OBSTETRICS

A simple model to predict the complicated operative vaginal deliveries using vacuum or forceps

José Antonio Sainz, MD; José Antonio García-Mejido, MD; Adriana Aquise, MD; Carlota Borrero, MD; María José Bonomi, MD; Ana Fernández-Palacín, MD

BACKGROUND: Complicated operative vaginal deliveries are associated with high neonatal morbidity and maternal trauma, especially if the procedure is unsuccessful and a cesarean delivery is needed. The decision to perform an operative vaginal delivery has traditionally been based on a subjective assessment by digital vaginal examination combined with the clinical expertise of the obstetrician. Currently there is no method for objectively quantifying the likelihood of successful delivery. Intrapartum ultrasound has been introduced in clinical practice to help predict the progression and final method of delivery.

OBJECTIVE: The aim of this study was to compare predictive models for identifying complicated operative vaginal deliveries (vacuum or forceps) based on intrapartum transperineal ultrasound in nulliparous women.

STUDY DESIGN: We performed a prospective cohort study in nulliparous women at term with singleton pregnancies and full dilatation who underwent intrapartum transperineal ultrasound evaluation prior to operative vaginal delivery. Managing obstetricians were blinded to the ultrasound data. Intrapartum transperineal ultrasound (angle of progression, progression distance, and midline angle) was performed immediately before instrument application, both at rest and concurrently with pushing. Intrapartum evaluation of fetal biometric parameters (estimated fetal weight, head circumference, and biparietal diameter) was also carried out. An operative vaginal delivery was classified as complicated when 1 or more of the following complications occurred: ≥3 tractions needed; third- to fourth-degree perineal tear; severe bleeding during episiotomy repair (decrease of ≥2.5 g/dL in the hemoglobin level); or significant traumatic neonatal lesion (subdural-intracerebral hemorrhage, epicranial subaponeurotic hemorrhage, skeletal injuries, injuries to spine and spinal cord, or peripheral and cranial nerve injuries). Six predictive models were evaluated (information available in Table 2).

RESULTS: We recruited 84 nulliparous patients, of whom 5 were excluded because of the difficulty of adequately evaluating the biparietal diameter and head circumference. A total of 79 nulliparous patients were studied (47 vacuum deliveries, 32 forceps deliveries) with 13 cases in the occiput-posterior position. We identified 31 cases of complicated operative vaginal deliveries (19 vacuum deliveries and 12 forceps deliveries). No differences were identified in obstetric, neonatal, or intrapartum characteristics between the 2 study groups (operative uncomplicated vaginal delivery vs operative complicated vaginal delivery), with the following exceptions: estimated fetal weight (3243 ± 425 g vs 3565 ± 330 g; $P = .001$), biparietal diameter (93.2 ± 2.1 vs 95.2 ± 2.3 mm; $P = .001$), head circumference (336 ± 12 vs 348 ± 6.4 mm; $P = .001$), sex (female 62.5% vs 29.0%; $P = .010$), newborn weight (3258 ± 472 g vs 3499 ± 383 g; $P = .027$), and number of tractions (median, interquartile range) (1 [1—2] vs 4 [3—5]; $P < .0005$). To predict complicated operative deliveries, all 6 of the studied models presented an area under the receiver-operating characteristics curve between 0.863 and 0.876 (95% confidence intervals, 0.775—0.950 and 0.790—0.963; $P < .0005$). The results of the study met the criteria of interpretability and parsimony (simplicity), allowing us to identify a binary logistic regression model based on the angle of progression and head circumference; this model has an area under the receiver-operating characteristics curve of 0.876 (95% confidence interval, 0.790—0.963; $P < .0005$) and a calibration slope B of 0.984 (95% confidence interval, 0.0.726—1.243; $P < .0005$).

CONCLUSION: The combination of the angle of progression and the head circumference can predict 87% of complicated operative vaginal deliveries and can be performed in the delivery room.

Key words: biomarker, birth trauma, cesarean delivery, complication, labor, neonatal injury, operative vaginal delivery, perineal laceration, postpartum hemorrhage, vacuum extraction

Operative vaginal deliveries are associated with increased neonatal (subdural or cerebral hemorrhage, convulsions, and mechanical ventilation)[1—3] and maternal morbidity (hemorrhage, perineal injuries).[3—7] This higher morbidity is even greater in cases of difficult operative vaginal deliveries and cesarean deliveries performed after failed operative vaginal delivery.[8—13] Indeed, the reported incidence of postpartum intracranial hemorrhages after a failed instrumental vaginal delivery is 1 in 334, which is 5.7 times greater than the incidence associated with spontaneous vaginal birth.[8]

According to standard clinical practice guidelines, operative vaginal deliveries must be performed only if the fetal head is engaged.[14,15] Thus far, the decision to attempt operative vaginal delivery, as well as the evaluation of its potential difficulty, has relied on digital examination.[14,15] However, digital exploration is a subjective and unreliable tool for this purpose.[16—19]

In this context, intrapartum transperineal ultrasound has been introduced in clinical practice to help predict the progression and final method of delivery (spontaneous vaginal delivery vs operative vaginal delivery[16,17]). Moreover, intrapartum transperineal ultrasound is used to predict cases of complicated operative vaginal deliveries and to

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AJOG at a Glance

Why was this study conducted?

- Operative vaginal deliveries are associated with a high maternal and neonatal morbidity.
- We sought to develop a model to predict complicated operative deliveries and compare the performance of our model with others previously reported in the literature

Key findings

A predictive model based on the angle of progression and head circumference has an identifying capacity of 87.5% for complicated operative deliveries

What does this study add to what is known?

