estimated fetal weight (EFW) > 4000 g, abdominal circumference–head circumference (AC–HC) ≥ 2.5 cm, gestational diabetes mellitus (GDM), maternal body mass index (BMI) > 28 kg/m², short maternal stature (≤ 150 cm), and prolonged second stage of labor. All associations reached statistical significance ($P < 0.001$).

Conclusions

Six independent antepartum predictors of shoulder dystocia during vaginal delivery were identified: EFW > 4000 g, AC–HC ≥ 2.5 cm, prolonged second stage of labor, short maternal stature (≤ 150 cm), BMI > 28 kg/m², and GDM. The nomogram developed from these variables demonstrated robust discriminative

ability and excellent calibration, indicating its potential utility for individualized antenatal risk stratification.

1. Introduction

Shoulder dystocia is an obstetric emergency characterized by failure of fetal shoulder delivery after vaginal emergence of the fetal head, necessitating additional maneuvers beyond routine traction[1]. Although relatively infrequent—occurring in approximately 0.2–3.0% of vaginal deliveries—it demands prompt, standardized intervention to mitigate risks of neonatal brachial plexus injury, hypoxic-ischemic encephalopathy, or fetal death, as well as maternal complications including postpartum hemorrhage and severe perineal trauma[2]. The primary anatomical basis lies in disproportion between the fetal bisacral (bi-acromial) diameter and the maternal pelvic inlet transverse diameter. Clinically, the anterior fetal shoulder most commonly becomes impacted behind the maternal symphysis pubis. Established risk factors fall into two categories: (1) Antepartum factors—including pregestational or gestational diabetes mellitus (associated with fetal macrosomia), maternal obesity (BMI ≥ 30 kg/m²), post-term gestation (≥ 42 weeks), and prior history of shoulder dystocia; and (2) Intrapartum factors—most notably suspected or confirmed fetal macrosomia (birth weight ≥ 4000 g), prolonged second stage of labor, and requirement for operative vaginal delivery (e.g., vacuum-assisted or forceps-assisted delivery)[3–4].

Shoulder dystocia remains an obstetric emergency that is frequently unpredictable—occurring even in deliveries involving normal-weight neonates with no identifiable antepartum or intrapartum risk factors. Consequently, all members of the delivery team must maintain constant readiness to manage this complication promptly and effectively[5]. Diagnosis is primarily clinical, relying on characteristic physical signs rather than imaging modalities. The hallmark finding is “turtle sign”—namely, retraction and tight apposition of the delivered fetal head against the maternal perineum—accompanied by failure of shoulder delivery despite standard axial traction[6–7]. Upon recognition, immediate initiation of evidence-based emergency maneuvers is imperative; the overarching objective is to expedite safe shoulder delivery while minimizing fetal hypoxia and maternal trauma[8].

In conclusion, shoulder dystocia represents a critical obstetric emergency characterized by significant maternal and neonatal morbidity. Accordingly, this study aims to develop and externally validate a robust clinical prediction model for identifying pregnant women at elevated risk of shoulder dystocia. To achieve this, we systematically evaluated potential antenatal and intrapartum risk factors, employed multivariate logistic regression to identify independent predictors, and rigorously assessed model performance in terms of discrimination, calibration, and clinical utility. The resulting model is designed to be incorporated into routine prenatal risk stratification protocols to facilitate timely, evidence-informed decision-making—ultimately contributing to a reduction in shoulder dystocia incidence and improved maternal and neonatal outcomes.

2. Materials and Methods

Ethical approval

for this study was granted by the Ethics Review Board of the Affiliated Suzhou Hospital of Nanjing Medical University (K-2024-172-K01), with all participants providing informed consent.

2.1 Participants

This retrospective cohort study enrolled a total of 800 parturients who underwent vaginal delivery at Suzhou Municipal Hospital between January 2020 and December 2025. Participants were stratified into two groups: the shoulder dystocia group (n = 160), comprising individuals who experienced shoulder dystocia during vaginal delivery; and the control group (n = 640), comprising individuals who delivered vaginally without shoulder dystocia (see Table 1). All participants retained the right to withdraw from the study at any time, in accordance with ethical principles governing human subject research.

Table 1
Baseline characteristics of study patients with shoulder dystocia (SD).

