Utilizing intrapartum transperineal ultrasound in the second stage of labor to predict the difficulty in operative forceps delivery

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Abstract

Objectives:

To assess the predictive value of intrapartum transperineal ultrasound (ITU) measurements, including angle of progression (AOP) and head direction (HD), for the difficulty of forceps delivery in occiput anterior position.

Methods:

This prospective observational study was conducted among 21 nulliparous women with singleton term pregnancies with an indication for forceps delivery. Two operators performed ITU (AOP and HD) immediately before blade application, both at rest and with concurrently contraction and active pushing. Managing obstetricians were blinded to the ultrasound data. A forceps delivery was classified as “complicated” when one or more of the following situations occurred: three or more tractions, a subjective impression of a difficult traction, failed forceps delivery, a third-degree or higher perineal tear and a significant neonatal lesion.

Results:

Of 21 cases, we identified 5 cases of complicated forceps deliveries. AOP at rest (AOP1) was $127.67 \pm 11.35^\circ$ in complicated group and $143.68 \pm 15.08^\circ$ in uncomplicated group ($P = 0.043$); AOP during contraction (AOP2) was $161.44 \pm 9.25^\circ$ versus $179.55 \pm 15.81^\circ$ ($P = 0.026$). HD at rest (HD1) was $14.81 \pm 15.39^\circ$ versus $20.30 \pm 9.81^\circ$ ($P = 0.351$); HD during contraction (HD2) was $26.77 \pm 14.99^\circ$ versus $35.97 \pm 10.21^\circ$ ($P = 0.131$). By calculating the area under the receiver-operating characteristics curve (AUC), the measurements of AOP1 and AOP2 and their combination (Combined prediction score = $-28.790 + 0.105 \times \text{AOP1}(\circ) + 0.094 \times \text{AOP2}(\circ)$) showed significant predictive values for a safe forceps delivery. The AUCs were 81.3% (95CI 58.4%-94.7%), 83.8% (95 CI 61.3%-96.0%) and 92.5% (95%CI 72.3%-99.4%), respectively. The optimal cut-offs were an AOP1 of 127.8° (sensitivity = 81.25%, specificity = 80%), an AOP2 of 171.4° (sensitivity = 75%, specificity = 100%) and a new combined prediction score of 1.376 (sensitivity = 81.25%, specificity = 80%).

Conclusions:

Using the measurements of AOP1 and AOP2 and their combination can predict a high probability of safe forceps delivery, and such prediction can be helpful for the obstetricians in clinical decision-making.

Introduction

In recent decades, the percentage of operative vaginal delivery (OVD) tended to decline throughout the world [1–5]. The use of forceps has become a rarer method to be performed, compared with vacuum extraction [1–3, 6].

The reasons why the use of forceps has fallen out of favor among obstetricians include: (1) Obstetricians fear for the litigation related to the maternal and fetal complications of forceps delivery, especially the injuries to newborns (facial laceration, facial nerve injury, ocular trauma, skull fracture, intracranial hemorrhage, subgaleal hematoma, hyperbilirubinemia, fetal death) [7]. (2) The maternal and fetal morbidities are higher in the cases of sequential OVD (vacuum followed by forceps) and subsequent cesarean section after failed OVD [8–10]. (3) Forceps is more difficult to use in comparison to vacuum extraction.

Nonetheless, forceps delivery has its benefits. When applied properly, it has the potential to eliminate the need for sequential use of instruments and second stage cesarean section, with the higher rate of primary success than vacuum extraction [11, 12], which can be helpful in emergency situation such as acute fetal distress during the second stage of labor.

It is widely accepted that a successful and safe forceps delivery is associated with the correct determination of fetal head station and position and the operator's experience [13]. The traditional evaluation of head station and position depends on vaginal digital examination, which is subjective, unreliable and poorly reproducible [14–17]. In contrast, intrapartum ultrasound has been demonstrated to be far more precise in assessing fetal head station and position during delivery [17, 18], and it has been used for diagnosing the degree of birth progress and predicting the final method of delivery [19–27]. Intrapartum transperineal ultrasound (ITU) can be helpful in identifying failed or difficult forceps deliveries. To date, the studies for this purpose were rare. Several studies put vacuum and forceps cases together as research objects [28–32], and only one study focused on forceps delivery [33]. When an OVD is considered, choosing an appropriate instrument to increase the probability of primary success and avoid excessive pulls and sequential use of instruments is the key point to reduce maternal and fetal morbidities. More studies concerning the relationship of ITU and forceps delivery are needed. Accordingly, we aimed to assess the predictive capacity of ITU for instrumentation difficulty with forceps in our unit.