- We report a simple and rapid predictive model for complicated operative deliveries. The model requires only 2 parameters that can be easily obtained with intrapartum sonography (angle of progression and head circumference).
- The predictive ability of the model is superior to other models previously reported (87% vs a range of 56−67%).
- This model can be implemented in any labor and delivery unit.

identify cases with a high probability of requiring cesarean delivery because of failed operative vaginal delivery.[20−29] Some studies have evaluated the usefulness of intrapartum transperineal ultrasound for this purpose.[22−29]

Bultez et al[24] reported that when using the optimal cutoff value of 145.5° for the angle of progression to predict vacuum extraction failure in nulliparous women, the calculated area under the receiver-operating characteristic curve (AUC) was 0.67 (95% confidence interval [CI], 0.57−0.77), with a sensitivity of 86.2% (95% CI, 68−97%), specificity of 49% (95% CI, 40−57%), and positive predictive value of 24% (95% CI, 16−34%).

According to Kahrs et al,[28] when using a head-perineum distance >35 mm as the cutoff, the sensitivity in predicting cesarean delivery was 56% (95% CI, 33−77%), the false-positive rate was 16% (95% CI, 11−21%), and the AUC was 0.83 (95% CI, 0.77−0.89).

Our group[29] has found that using an angle of progression with pushing <153° when identifying complicated operative vaginal deliveries provides a sensitivity of 86.9% and a false-positive rate of 5.9% (AUC, 86.9% [95% CI, 80−91]). In that study, a complication was defined as the occurrence of 1 or more of the following situations: 3 or more tractions needed; a third- or fourth-degree perineal tear; severe bleeding during the episiotomy repair; a major tear; or a significant traumatic neonatal lesion.

However, previous studies assessing predictive models for complicated vaginal deliveries did not include fetal characteristics, such as estimated fetal weight or head circumference, which are known independent risk factors for operative vaginal and cesarean deliveries.[30−32]

Taking this information into account, we sought to develop a model to predict complicated operative vaginal deliveries (vacuum and forceps) in nulliparous women.

FIGURE 1
Fetal head image and biparietal diameter and fetal head circumference

A and B, Acquisition of fetal head image using transperineal ultrasound. **C,** Evaluation of biparietal diameter and fetal head circumference (using the transthalamic plane of the fetal head).

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Materials and Methods

This was a prospective observational study in nulliparous women with a singleton pregnancy at ≥37 weeks' gestation and cephalic presentation. The study was performed between May 2016 and June 2017 at Valme University Hospital Maternity Unit in Seville, Spain. The study (PI-232013) was approved by the local ethics and research committees (May 2015).

The inclusion criteria were a term nulliparous women with uncomplicated pregnancies who required operative vaginal delivery (forceps or vacuum). The indications for operative delivery were nonreassuring fetal heart rate, failure to progress in labor, or maternal exhaustion. Intrapartum ultrasound was not performed in cases of prolonged fetal bradycardia or late heart rate decelerations with absent fetal heart rate variability.

Operative deliveries were performed by obstetricians with more than 4 years of experience in operative vaginal deliveries. All forceps deliveries were performed using Kielland's forceps, while for all vacuum-assisted deliveries, the same model of a rigid metal vacuum was used (Bird's cup number 5).

The fetal head station was assessed by digital examination for low or outlet operative vaginal deliveries, as defined by the American College of Obstetricians and Gynecologists.[14] Subsequently, a transabdominal ultrasound was performed to monitor the fetal head position.

TABLE 1
Ecographic parameters evaluated in the Intrapartum Transperineal ultrasound

Intrapartum transperineal ultrasound	Parameter
Longitudinal plane	
Angle of progression at rest	AoP 1 (°)
Angle of progression with active pushing	AoP 2 (°)
Progression distance at rest	PD 1 (mm)
Progression distance with active pushing	PD 2 (mm)
Transverse plane	
Midline angle at rest	MLA 1 (°)
Midline with active pushing	MLA 2 (°)

AoP, angle of progression; *MLA*, midline angle; *PD*, progression distance.

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The managing obstetricians were different from those performing the intrapartum transperineal ultrasound and were blinded to the recorded sonographic data. The intrapartum transperineal ultrasound was performed exclusively by a group of 5 obstetricians (J.A.S., C.B., M.J.B., A.A., and J.A.G.-M.) who had demonstrated competency for this type of ultrasound examination.[29]

Whenever a potentially eligible woman was identified at our maternity unit during the beginning of labor, she was invited to participate in the trial and was asked to provide informed consent before being enrolled in the study. Once the patient provided signed informed consent, an intrapartum transperineal ultrasound was performed as described in the following text. In the presence of 1 of the abovementioned indications for operative vaginal delivery, the managing obstetrician chose the instrument that was considered most appropriate for the clinical circumstance and his/her skill level.[14]

Ultrasound examination was performed using a Toshiba Famio 8 ultrasound system (Tokyo, Japan) with a 3.75-MHz convex probe (2-dimensional ultrasound method). Fetal weight[33] was estimated by intrapartum transabdominal ultrasound, whereas biparietal diameter and head circumference were evaluated by either transabdominal or translabial ultrasound (using the transthalamic plane of the fetal head) (Figure 1).[34]

Intrapartum transperineal ultrasound was performed with the woman in a semirecumbent position, with an empty bladder and ruptured membranes. The probe was placed between the labia below the pubic symphysis.

The following intrapartum parameters were assessed by transperineal ultrasound[35,36] (Table 1 and Figures 2—4): angle of progression (AoP) and progression distance (PD) evaluated on the longitudinal plane and midline angle (MLA) assessed on the transverse plane. Furthermore, the angle of progression, progression distance, and midline angle were assessed at rest (AoP1, PD1, and MLA1, respectively) and concurrently with contraction and active pushing (AoP2, PD2, and MLA2, respectively).

The angle of progression is defined as the angle between a line through the midline of the pubic symphysis and another line from the anterior margin of the pubic symphysis to the leading edge of the bony part of the fetal head.