Characteristic	SD (n = 160)	No SD (n = 640)	Statistic (t//Z/ χ^2)	*P*
Age (years)	27.305 ± 4.836	27.837 ± 5.025	1.207	0.228
Weight gain	14.208 ± 3.742	11.836 ± 2.553	9.483	< 0.001
BMI (kg/m^2)	26.972 ± 4.358	26.131 ± 4.273	2.218	0.027
Maternal stature	157.393 ± 8.257	159.058 ± 8.368	2.257	0.024
Nulliparity	72 (45.000)	333 (52.031)	2.532	0.112
In-vitro fertilization	7 (4.375)	33 (5.156)	0.164	0.685
Gestational age	39.462 ± 1.693	39.385 ± 1.587	0.542	0.588
Gestational age ≥ 41 weeks	25 (15.625)	51 (7.969)	8.727	0.003
SD at previous delivery	4 (2.500)	9 (1.406)	0.958	0.328
Pregnancy-induced hypertension	10 (6.250)	32 (5.000)	0.402	0.526
Diabetic disorders	27 (16.875)	53 (8.281)	10.503	0.001
PROM	18 (11.250)	69 (10.781)	0.029	0.865
Induction of labor	41 (25.625)	196 (30.625)	1.535	0.215
Stimulation with oxytocin	53 (33.125)	223 (34.844)	0.167	0.682
Epidural analgesia	148 (92.500)	568 (8.750)	1.915	0.166
Abdominal circumference (cm)	36.625 ± 2.027	35.728 ± 1.937	5.190	< 0.001
Head circumference (cm)	33.815 ± 1.438	33.362 ± 1.274	3.917	< 0.001
AC-HC ≥ 2.5 cm	39 (24.375)	62 (9.688)	25.032	< 0.001
Caput Succedaneum	55 (34.375)	164 (25.625)	4.929	0.026
Duration of latent phase (min)	519.362 ± 144.072	494.725 ± 127.846	2.124	0.034
Duration of active phase (min)	223.058 ± 52.942	216.847 ± 47.947	1.435	0.152
Prolonged second stage of labor	11 (6.875)	19 (2.969)	5.411	0.020

Characteristic	SD (n = 160)	No SD (n = 640)	Statistic (t//Z/ χ^2)	*P*
Total duration of labor (min)	853.162 ± 225.385	819.639 ± 201.403	1.838	0.067
Vaginal operative delivery	7 (4.375)	41 (6.406)	0.936	0.333
Estimated fetal weight (g)	3856.327 ± 438.602	3692.745 ± 397.504	4.558	< 0.001

The enrolled parturients were randomly allocated to either the model development cohort (n = 560) or the validation cohort (n = 240) in a 7:3 ratio (see Table 2). A predictive model for shoulder dystocia during vaginal delivery was developed using data from the model development cohort and subsequently validated using the independent validation cohort. Protocol adherence and data quality were rigorously monitored; ultimately, complete and analyzable data from all 800 participants were retained for final analysis.

Table 2
The characteristics of development and validation sets

Characteristic	Training Set (n = 560)	Validation Set (n = 240)	Statistic (t//Z/ χ^2)	*P*
Age (years)	27.504 ± 4.918	27.381 ± 4.774	0.327	0.744
Weight gain	12.748 ± 2.769	12.539 ± 2.635	0.992	0.321
BMI (kg/m^2)	26.492 ± 4.296	26.406 ± 4.318	0.259	0.796
Maternal stature	158.738 ± 8.263	158.616 ± 8.295	0.191	0.849
Nulliparity	274 (48.929)	131 (54.583)	2.149	0.143
In-vitro fertilization	23 (4.107)	17 (7.083)	3.133	0.077
Gestational age	39.417 ± 1.615	39.439 ± 1.624	0.176	0.860
Gestational age ≥ 41 weeks	47 (8.393)	29 (12.083)	2.661	0.103
SD at previous delivery	7 (1.250)	6 (2.500)	1.642	0.200
Pregnancy-induced hypertension	31 (5.536)	11 (4.583)	0.306	0.580
Diabetic disorders	61 (10.893)	19 (7.917)	1.653	0.198
PROM	55 (9.821)	22 (9.167)	0.083	0.774
Induction of labor	156 (27.857)	81 (33.750)	2.798	0.094
Stimulation with oxytocin	183 (32.679)	93 (38.750)	2.741	0.098
Epidural analgesia	507 (90.536)	209 (87.083)	2.131	0.144
Abdominal circumference (cm)	35.905 ± 1.974	35.863 ± 1.948	0.277	0.782
Head circumference (cm)	33.539 ± 1.361	33.688 ± 1.485	1.380	0.168
AC-HC ≥ 2.5 cm	67 (11.964)	34 (14.167)	0.739	0.390
Caput Succedaneum	157 (28.036)	62 (25.833)	0.410	0.522
Duration of latent phase (min)	505.362 ± 133.057	507.368 ± 132.764	0.196	0.845
Duration of active phase (min)	218.326 ± 48.833	217.752 ± 49.211	0.152	0.879
Prolonged second stage of labor	17 (3.036)	13 (5.417)	2.639	0.104
Total duration of labor (min)	831.683 ± 211.047	829.477 ± 209.539	0.136	0.892

Characteristic	Training Set (n = 560)	Validation Set (n = 240)	Statistic (t//Z/ χ^2)	*P*
Vaginal operative delivery	29 (5.179)	19 (7.917)	2.233	0.135
Estimated fetal weight (g)	3716.705 ± 407.364	3725.436 ± 405.901	0.278	0.781

2.2 Study Outcomes

The primary outcomes included six key risk factors for shoulder dystocia in women attempting vaginal delivery and developed a nomogram to predict it.