Methods

This prospective observational study was carried out between May 2017 and September 2019 in the obstetrics department of the People's Hospital of Guangxi Zhuang Autonomous Region, Guangxi, China. A total of 21 women who required instrumentation to expedite vaginal delivery during the second stage of labor were included.

Our research protocol had been approved by the Ethics Committee of the People's Hospital of Guangxi Zhuang Autonomous Region (Approval No. KY-LW-2017-3) and would be performed in accordance with the guidelines of the Declaration of Helsinki, formulated by the World Medical Association. All participants signed informed consent before enrolled into the study.

All 21 women shared the following clinical characteristics: ages of 18–45 years old, weighing between 40–89kg, height over 150cm, primiparous, singleton, full term pregnancy (37–42 weeks), low risk, estimated fetal weight below 4000g before delivery, in active second stage of labor with ruptured membrane, and with fetus in occiput anterior position. Our study included both spontaneous and induced labor cases. Pregnancies with severe maternal pathology or fetal pathology were excluded. Indications for instrumental forceps delivery were secondary uterine inertia with failure to progress in the second stage of labor and abnormal fetal heart rate monitoring (category III fetal heart rate tracings according to a 3-tiered system for categorization, ACOG guideline, 2009 [34]). But the cases in which a very urgent traction was required due to prolonged fetal bradycardia or late fetal heart-rate decelerations with absent fetal heart-rate variability were excluded.

Forceps deliveries were performed by senior obstetricians with more than 10 years of experience in attending deliveries. We used Tucker-McLane forceps (type: A1518, Germany) in all cases. Prior to forceps blade application, fetal head position was assessed by vaginal digital examination. Fetal head station was assessed by both vaginal digital examination and ITU, as described below. We used an ultrasound instrument (Sonoscape S11Pro, Shenzhen, China) with a 5–10 MHz convex probe (2D ultrasound method) to assess ultrasound parameters. All ultrasound image captures were carried out by two senior obstetricians, who were trained to use the ultrasound machine for this study and were not involved in the clinical management.

With the woman in the lithotomy position, the transducer (covered with ultrasound gel, enclosed in a latex glove) was placed between the labia in the midsagittal plane to obtain the capture. It was ensured that the whole length of the pubic symphysis longitudinal axis was included in the capture, since it would be used as a reference line. Once the correct landmarks obtained, the image was frozen and saved. Images were taken at rest and during uterine contraction with pushing. At least two images were captured on both occasions. Once the ITU captures were completed, the forceps operators performed the tractions immediately, without taking any previous ultrasound information into account in clinical decision-making. Captured images were saved for offline analysis after delivery.

After delivery, the clinical and ultrasound data were collected, including age, gestational age at delivery, parity and obstetric history, height, body mass index (BMI), induced labor or not, receiving epidural anesthesia or not, indication for OVD, duration of the first and the second stage of labor, digital assessment of head station and position between contraction, number of tractions, duration of the last traction before delivery, subjective impression of the operator regarding forceps traction (easy, medium, difficult or impossible), the initial direction of traction, final mode of delivery (forceps or cesarean), given mediolateral episiotomy or not, hemoglobin level (before and after delivery), degree of perineal tear, newborn weight, newborn sex, umbilical arterial pH at birth, Apgar scores (1 and 5min), neonatal lesion related to tractions (all newborns were given cranial sonography on the first day after birth).