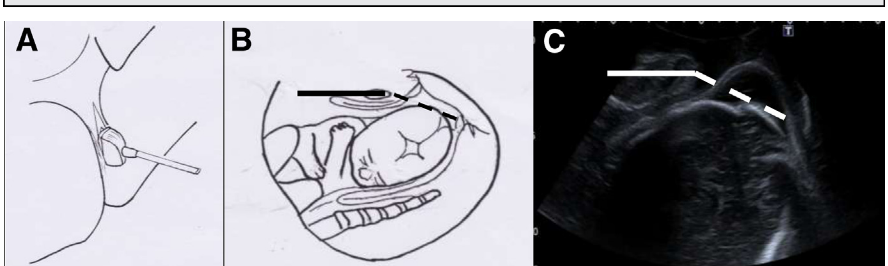
Progression distance is defined as the distance between the infrapubic line (the line through the inferior margin of the pubic symphysis perpendicular to the long axis of the symphysis) and a parallel line through the deepest bony part of the fetal head.

Midline angle is defined as the angle between the anteroposterior axis of the pelvis and the fetal brain midline. Intrapartum transperineal ultrasound measurements were performed according to a previously published technique.[35,36]

The following demographic and obstetric data were recorded: maternal age; gestational age at delivery; body mass index (BMI); obstetric history; duration of the first and second stages of labor; indication for operative delivery; number of tractions performed; need for episiotomy; birthweight; and sex.

Data on the following maternal and neonatal morbidity outcomes were also collected: maternal vaginal or anal sphincter tear (using Sultan's classification of perineal tears)[37] and postpartum hemorrhage; Apgar scores after 1 and 5 minutes; arterial cord blood pH at delivery; birth trauma (cephalohematoma, intracranial hemorrhage, clavicle fracture, or peripheral and cranial nerve injuries);

FIGURE 2
Transperineal longitudinal plane at rest and angle of progression



Transperineal longitudinal plane at rest **(A)** and AoP **(B and C)**.

AoP, angle of progression.

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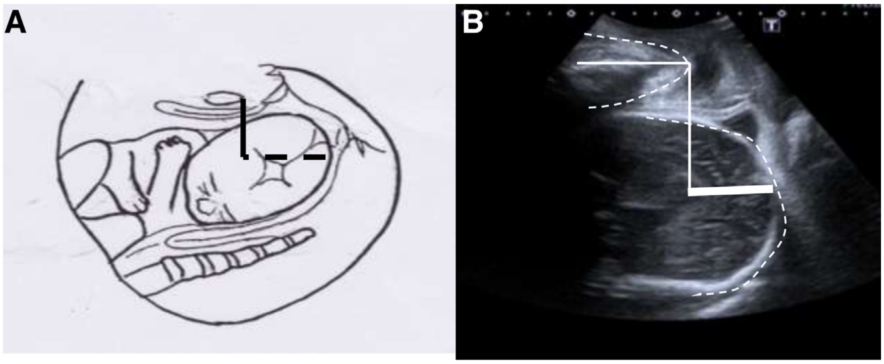
FIGURE 3
Transperineal longitudinal plane and progression distance



Transperineal longitudinal plane **(A)** and PD **(B)**.

PD, progression distance.

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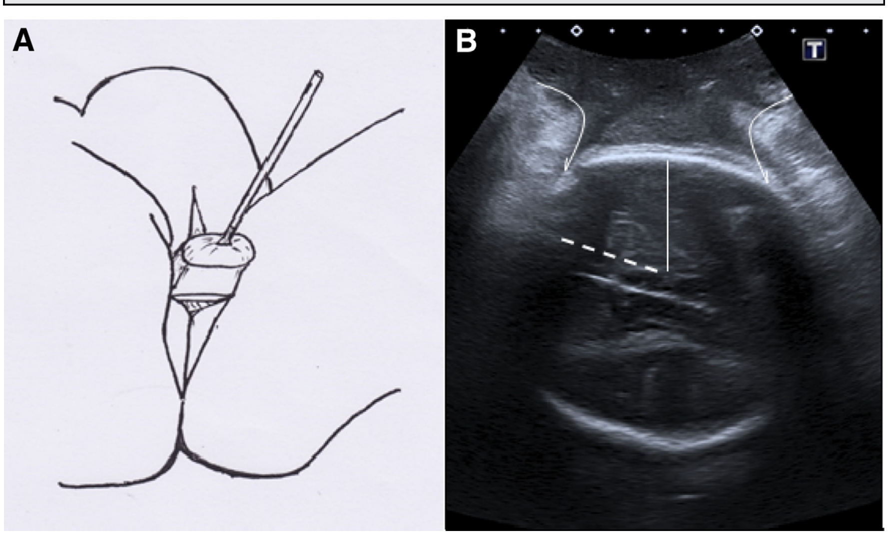
and admission of the newborn to the neonatal unit (respiratory distress, neonatal jaundice, or risk of neonatal sepsis).

An operative delivery was classified as complicated when 1 or more of the following situations occurred[29,38]: 3 or more tractions were required to complete fetal extraction;[39] failed operative vaginal delivery; third- or higher-degree perineal tear according to Sultan's classification;[37] major tear reported by the obstetrician; severe bleeding during the episiotomy repair confirmed by a decrease in the hemoglobin level of $\geq$2.5 g/dL following delivery;[40] or a significant traumatic neonatal lesion (subdural and intracerebral hemorrhage, epicranial subaponeurotic hemorrhage, skeletal injuries, injuries to spine and spinal cord, or peripheral and cranial nerve injuries).[29,38]

Statistical analyses

We determined the mean and SD for numeric variables and the percentage for qualitative variables. Comparisons of the numeric variables between complicated and uncomplicated operative vaginal deliveries were performed using a Student *t* test. Comparison of qualitative variables between study groups was performed using a χ^2 test. Individual predictive capabilities were evaluated using a receiver-operating characteristic curve and the AUC. All statistical comparisons were performed using a 2-sided test, and $P < .005$ was considered statistically significant for all comparisons. Statistical analyses were performed using IBM SPSS statistics software version 22 (IBM, Armonk, NY).