2.3 Study Protocol

A retrospective cohort study was conducted to analyze clinical data from 800 patients. Subjects were stratified into a model development cohort (n = 560) and an independent validation cohort (n = 240) using a 7:3 allocation ratio. A multivariable logistic regression model was developed to predict the risk of shoulder dystocia during vaginal delivery. Candidate variables were first identified via univariate analysis, followed by LASSO regression to narrow down nine statistically significant predictors. Subsequently, six independent predictors were selected through multivariate logistic regression. A nomogram was constructed to facilitate clinical interpretation, and the model's performance was rigorously evaluated using multiple validation strategies: receiver operating characteristic (ROC) curve analysis for discrimination, decision curve analysis (DCA) for clinical utility, and calibration plots for calibration accuracy. Finally, both discrimination and calibration were externally validated in an independent cohort.

2.4 Measurements

Demographic and anthropometric characteristics of the parturients—including age, height, gestational age at delivery, total gestational weight gain, and pre-pregnancy BMI—were systematically collected.

Obstetric history, antenatal complications (e.g., hypertensive disorders of pregnancy, gestational diabetes mellitus, and premature rupture of membranes), and intrapartum interventions (e.g., labor induction, oxytocin augmentation, and neuraxial analgesia) were also documented. Furthermore, labor progression parameters—including duration of the latent and active phases, second-stage prolongation, and total duration of labor—were recorded.

Fetal biometric measurements (AC, HC, and EFW) and mode of delivery (including operative vaginal delivery, e.g., forceps-assisted delivery) were also captured.

2.5 Statistical Analysis

All statistical analyses were performed using R software (version 4.5.0). LASSO regression was employed for variable selection to enhance model interpretability and mitigate overfitting by imposing an L1 penalty on the regression coefficients. A total of 25 candidate variables were included in the initial analysis. To select the most predictive features and address potential multicollinearity, the LASSO

regression method was applied. The optimal penalty parameter λ (lambda) was determined via 10-fold cross-validation using the 1-standard error (1-SE) criterion. This procedure yielded a parsimonious set of 9 potential predictors associated with shoulder dystocia. The 9 variables selected by LASSO were subsequently entered into a multivariate logistic regression model to identify independent risk factors for shoulder dystocia. As a result, 6 independent risk factors demonstrated statistically significant associations with shoulder dystocia (all $P < 0.05$). A nomogram was constructed based on these 6 independent risk factors to provide a quantitative, individualized prediction of shoulder dystocia risk. Internal validation was performed using the Bootstrap resampling method with 1,000 replicates. The discriminative ability of the nomogram was evaluated using the ROC curve. The area under the ROC curve (AUC) along with its 95% confidence interval (CI) was calculated. Model calibration was assessed using the Hosmer-Lemeshow goodness-of-fit test (with $P > 0.05$ indicating good calibration) and visualized with a calibration plot comparing the predicted probabilities against the observed outcomes. DCA was performed to evaluate the clinical applicability of the nomogram by calculating the net benefit across a range of threshold probabilities. All statistical tests were two-sided, and $P < 0.05$ was considered statistically significant.

3. Results

A total of 800 parturients were included in the final analysis. No statistically significant differences were observed between the two groups with respect to baseline demographic and clinical characteristics, including age, primiparity rate, history of in-vitro fertilization (IVF), gestational age at enrollment, SD at previous delivery, gestational hypertension, premature rupture of membranes (PROM), indications for labor induction, oxytocin administration, and epidural analgesia utilization ($P > 0.05$). However, compared with the control group—comprising parturients who underwent vaginal delivery without shoulder dystocia—the study group—comprising parturients who experienced shoulder dystocia during vaginal delivery—demonstrated statistically significant differences in the following parameters: weight gain, BMI, maternal stature, gestational age ≥ 41 weeks, pregestational or gestational diabetes mellitus, AC–HC ≥ 2.5 cm, presence of caput succedaneum, duration of the latent phase of labor, second-stage labor prolongation, and EFW ($P < 0.05$). (see Table 1)