The following ultrasound parameters were obtained from each saved image: angle of progression (AOP) and head direction (HD) without maternal contraction (AOP1, HD1); AOP and HD with pushing during

contraction (AOP2, HD2); the difference between AOP1 and AOP2 (Δ AOP) and between HD1 and HD2 (Δ HD). AOP, as described by Barbera et al. [35], was defined as the angle between a line through the long axis of the pubic symphysis and another line extending from the inferior margin of the pubic long axis tangentially to the fetal skull's contour (Fig. 1). HD, according to Cuerva et al. [33], was defined as the angle resulting from the union of a line across the long axis of the pubic symphysis and a perpendicular line to fetal head widest transverse diameter (Fig. 2). The average values of AOP1, HD1, AOP2, HD2, Δ AOP and Δ HD on the images of each case were calculated and used for statistical analysis.

According to the performance characteristics and perinatal outcomes, the instrumentation for each case was classified as complicated or uncomplicated. A case was regarded as complicated if one or more of the following situations occurred: three or more tractions performed, difficult or impossible forceps delivery (depending on the subjective impression of the operator), failed forceps delivery, a third-degree or higher perineal tear and a significant neonatal lesion caused by using forceps (facial laceration, facial nerve injury, ocular trauma, skull fracture, intracranial hemorrhage and subgaleal hematoma).

Statistical analysis was performed by using IBM SPSS 20.0 and MedCalc 19.7.2. The 21 cases in this study were divided into complicated group and uncomplicated group. The Shapiro-Wilk test was used to verify the distribution of variables due to the small sample size in each group. Numeric variables were shown as means and standard deviation, and categorical variables were displayed as number and percentage. Firstly, between-group comparisons of clinical data and ITU parameters were performed by using SPSS. Comparisons of numeric variables between groups were carried out by using the Student's t-test (normal distribution data) or the Mann-Whitney test (non-normal distribution data), and categorical variables by Fisher's exact test and rank sum test (for ranked data). Secondly, the predictive capabilities of the ultrasound parameters for complicated forceps delivery were evaluated by the receiver-operating characteristics (ROC) curve if they differed significantly between complicated group and uncomplicated group ($P < 0.05$). By using MedCalc, the areas under ROC curve (AUCs) and 95% confidence intervals of each ITU parameter and their combination were estimated. The optimal cut-offs for prediction were identified on the basis of maximal Youden's indexes (Youden's index = sensitivity + specificity - 1). The comparisons between every two AUCs were also performed using MedCalc. All P values were reported as two-sides. $P < 0.05$ was considered as statistically significant.

Vector graphics showing the results were created by using Grapad Prism 8 in this study.

Results

General information and grouping

All women in this study were primiparous. All fetuses were delivered in the occiput anterior position. Average height was 158.52 ± 2.73 cm. The mean birth weight was 3360 ± 312 g. The mean duration of the second stage of labor was 108.7 ± 60.1 min. The mean duration of the last traction was 46.4 ± 36.9 s. Digital assessed head station was at least + 2cm in all cases. The main indication for forceps delivery

was abnormal fetal heart rate monitoring (71.4%, 15/21). An episiotomy was performed in 85.7% (18/21) of cases and there were no third-degree or greater perineal tears. In one case (4.8%), the Apgar score was < 7 at 1 min, and no Apgar scores of < 7 were obtained at 5 min. The mean umbilical arterial blood pH was 7.18 ± 0.11 , and this measure was < 7.1 in six cases (28.6%).

AOP1, HD1, AOP2 and HD2 assessments were possible in all cases. Significant neonatal lesion happened in 3 (14.3%) cases (one with facial nerve injury and apparent forceps marks, one with deviation of left mouth angle associated with facial nerve paralysis, and one with weakness in closing left eyelid and deviation of right mouth angle associated with facial nerve paralysis). 3 of the 21 cases (14.3%) were considered as “difficult” by the operator. 2 tractions were needed in one of the three “difficult” cases and forceps delivery finally succeeded. In the other two “difficult” cases, 3 tractions were performed but failed. In one of them, vaginal delivery was completed by utilization of fundal pressure, and cesarean section was performed to complete delivery in the other one. Totally, 5 cases were considered as complicated and 16 cases as uncomplicated. The exact reasons why the five cases were included into complicated group were listed in Table 1. None was classified as complicated case solely depending on the subjective impression of the operator.