FIGURE 4
Transperineal axial plane at rest and midline angle (MLA)



Transperineal axial plane at rest **(A)** and midline angle **(B)**.

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Evaluation of logistic regression models

We generated different multivariate binary logistic regression models using nonautomated methods to predict complicated operative vaginal delivery, including intrapartum transperineal ultrasound parameters, estimated fetal weight, biparietal diameter, and head circumference. These parameters were added progressively according to the simplicity of their evaluation and their predictive capacity for identifying complicated operative delivery.

We implemented and compared 6 binary logistic regression models (Table 2). We performed a goodness-of-fit test (−2 log likelihood) and the Hosmer and Lemeshow test for each model. Harrell's C statistic (a statistical index used to evaluate the performance of a regression model that analyzes the ability of the model to discriminate between the presence and absence of the event) was then determined for those models with an adequate fit to evaluate their discriminatory capacity (obtained as the AUC of the predicted probabilities given by the model), and the slope and calibration graphic were also obtained.

The final model was chosen according to its discriminatory capacity and calibration graphic, in line with parsimony and interpretability principles. The models were calibrated by calculating calibration slopes and graphs. The last 2 analyses were performed based on the original model and the model adjusted for a uniform shrinkage factor. Once the definite multivariate binary regression model was identified, we developed

TABLE 2
Predictive models evaluated by binary logistic regression

Model	Parameters included in the predictor model
Model 1	Estimated fetal weight plus biparietal diameter plus fetal head circumference plus angle of progression (rest)
Model 2	Estimated fetal weight plus biparietal diameter plus fetal head circumference plus angle of progression plus midline angle (rest)
Model 3	Estimated fetal weight plus biparietal diameter plus fetal head circumference plus angle of progression plus midline angle plus progression distance (rest)
Model 4	Estimated fetal weight plus biparietal diameter plus fetal head circumference plus angle of progression plus midline angle plus progression distance (rest) plus angle of progression (push)
Model 5	Estimated fetal weight plus biparietal diameter plus fetal head circumference plus angle of progression plus midline angle plus progression distance (rest) plus angle of progression plus progression distance (push)
Model 6	Estimated fetal weight plus biparietal diameter plus fetal head circumference plus angle of progression plus midline angle plus progression distance (rest) plus angle of progression plus progression distance plus midline angle (push).

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TABLE 3
Maternal and neonatal characteristics in 79 nulliparous requiring operative delivery to complete fetal extraction

	Complete study population (n=79)		
Characteristics	Uncomplicated operative delivery (n = 48)	Complicated operative delivery (n = 31)	*P* value
Maternal age, y	28.6 ± 5.8	30.4 ± 4.3	.148
Maternal BMI, kg/m^2	23.3 ± 2.1	23.8 ± 1.9	.620
Gestational pathology	7 (14.6%)	3 (9.7%)	.769
Gestational age at delivery, wks)	39.4 ± 1.3	39.7 ± 1.3	.930
Cause of operative delivery			.585
Failure to progress in labor	36 (75%)	22 (70.9%)	
Maternal exhaustion	4 (8.3%)	3 (9.6%)	
Nonreassuring fetal heart rate	8 (16.6%)	6 (19.3%)	
Estimated fetal weight, g	3,243 ± 425	3565 ± 330	.001
Head circumference, mm	336 ± 12	348 ± 6.4	.001
Fetal biparietal diameter, mm	93.2 ± 2.1	95.2 ± 2.3	.001
Duration of first stage of labor, min	398 ± 142	402 ± 154	.868
Duration of second stage of labor, min	136 ± 54	155 ± 54	.162
Mediolateral episiotomy	44 (93.7%)	30 (96.7%)	.655
Occiput posterior position	5 (10.4%)	8 (25.8%)	.085
Forceps operative delivery	20 (62.5%)	12 (37.5%)	.979
Caesarean delivery after failed attempt at vaginal delivery	0 (0%)	4 (12.9%)	.108
Gender (females)	30 (62.5%)	9 (29.0%)	.010
Birthweight, g	3258 ± 472	3499 ± 383	.027
Apgar 1 min	8.9 ± 1.0	8.7 ± 0.7	.165
Apgar, 5 min	9.9 ± 0.8	9.8 ± 0.8	.118
Umbilical cord artery pH	7.27 ± 0.06	7.24 ± 0.07	.121

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TABLE 4

Intrapartum transperineal ultrasound data from 79 nulliparous requiring operative delivery to complete fetal extraction

Intrapartum transperineal ultrasound	Uncomplicated operative delivery (n = 48)	Complicated operative delivery (n = 31)	*P* value
AoP1, °	138.12 ± 13.4	119.1 ± 16.8	< .0005
AoP2, °	149.5 ± 15.2	126.2 ± 13.3	< .0005
PD1, mm	45.0 ± 11.5	36.4 ± 13.7	.004
PD2, mm	52.2 ± 14.0	41.7 ± 13.3	.002
MLA1, °	37.8 ± 28.9	49.0 ± 23.1	.036
MLA2, °	37.3 ± 31.1	40.5 ± 19.5	.537
Instrumental tractions (median and IQR), n	1 (1—2)	4 (3—5)	< .0005

AoP1, angle of progression at rest; *AoP2*, angle of progression with active pushing; *IQR*, interquartile range; *MLA1*, midline angle at rest; *MLA 2*, midline with active pushing; *PD1*, progression distance at rest; *PD2*, progression distance with active pushing.

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software to predict complicated operative vaginal deliveries (vacuum and forceps) with the aim of making the model applicable to clinical practice.

Results

Study population

We recruited 84 nulliparous patients, 5 of whom were excluded because of the difficulty of adequately evaluating the biparietal diameter and fetal head circumference. In total, we evaluated 79 nulliparous patients who required operative vaginal assistance (47 vacuum-assisted deliveries and 32 forceps-assisted deliveries).