All study participants were randomly allocated to either the training set or the validation set in a 7:3 ratio. Baseline demographic and clinical characteristics—including age, gestational weight gain, BMI, maternal stature, nulliparity, use of IVF, gestational age at delivery, post-term gestation (≥ 41 weeks), SD at previous delivery, pregnancy-induced hypertension, pregestational or gestational diabetes mellitus, PROM, labor induction, stimulation with oxytocin, epidural analgesia, AC–HC ≥ 2.5 cm, caput succedaneum, duration of the latent phase, duration of the active phase, prolonged second stage of labor, total duration of labor, and vaginal operative delivery—were comparable between the two sets ($P > 0.05$). (see Table 2)

This study applied the LASSO regression method to identify nine independent predictors significantly associated with shoulder dystocia: EFW > 4000g; AC–HC ≥ 2.5 cm; prolonged second stage of labor;

abdominal circumference > 3.8 cm; short maternal stature (≤ 150 cm); caput succedaneum; BMI > 28 kg/m²; head circumference > 3.5 cm; and diabetic disorders. (see Fig. 1) And a multivariate logistic regression analysis was performed on the development set using the predictors selected via LASSO regression, yielding six statistically significant independent risk factors for shoulder dystocia: EFW > 4000 g (OR = 3.906 95% CI:2.705–5.973), AC-HC ≥ 2.5 cm (OR = 2.463 95% CI: 1.584–3.852), prolonged second stage of labor (OR = 3.486 95% CI: 2.107–5.628), short maternal stature (≤ 150 cm) (OR = 2.359 95% CI: 1.562–3.486), BMI > 28 kg/m^2 (OR = 1.735 95% CI: 1.258–2.579), and GDM (OR = 2.043 95% CI: 1.383–3.395).(all $P < 0.001$)(see Table 3)

Table 3. Multivariate logistic regression analysis of predictors selected by LASSO regression procedure in the development set.

Independent variables	**Multivariable logistic regression analysis**	
	OR (95% CI)	***P*-value**
EFW > 4000 g	3.906 (2.705–5.973)	< 0.001
AC-HC ≥ 2.5 cm	2.463 (1.584–3.852)	< 0.001
Prolonged second stage of labor	3.486 (2.107–5.628)	< 0.001
Short maternal stature (≤ 150 cm)	2.359 (1.562–3.486)	< 0.001
BMI > 28 kg/m^2	1.735 (1.258–2.579)	< 0.001
GDM	2.043 (1.383–3.395)	< 0.001
AC: abdomen circumference, BMI: body mass index, EFW: estimated Fetal Weight,		
GDM: gestational diabetes mellitus, HC: head circumference,		

Based on the six independent predictors identified by multivariate logistic regression, a nomogram was constructed to predict the risk of shoulder dystocia during labor (see Fig. 2). The points assigned to each predictor were proportional to its regression coefficient, with EFW > 4000 g contributing the highest points, followed by prolonged second stage of labor, AC-HC ≥ 2.5 cm, short maternal stature (≤ 150 cm), GDM, and BMI > 28 kg/m². The nomogram demonstrated good discriminative ability in both the training and validation sets. The area under the receiver operating characteristic curve (AUC) was 0.832 (95% CI: 0.798–0.866) in the training set and 0.806 (95% CI: 0.764–0.848) in the validation set (see Fig. 3A and 3B). The calibration curves showed good agreement between the predicted probabilities and observed outcomes in both sets (see Fig. 3C and 3D). The Hosmer–Lemeshow test yielded non-significant results, indicating no significant lack of fit (training set: $\chi^2 = 8.24$, $P = 0.412$; validation set: $\chi^2 = 6.97$, $P = 0.538$). Decision curve analysis (DCA) demonstrated that the nomogram provided a positive net benefit across a wide range of threshold probabilities in both the training and validation sets (see Fig. 3E and 3F). Specifically, the nomogram showed clinical utility when the threshold probability for intervention was

between 5% and 35%, suggesting that using this model to guide clinical decisions would improve patient outcomes without additional harm.

4. Discussion

The principal finding of this study is the development and validation of a nomogram that integrates six independent risk factors—EFW > 4000 g, AC–HC ≥ 2.5 cm, prolonged second stage of labor, short maternal stature (≤ 150 cm), BMI > 28 kg/m², and GDM—to predict the risk of SD during vaginal delivery. To the best of our knowledge, this is the SD prediction model specifically developed for a Chinese obstetric population using LASSO regression and internal validation. The nomogram demonstrated good discriminative ability in both the training (AUC = 0.832) and validation (AUC = 0.806) cohorts, with satisfactory calibration and positive net benefit across a range of threshold probabilities, suggesting its potential utility for prenatal risk stratification.