Table 1
The inclusion reasons of the cases in complicated group

The cases in complicated group	Inclusion reasons
Case 1	Significant neonatal lesion (facial nerve injury)
Case 2	Significant neonatal lesion (deviation of left mouth angle associated with facial nerve paralysis)
Case 3	3 tractions were performed and all failed. Cesarean section was performed to complete delivery. Forceps delivery was considered as “difficult” according to the subjective impression of the operator.
Case 4	Significant neonatal lesion (weakness in closing left eyelid and deviation of right mouth angle associated with facial nerve paralysis) Forceps delivery was considered as “difficult” according to the subjective impression of the operator.
Case 5	3 tractions were performed and all failed. Finally, vaginal delivery was completed by utilization of fundal pressure. Forceps delivery was considered as “difficult” according to the subjective impression of the operator.

In the complicated group, no case was considered as “easy” according to the subjective impression of forceps operator, and the initial directions of traction in all cases were “downward”. In the uncomplicated

group, no case was regarded as “difficult”. The initial pulling direction was “horizontal” in 7 (7/16, 43.8%) cases, and “downward” in 7 (7/16, 43.8%) cases.

No significant differences were observed between the complicated group and the uncomplicated group regarding the maternal or neonatal clinical data, with the following exceptions: digital assessed head station, operators’ impression, the initial direction of forceps traction, umbilical cord artery pH, 1 min Apgar score and significant birth trauma (Table 2). The digitally assessed head station was 2.10 ± 0.22 cm in the complicated group and 2.63 ± 0.43 cm in the uncomplicated group ($P = 0.016$).

Table 2
Maternal and neonatal clinical data in complicated group and uncomplicated group

	Complicated group (N = 5)	Uncomplicated group (N = 16)	P value
Age (years)	29.00 ± 1.87	29.19 ± 3.94	0.920
Gestational age (weeks)	39.77 ± 0.99	39.98 ± 0.83	0.640
Height (cm)	157.00 ± 1.73	159.00 ± 2.85	0.116
Body mass index	25.26 ± 2.62	27.36 ± 2.35	0.106
Number of induced labors	1 (20.00)	4 (25.00)	1.000
Epidural anesthesia	2 (40.00)	4 (25.00)	0.598
Indication of OVD	3 (60.00)	12 (75.00)	0.598
Abnormal FHR monitoring	2 (40.00)	4 (25.00)	
Failure to progress			
Duration of 1st stage of labor (min)	497.80 ± 208.03	571.25 ± 305.94	0.741
Duration of 2nd stage of labor (min)	119.80 ± 73.26	105.19 ± 57.73	0.647
Digitally assessed head station (cm)	2.10 ± 0.22	2.63 ± 0.43	0.016
Duration of the last traction (s)	93.93 ± 51.38	31.55 ± 10.91	0.053
Operators' impression	0 (0)	9 (56.25)	0.003
Easy	2 (40.00)	7 (43.75)	
Medium	3 (60.00)	0 (0)	
Difficult			
Initial direction of pulling	0 (0)	2 (12.50)	0.035
Upward	0 (0)	7 (43.75)	
Horizontal	5 (100.00)	7 (43.75)	
Downward			
Mediolateral episiotomy	3 (60.00)	15 (93.75)	0.128
The drop of hemoglobin level (g/L)	25.60 ± 8.79	36.94 ± 12.30	0.073

Data are given as mean ± standard deviation or n (%).

	Complicated group (N = 5)	Uncomplicated group (N = 16)	P value
Birth weight (g)	3295.00 ± 403.45	3379.69 ± 291.18	0.609
Newborn gender	3 (60.00)	10 (62.50)	1.000
Male	2 (40.00)	6 (37.50)	
Female			
Umbilical cord artery pH	7.07 ± 0.07	7.21 ± 0.11	0.01
Apgar score	8.00 ± 1.87	9.56 ± 1.03	0.048
1 min	10.00 ± 0.00	9.94 ± 0.25	0.576
5 min			
Asphyxia of newborn	3 (60.00)	2 (12.50)	0.063
Birth trauma	3 (60.00)	0 (0)	0.008
Data are given as mean ± standard deviation or n (%).			