Forty-eight cases were classified as uncomplicated operative vaginal deliveries (28 vacuum-assisted deliveries and 20 forceps-assisted deliveries), and 31 were classified as complicated operative vaginal deliveries (19 vacuum-assisted deliveries and 12 forceps-assisted deliveries).

Of the 31 cases of complicated operative vaginal deliveries, a third-degree perineal tear occurred in 6 cases (19.35%). In 7 cases (22.5%), severe bleeding was noted while repairing the episiotomy and was confirmed by a decrease of ≥2.5 g/dL in the maternal hemoglobin level. Three or more tractions were performed in 18 cases (58.06%).

Regarding maternal and neonatal demographic data, significant differences were noted between uncomplicated and complicated operative vaginal deliveries in estimated fetal weight, biparietal diameter, head circumference, gender, and birthweight (Table 3).

TABLE 5

Final logistic regression model obtained with the angle of progression with pushing and head circumference

Variables in the equation	Exp (B)	IC 95% Lower	IC 95% Upper
Angle of progression with pushing (per 5°)	0.698	0.568	0.855
Head circumference (per 5 mm)	1.665	1.111	2.484
Constant	-25.376		

Prob.COD, probability for the identification of complicated operative deliveries; *Prob.*, $1/1 + e^{(-[-25.376-0.36 \text{ angle of progression} + 0.508 \text{ head circumference}])}$.

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The proportion of cases with the occiput posterior position was 13.6% (13 cases); the main indication for operative vaginal delivery was failure to progress in labor (60.75%, 48 cases), and 76.2% (74 cases) required mediolateral episiotomy. Four cases (12.9%) in the group of complicated operative vaginal deliveries required a cesarean delivery. One newborn required admission to the neonatal unit (mild respiratory distress).

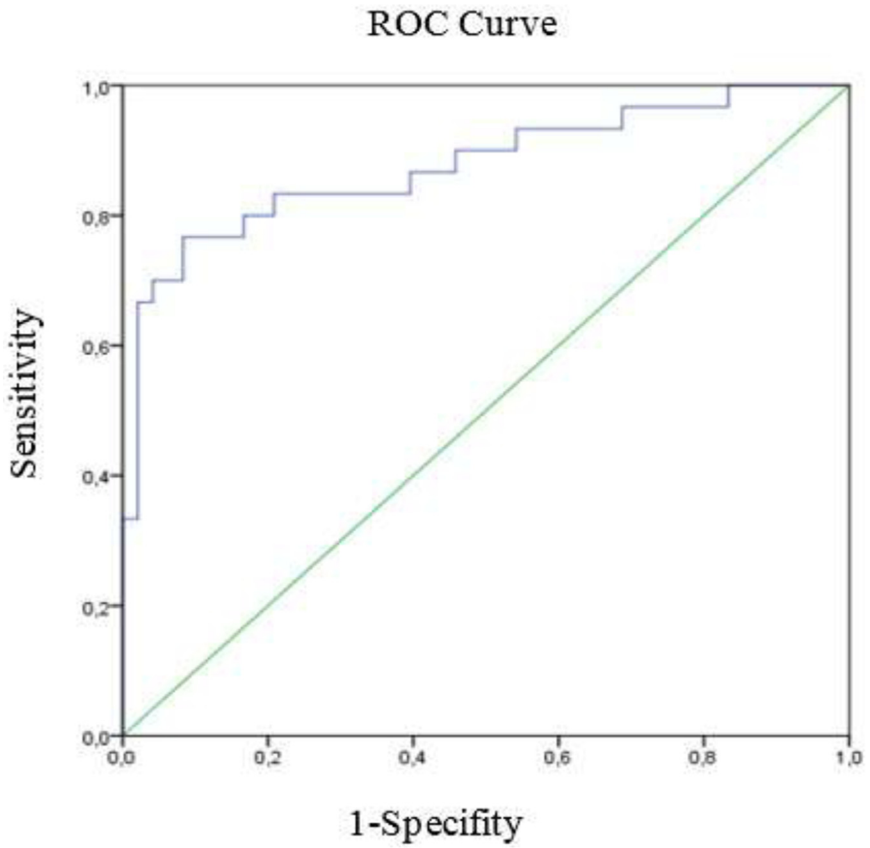
Intrapartum transperineal ultrasound as a predictor of complicated operative vaginal deliveries

Significant differences were observed between the uncomplicated and complicated operative vaginal delivery cases regarding the angle of progression at rest, progression distance at rest, midline angle at rest, angle of progression with pushing, and progression distance with pushing, with no statistically significant difference found in the midline angle with pushing (Table 4). The complicated operative vaginal delivery group required a significantly higher number of tractions (4 tractions) than the uncomplicated operative vaginal delivery group (1 traction).

Predictive models of complicated deliveries

We used several binary logistic regression models to predict and explain

FIGURE 5
ROC Curve for logistic regression model by AoP



ROC curve for logistic regression model obtained from the association between angle of progression with pushing and head circumference. Area under ROC curve = 0.876 (95% CI, 0.790–0.963; $P < .0005$).

AoP, angle of progression; *CI*, confidence interval; *ROC*, receiver-operating characteristic.

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complicated operative vaginal deliveries. The Harrell's C statistic values of the models oscillated between 0.863 and 0.876, as determined as the AUC of the predicted probabilities. The binary logistic regression model that identified the variables, angle of progression with pushing and head circumference, as predictors of complicated operative vaginal delivery was chosen because these variables were included in the final multivariate analysis, which is shown in Table 5.

Harrell's C statistic, which was obtained from the AUC of the predicted probabilities by the model, was 0.876 (95% CI, 0.790–0.963; $P < .0005$) (ie, an initial discriminatory capacity >0.75, which is the same as the values obtained for the model adjusted by the shrinkage uniform model, in which the C statistic values were 0.876 [95% CI, 0.790–0.963; $P < .0005$]) (Figures 5 and 6). The calibration of the selected model was evaluated by calculating the calibration slope B, which was 0.984 (95% CI, 0.726–1.243; $P < .0005$). Pearson linear correlation coefficients were also calculated (0.906 and 0.849) (Figures 7 and 8).