Among the six predictors, EFW > 4000 g contributed the highest points in the nomogram, consistent with a large body of evidence identifying fetal macrosomia as the strongest antecedent of SD[9–11]. Macrosomic fetuses have increased biacromial diameter, chest circumference, and soft tissue thickness, all of which predispose to impaction at the pelvic inlet. However, EFW alone is insufficient to rule out SD; indeed, up to 50% of SD cases occur in neonates with birth weight < 4000 g[3]. This underscores the importance of other predictors in our model, particularly the AC–HC difference ≥ 2.5 cm. This parameter reflects asymmetric fetal overgrowth—a pattern commonly seen in diabetic pregnancies—where accelerated truncal adiposity occurs without proportional increase in head circumference[12–14]. Such disproportional geometry may predispose the anterior shoulder to impact behind the pubic symphysis even when EFW is not markedly elevated. Our results support the inclusion of AC–HC as a complementary sonographic marker beyond EFW alone.

Short maternal stature (≤ 150 cm) was identified as an independent predictor of SD, with an OR of 2.359 (95% CI: 1.562–3.486). This finding aligns with previous studies demonstrating that shorter stature is often associated with a smaller pelvic inlet, particularly a flattened sacral promontory or reduced anteroposterior diameter, thereby reducing the available space for shoulder passage[18–20]. Mechanistically, a shortened maternal height may reflect a constitutionally smaller pelvis; however, direct pelvimetry was not performed in our study, which could have provided additional insight. Meanwhile, maternal obesity (BMI > 28 kg/m²) conferred a more modest but still significant increased risk (OR = 1.735). Excessive maternal adiposity may contribute to SD through multiple pathways: increased soft tissue deposition in the pelvic outlet narrowing the birth canal, higher rates of fetal macrosomia, and altered myometrial contractility leading to dysfunctional labor[19–20]. Notably, the combination of short stature and obesity (often termed “small and heavy”) may have a synergistic effect, although our sample size precluded robust interaction testing.

Prolonged second stage of labor emerged as a strong predictor (OR = 3.486), which is consistent with prior reports[4–6]. However, interpretation of this factor requires caution. Prolonged second stage likely

serves as a clinical indicator of underlying fetopelvic disproportion rather than a purely mechanistic cause of SD. In many cases, subtle disproportion manifests as slow descent and rotation of the presenting part, culminating in shoulder impaction once the head is delivered. From a clinical management perspective, recognition of second-stage prolongation—especially when combined with other risk factors such as EFW > 4000 g or short stature—should prompt the obstetrician to prepare for potential SD maneuvers, ensure appropriate personnel availability, and consider the judicious use of operative vaginal delivery with caution, as instrumental deliveries themselves may increase SD risk. Importantly, our multivariable analysis retained prolonged second stage as an independent predictor after adjusting for EFW, BMI, and other confounders, reinforcing its clinical relevance.

GDM was independently associated with SD in our model (OR = 2.043). This association is likely mediated through several pathways: GDM promotes fetal hyperinsulinemia and macrosomia, particularly asymmetric truncal overgrowth reflected by an increased AC–HC difference[15–17]. Additionally, GDM may be associated with altered maternal pelvic soft tissue properties, though this has not been well-studied. Our data suggest that GDM contributes to SD risk beyond its effect on EFW and AC–HC, as all three variables remained significant when entered together in the LASSO and multivariable models. This observation raises the possibility that GDM may influence labor dynamics independently of fetal size, for instance through changes in myometrial function or increased risk of polyhydramnios leading to malpresentation, though further research is needed.

Several previous studies have attempted to develop SD prediction tools. For example, the GROW model (Gestation Related Optimal Weight) and the Brachial Plexus Injury risk calculator have shown moderate performance, but many were limited by small sample sizes or lack of validation cohorts. Compared with these models, our nomogram offers several advantages: (1) use of LASSO regression for parsimonious predictor selection; (2) internal validation with a separate cohort; (3) inclusion of AC–HC difference, a novel predictor not commonly incorporated; and (4) DCA demonstrating clinical net benefit. However, direct external validation in different populations remains necessary before widespread adoption.

The proposed nomogram provides a quantitative, individualized risk estimate for SD using variables routinely available before or during labor. For patients with a predicted risk above a certain threshold (e.g., 10–15%), obstetricians may consider several preventive measures: (1) ensuring the presence of an experienced obstetrician and pediatrician at delivery; (2) discussing the possibility of prophylactic maneuvers such as the “hands off” technique or avoiding excessive axial traction; (3) preparing for early use of SD maneuvers (McRoberts, suprapubic pressure, rotational maneuvers); and (4) in selected high-risk cases, considering elective cesarean section—though this decision must carefully balance maternal risks and the absolute risk of SD-related neonatal injury. Importantly, even deliveries with low predicted risk should not be complacent, as SD can occur unpredictably.