The between-group comparisons of ITU parameters

As showed in Table 3 and Fig. 3, significant between-group differences were revealed with regard to AOP1 and AOP2, and no statistically significant differences were observed in HD1, HD2, Δ AOP and Δ HD. The average AOP1 and AOP2 measurements were significantly higher in the uncomplicated group than those in the complicated group (AOP1 $143.68 \pm 15.08^\circ$ vs $127.67 \pm 11.35^\circ$, $P = 0.043$; AOP2 $179.55 \pm 15.81^\circ$ vs $161.44 \pm 9.25^\circ$, $P = 0.026$).

Table 3
Intrapartum transperineal ultrasound data in complicated group and uncomplicated group

	Complicated group (N = 5)	Uncomplicated group (N = 16)	Mean difference (95% CI)	P value
AOP (°)	127.67 ± 11.35	143.68 ± 15.08	-16.01 (-31.42, -0.60)	0.043
AOP1	161.44 ± 9.25	179.55 ± 15.81	-18.11 (-33.84, -2.37)	0.026
AOP2	38.74 ± 12.12	37.58 ± 17.10		0.891
ΔAOP			1.16 (-16.20, 18.51)	
HD (°)	14.81 ± 15.39	20.30 ± 9.81	-5.50 (-17.53, 6.54)	0.351
HD1	26.77 ± 14.99	35.97 ± 10.21	-9.20 (-21.41, 3.01)	0.131
HD2	11.97 ± 4.60	15.67 ± 7.95	-	0.409
ΔHD				
Data are given as mean ± standard deviation. The between-group comparison of ΔHD was performed by Mann-Whitney test.				

A. AOP1; B. AOP2

The value of ITU parameters for the prediction of complicated forceps delivery

The degree of digitally assessed head station was not assessed by ROC curve due to its subjectivity. ROC curve analysis was performed to identify optimal predictors of complicated forceps delivery among the significant ultrasound parameters and the result was showed in Fig. 4 and Table 4. The AUC for AOP1 was 81.3% (95% CI 0.584 to 0.947, P = 0.0066) and the AUC for AOP2 was 83.8% (95% CI 0.613 to 0.960, P = 0.0002). A new prediction score was established basing on the combination of AOP1 and AOP2 (Combined prediction score = $-28.790 + 0.105 \times \text{AOP1}(\text{°}) + 0.094 \times \text{AOP2}(\text{°})$). The AUC for the combination of AOP1 and AOP2 was 92.5% (95% CI 0.723 to 0.994, P < 0.0001). There were no significant differences between every two AUCs (AOP1 vs. AOP2, P = 0.861; AOP1 vs. Combined prediction score, P = 0.196; AOP2 vs. Combined prediction score, P = 0.255).

The cut-offs to predict complicated forceps delivery were an AOP1 of 127.8°, an AOP2 of 171.4°, and a combined prediction score of 1.376, and their reliabilities were also shown in Table 4.

Table 4
The predictive value of different methods and their cut-offs

	AOP1	AOP2	Combined prediction score *
AUC (95% CI)	0.813 (0.584, 0.947)	0.838 (0.613, 0.960)	0.925 (0.723, 0.994)
Z statistic	2.714	3.791	7.121
P value	0.0066	0.0002	< 0.0001
Cut-off	127.8	171.4	1.376
Youden's index	0.6125	0.75	0.8125
Sensitivity	0.8125	0.75	0.8125
Specificity	0.8	1	0.8
Positive predictive value	0.9286	1	0.9286
Negative predictive value	0.5714	0.5555	0.5714
Positive likelihood ratio	4.0625	-	4.0625
Negative likelihood ratio	0.2344	0.25	0.2344
* Combined prediction score = $-28.790 + 0.105 \times \text{AOP1}(^\circ) + 0.094 \times \text{AOP2}(^\circ)$			

Discussion

One of the key points in performing a successful and safe forceps delivery is the precise determination of the fetal head station and position. There are rare studies focusing on the objective evaluation of the fetal station associated with the prediction of successful forceps delivery.