Comment

Principal findings

The main finding of our study is that a model based on angle of progression and head circumference can predict 87.5% of complicated operative vaginal deliveries. Because this model requires only 2 parameters that can be easily obtained with intrapartum sonography (angle of progression and head circumference), we report an easy-to-implement model that provides rapid prediction. Finally, this model can be implemented in any labor and delivery unit.

Clinical implications

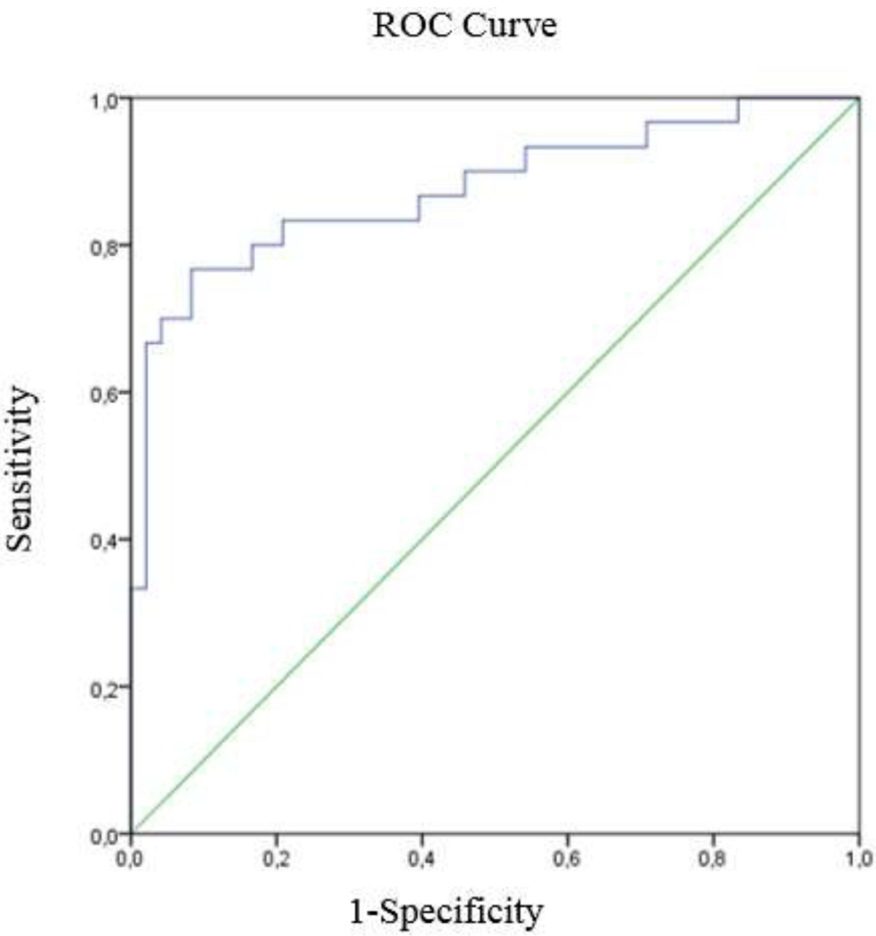
By applying the proposed predictive model, any obstetrician can easily predict the type of operative vaginal delivery that he or she will encounter in the delivery room because a variation in head circumference can shift the situation from an uncomplicated operative vaginal delivery. In such cases, 1 or 2 tractions are needed (when an angle of progression with pushing of 146° is identified by intrapartum transperineal ultrasound) for a complicated operative vaginal delivery, requiring 3 or 4 instrumental tractions to complete fetal extraction (if an angle of progression with pushing of 115° is identified) (Figure 9 and video 1).

Research implications

Knowing that digital examination presents a high rate of error (20–75%) in identifying the fetal station and its degree of engagement,[16–19,35] intrapartum transperineal ultrasound has been introduced in the delivery room to improve assessments of the progression and final method of delivery. Accordingly, Kalache et al[41] reported that an angle of progression ≥120° is associated with a high probability of vaginal delivery, whereas Ramphul et al[42] discussed the utility of intrapartum ultrasound for evaluating fetal head position before operative vaginal delivery.

Operative vaginal deliveries are associated with higher maternal and neonatal morbidity,[1–13] especially when a cesarean delivery is required because of a failed operative vaginal delivery. An emergency cesarean delivery after a failed vacuum-assisted delivery is associated with an intracranial hemorrhage rate of 1 in every 334 newborns and a convulsion rate of 1 in 145, with 1 in every 64 newborns needing mechanical ventilation.[1]

FIGURE 6
ROC Curve for adjusted logistic regression model adjusted by shrinkage method



ROC curve for logistic regression model adjusted by shrinkage method obtained from the association between angle of progression with pushing and head circumference. Area under ROC curve = 0.876 (95% CI, 0.790—0.963; $P < .0005$).

CI, confidence interval; *ROC*, receiver-operating characteristic.

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In this context, intrapartum transperineal ultrasound has been introduced in clinical practice to enable the prediction of the difficulty and possible complications of operative vaginal deliveries. Bultez et al[24] reported that the optimal cutoff for angle of progression was 145.5° for predicting vacuum extraction failure in nulliparous women; the calculated AUC was 0.67 (95% CI, 0.57—0.77), with a sensitivity of 86.2% (95% CI, 68—97%), specificity of 49% (95% CI, 40—57%), and positive predictive value of 24% (95% CI, 16—34%). Kahrs et al[28] found that in nulliparous women with a prolonged second stage of labor, a head-perineum distance of >35 mm is associated with a 22% (9 of 41) risk of an emergency cesarean delivery.