Several limitations warrant acknowledgment. First, this is a single-center retrospective study, which may introduce selection bias and limit generalizability to other populations with different ethnic compositions, obesity rates, or obstetric practices. Second, external validation in an independent

multicenter cohort is lacking, and such validation is essential before clinical implementation. Third, we did not assess long-term neonatal outcomes (e.g., brachial plexus injury), which would have strengthened the clinical relevance of the model. Finally, unmeasured confounders—including detailed pelvic dimensions, labor positioning, clinician experience, and timing of specific SD maneuvers—may influence both the occurrence and management of SD. Sixth, the relatively modest sample size in the validation cohort (n = 240) limits the precision of some estimates.

Prospective, multicenter studies with larger sample sizes are needed to externally validate our nomogram. Future work should also explore the potential benefit of incorporating additional variables, such as three-dimensional pelvimetry or advanced sonographic measures of fetal soft tissue (e.g., shoulder circumference or subcutaneous fat thickness), which may further improve predictive accuracy. Additionally, clinical implementation studies evaluating whether use of the nomogram actually reduces SD-related morbidity are necessary.

In summary, we have developed and internally validated a practical nomogram for predicting shoulder dystocia based on six readily available risk factors: EFW > 4000 g, AC–HC ≥ 2.5 cm, prolonged second stage of labor, short maternal stature (≤ 150 cm), BMI > 28 kg/m², and GDM. This tool demonstrates good discrimination, calibration, and clinical utility, and may assist obstetricians in risk stratification and timely preparation for emergency maneuvers. Prospective external validation is warranted before routine clinical use.

5. Conclusions

Six independent antepartum predictors of shoulder dystocia during vaginal delivery were identified: EFW > 4000 g, AC–HC ≥ 2.5 cm, prolonged second stage of labor, short maternal stature (≤ 150 cm), BMI > 28 kg/m², and GDM. The nomogram developed from these variables demonstrated robust discriminative ability and excellent calibration, indicating its potential utility for individualized antenatal risk stratification.

Abbreviations

SD, shoulder dystocia; LASSO, Least Absolute Shrinkage and Selection Operator; EFW, estimated fetal weight; AC, abdominal circumference; HC, head circumference; GDM, gestational diabetes mellitus; BMI, body mass index; ROC, receiver operating characteristic; DCA, decision curve analysis; AUC, area under the curve; CI, confidence interval; IVF, in-vitro fertilization; PROM, premature rupture of membranes; OR, odds ratio

Declarations

7. Ethics approval and consent to participate

This study has received approval from the Ethics Review Board of the Affiliated Suzhou Hospital of Nanjing Medical University (K-2024-172-K01). All research participants provided written informed consent after being fully informed of the study's nature, objectives, potential risks, and benefits. The study adhered to relevant ethical guidelines, including the Declaration of Helsinki, and strictly protected patient privacy by ensuring that no personally identifiable information appears in any imaging, written, or photographic records.

8. Consent for publication

Written informed consent was obtained from the patient for publication of this case report and any accompanying images.

9. Availability of data and materials

The data presented in this study are available on request from the corresponding author (Yongfei Yue; yueyongfeiyyf@163.com). The data are not publicly available because this was a clinical trial containing information that could compromise the privacy of research participants.

10. Competing Interests

The authors declare that they have no competing interests in this work.

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12. Authors' contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Figures

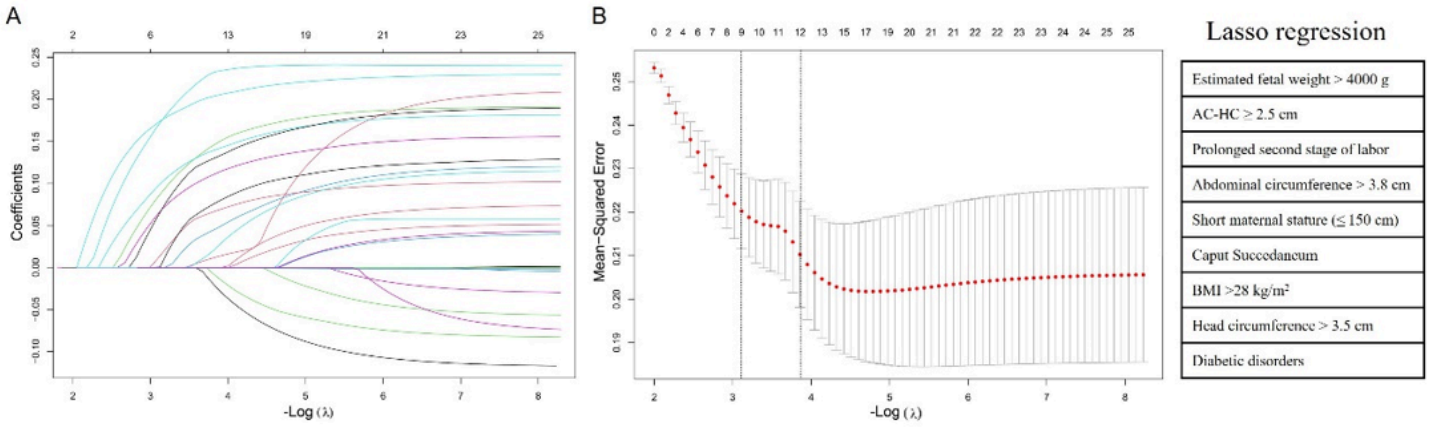


Figure 1

Variable screening based on Lasso regression

A Characteristics of variable coefficients

B Cross-validation procedure for optimal λ selection

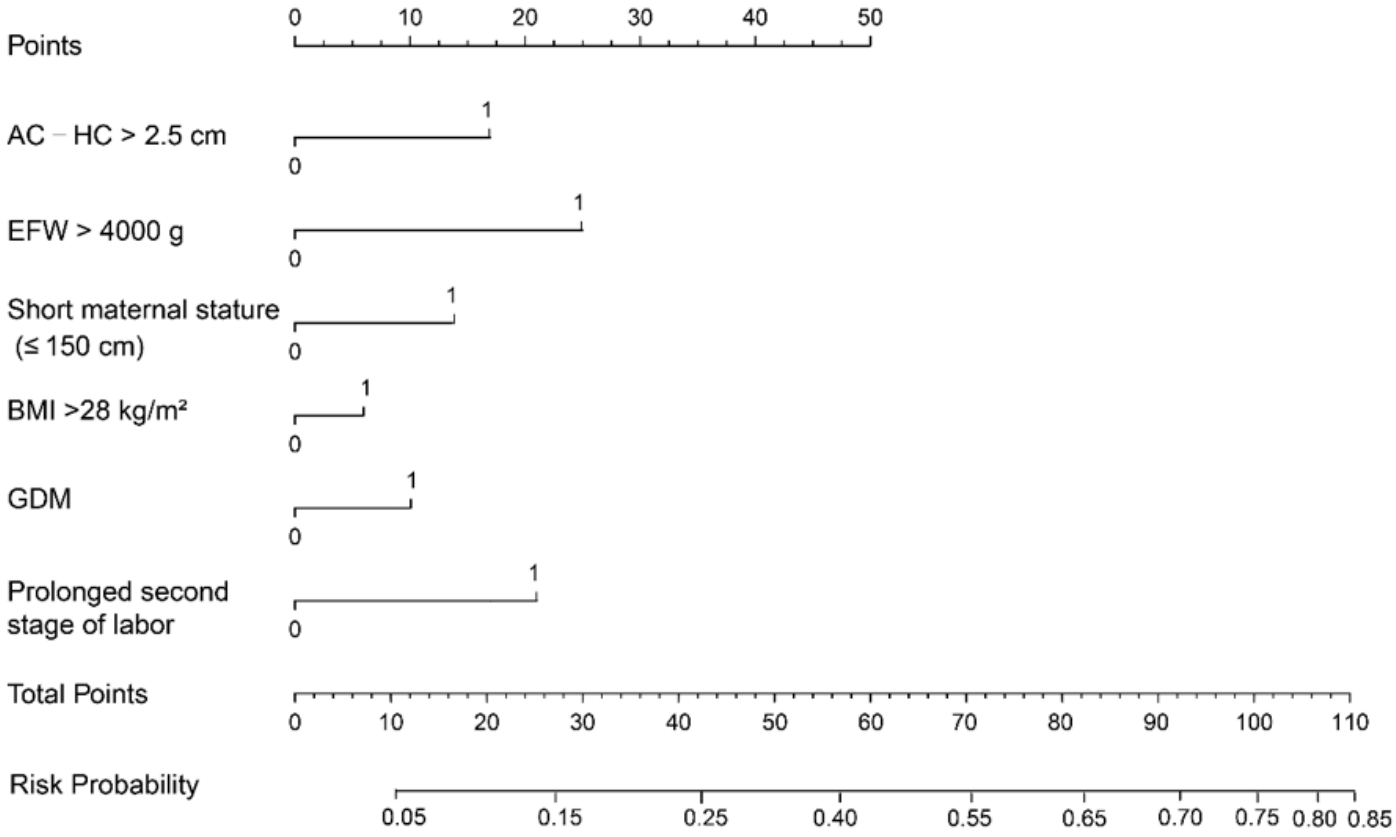


Figure 2

Nomogram prediction model for shoulder dystocia in patients during labor.