In addition, Kasbaoui et al[43] carried out a prospective cohort study including 659 women, in which the head-perineum distance was measured prior to operative vaginal delivery. After adjustment for parity, presentation type and fetal macrosomia, head-perineum distance ≥40 mm was significantly associated with the occurrence of a difficult extraction (odds ratio, 2.38).

Martins et al[44] found that a cutoff of 142° for the angle of progression was a predictor for complicated operative vaginal deliveries. This is consistent with the results of our study,[29] which identified an angle of progression with pushing <153.5° as a predictor of complicated operative deliveries (sensitivity of 86.9% and false-positive rate of 5.9% (AUC of 86.9% [95% CI, 80—91]).

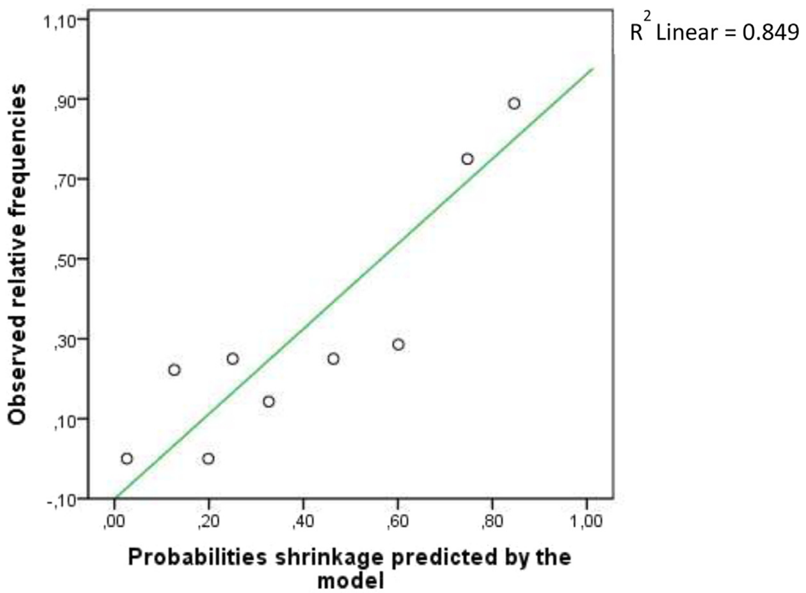
Several authors have expressed interest in predicting the type of vaginal operative delivery they will encounter and the risk for cesarean delivery.[45—47] Their efforts have been focused on predicting the outcome of labor, that is, vaginal vs cesarean delivery, by assessing the first stage of labor. Thus, Burke et al[46] presented a predictive model of cesarean risk based on 5 parameters (maternal age, BMI, height, fetal abdominal circumference, and fetal head circumference) that were evaluated in the first stage of labor and found excellent calibration and discriminative ability (Kolmogorov-Smirnov, D statistic, 0.29; 95% CI, 0.28—0.30).

With the same purpose of predicting the probability of vaginal delivery vs required cesarean delivery, Eggebø et al[47] introduced intrapartum transperineal ultrasound in his evaluation and presented a model based on 6 parameters (head-perineum distance, caput succedaneum, occiput posterior position, maternal age, gestational age, and maternal BMI), which were all evaluated during the first stage of labor, and obtained an AUC of 0.853% (95% CI, 0.678—1.000).

We observed a significant difference in fetal sex between study groups (62.5% female fetuses in the uncomplicated operative vaginal deliveries vs 29% in the complicated operative vaginal deliveries). In 5.9% of cases, we were not able to measure the head circumference during the second stage of labor because the fetal head was already engaged in the maternal pelvis.

Nonetheless, unlike previously published models[24,46,47] for predicting complicated or difficult operative deliveries, our predictive model presents the following characteristics: (1) the model can be used in the delivery room;

FIGURE 7
Original adjusted logistic regression model adjusted by shrinkage method



Calibration graphic of original logistic regression model adjusted by shrinkage method obtained from the association between angle of progression with pushing and head circumference.

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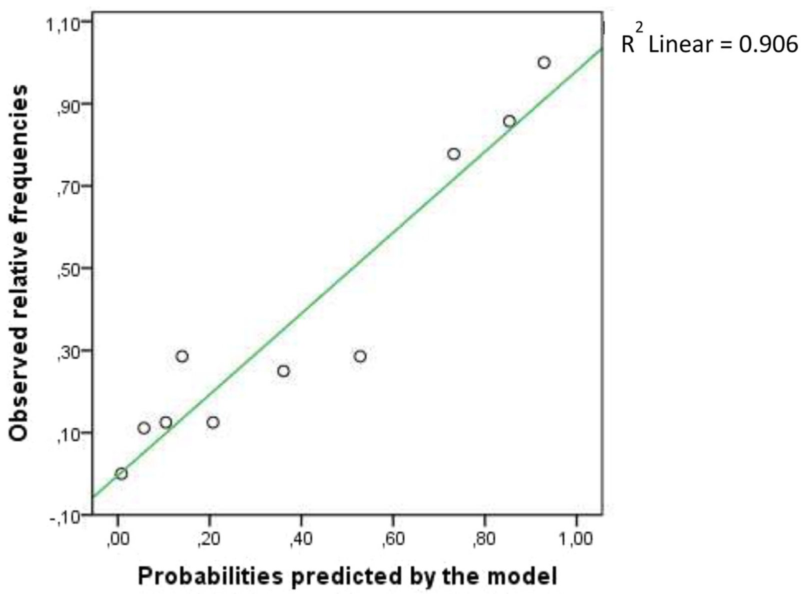
FIGURE 8
Logistic regression model by association between AoP with pushing and HC



Calibration graphic of original logistic regression model obtained from the association between angle of progression with pushing and head circumference.

AoP, angle of progression; *HC*, head circumference.

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(2) the model provides a quick evaluation because only 2 ultrasound parameters are involved; and (3) the echographic measurements used in the model appear to be easy to perform.

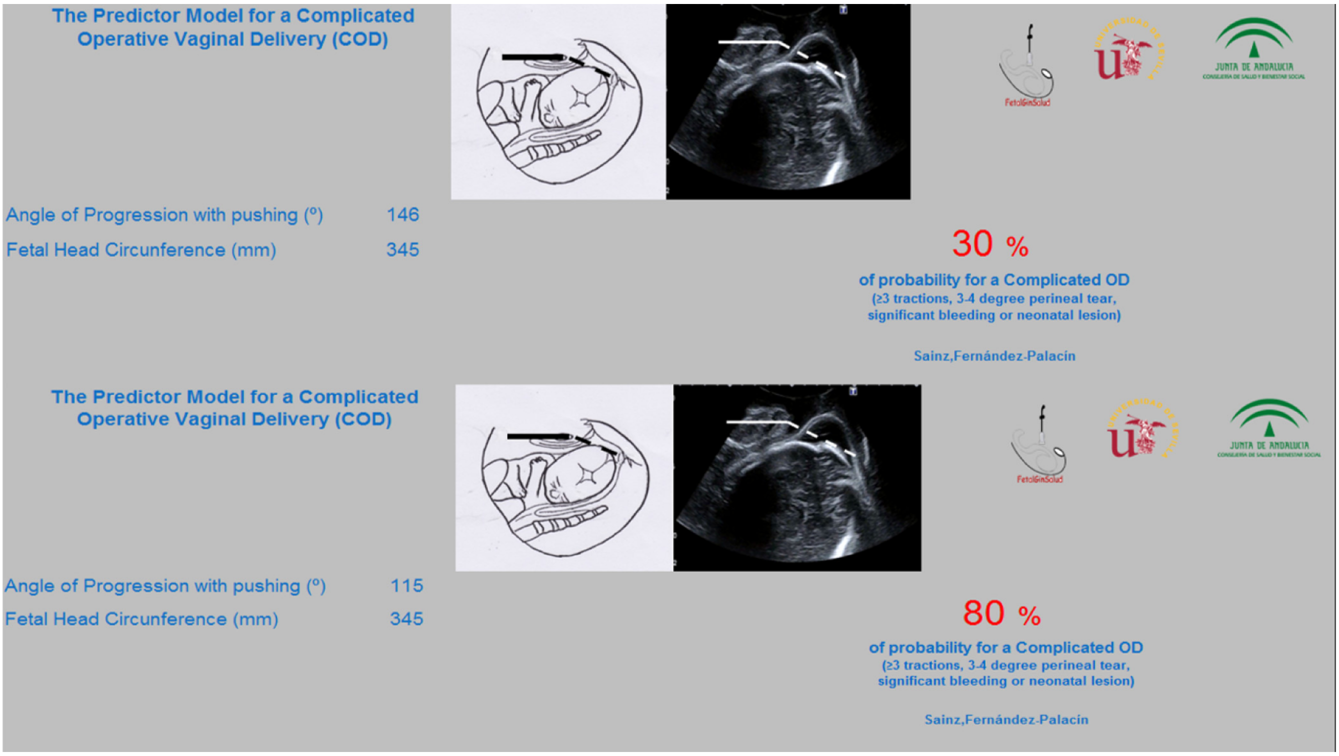
Strengths and limitations

This study has several strengths. First, our study includes a large series of deliveries at high risk of resulting in complicated operative vaginal deliveries (ie, nulliparous women and occiput posterior position),[10,48] the use of 2 types of instruments (vacuum and forceps), and an evaluation by intrapartum transperineal ultrasound. Moreover, the population included in this study is representative of pregnant women who require operative vaginal delivery to complete fetal extraction, including cases with the main indications for operative vaginal deliveries, such as nonreassuring fetal heart rate, failure to progress in labor, or maternal exhaustion.

Regarding the method, operative vaginal deliveries were performed exclusively by senior obstetricians who had extensive experience in obstetric practice. We identified an adequate predictive model for complicated operative vaginal deliveries that we consider easy to apply in the delivery room because it involves only 2 variables, a fetal ultrasound parameter (head circumference)[30–32] and an intrapartum transperineal ultrasound parameter (angle of progression), which have proven to be useful in the identification of difficult or complicated operative vaginal deliveries.[23–29]

Lastly, this study is based on the fact that transperineal ultrasound requires little training and can be undertaken with the type of ultrasound equipment that is frequently found in most delivery units worldwide. Therefore, this technique is generalizable. Angle of progression has proven to be easy to evaluate and is very useful for this purpose.[29] Estimated fetal weight and head circumference are risk factors for cesarean and operative deliveries;[30–32] accordingly, these parameters should be considered when assessing and predicting the success of instrumentation. Head

FIGURE 9
Example of using the binary model by AoP and HC



Example of using the binary model based on angle of progression with pushing and head circumference as a predictor for a complicated operative vaginal delivery.

AoP, angle of progression; *HC*, head circumference.

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circumference presents an adequate correlation with the difficulty of instrumental delivery, the probability of failure, and the need for cesarean delivery.[30,32,49] However, estimated fetal weight is more difficult to evaluate and presents a higher error rate than does head circumference.[50–52]

We consider the following to be limitations of our work: in our predictive model, we did not evaluate the head-perineum distance, an ultrasound parameter that appears to be very useful in predicting the difficulty of vaginal delivery, although our group has not achieved adequate reproducibility of this parameter (interobserver correlation of 0.53 [95% CI, 0.1–0.9).[36] In addition, we believe that the reproducibility of head circumference measurement during the second stage of labor (when the fetal head is already engaged in the maternal pelvis) must be proven. External validation of the predictive model should also be carried out.

Lastly, we consider that including other types of forceps instead of only Kielland's forceps and using additional objective parameters to classify a delivery as a complicated operative vaginal delivery, such as the need for maternal blood transfusion, traumatic fetal lesion, or cup detachment, should be considered in future studies.

Conclusion

The combination of angle of progression and head circumference can predict 87% of complicated operative vaginal deliveries, and such prediction can be performed in the delivery room. ■

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