AC: abdomen circumference, BMI: body mass index, EFW: estimated Fetal Weight,

GDM: gestational diabetes mellitus, HC: head circumference

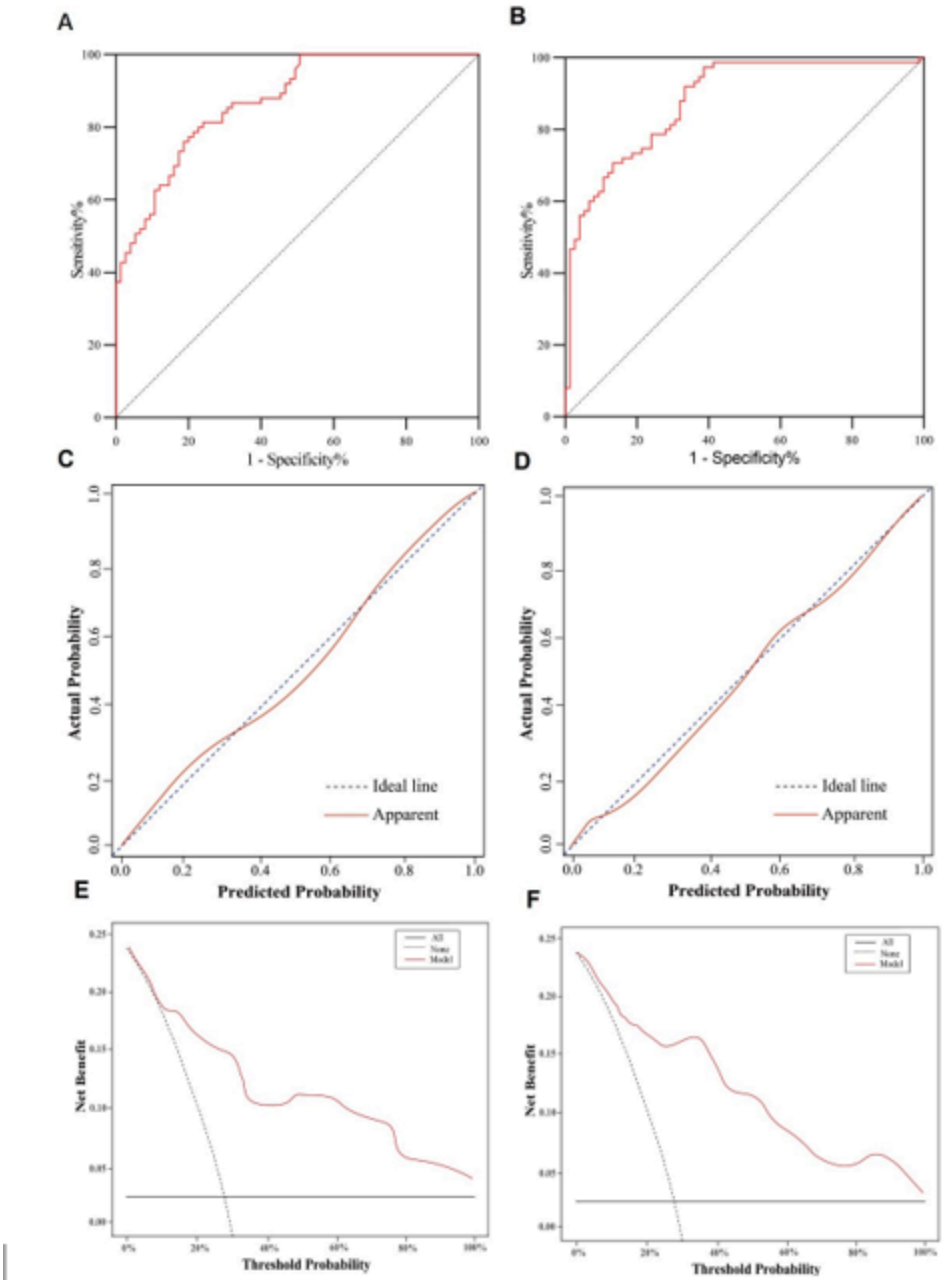


Figure 3

A. Receiver operating characteristic curve in the Training Set.

B. Receiver operating characteristic curve in the Validation Set.

C. Calibration plot in the Training Set.

D. Calibration plot in the Validation Set.

E. Decision curve analysis of the Training Set.

F. Decision curve analysis of the Validation Set.