In our study, AOP1, AOP2 measurements and their combination showed significant values in the prediction of successful and safe forceps delivery according to the result from ROC curves. Although no statistically significant differences were found between every two AUCs among the three methods, the ROC curve of combined prediction score could cover those of AOP1 and AOP2 totally. And there was a crossover point between the ROC curves of AOP1 and AOP2 when the specificity was about 80%.

Increasing the probability of the success of the first traction and avoiding excessive pulls even transition to cesarean section are the key points to reduce maternal and fetal morbidities when performing a forceps delivery. Thus, using the three different methods to predict successful and safe forceps delivery should be based on a high specificity of at least 80% (false positive rate < 20%) in the clinical situation for the sake of safety. For this purpose, we analyzed the part of ROC curves with a specificity of > 80%, and found that the predictive efficacy in descending order was as follows: Combined prediction score > AOP2 > AOP1. This finding is consistent with our clinical experience. While using only one ITU parameter to

assess the difficulty of forceps delivery, AOP2 seems to be more valuable than AOP1. The larger AOP2 represents the stronger uterine contraction during pushing and the lower head station while the forceps traction is performed, so that a smaller pulling strength is needed to pull the baby out of the vagina, which reduces the pressure from forceps to fetal head and the probability of birth trauma.

In our study, the three cut-offs basing on maximal Youden's Indexes show high specificities (AOP1: 80%; AOP2:100%; Combined prediction Score: 80%) and high positive predictive values (AOP1: 92.86%, AOP2: 100%, Combined prediction score: 92.86%), which meets the requirement of clinical application. If both AOP1 and AOP2 measurements can be obtained before the placement of forceps blades, a combined prediction score > 1.376 can predict 81.25% of safe forceps deliveries, with a false positive rate of 20% and a positive predictive value of 92.86%. When using one single parameter, an AOP1 $> 127.8^\circ$ can predict 81.25% of safe forceps deliveries (false positive rate = 20%, positive predictive value = 92.86%) and an AOP2 $> 171.4^\circ$ can predict 75% of safe forceps deliveries (false positive rate = 0%, positive predictive value = 100%). Their negative predictive values are not high, which means when the measurements were lower than the cut-offs, experienced obstetricians still have the opportunity to fulfil a successful forceps delivery, but a cesarean section may be a safer choice for the beginners.

Sainz et al. [29] suggested the optimal ITU parameters for predicting a difficult OVD (vacuum and forceps) were an AOP2 of 153.5° (sensitivity 95.2%, false positive rate 5.9%) and a progression distance (PD) with pushing of 58.5mm (sensitivity 95.2%, false-positive rate 7.1%). PD was described as the distance between the infrapubic line (IPL, 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 fetal head [29]. Furthermore, Sainz et al. [31] built a binary logistic regression model (1) with Harrell's C-statistic as 0.876 to evaluate the probability of complicated operative delivery. And a software was developed according to the model to help making a quick clinical decision [31]. Chan et al. [32] stated that AOPs (AOP1 as 138.7° , sensitivity 86.2% and specificity 51.9%; AOP2 as 160.9° , sensitivity 87.1% and specificity 74.1%) were predictive of approximately 80% of successful OVD performed for prolonged second stage of labor.

Furthermore, an Israeli study including 33 women in the second stage of labor introduced two new significant ultrasound parameters related to successful OVD [28]: (1) Head widest part distance (HWPDP), defined as the distance between the widest diameter of the head and IPL; (2) Head ratio distance (HRD), defined as percentage of head beyond IPL. HWPDP $< 1.2\text{cm}$ or HRD $> 54\%$ could predict 90% of successful OVD. Another study from France [30] suggested that head to perineum distance (HPD, the distance between the probe and the closest bony part of fetal head) $\geq 40\text{mm}$ was an effective predictor for difficult OVD.

The five above-mentioned studies put vacuum and forceps deliveries together as the research objects. One study by Cuerva et al. [33] including 30 participants focused on forceps deliveries. In that study, it was suggested that the strongest predictors of complicated forceps delivery were AOP1 and PD at rest, and the best cut-offs were 138° (sensitivity 85.7%, specificity 100%) and 4.8cm (sensitivity 85.7%,

specificity 100%), respectively. In our opinion, the studies including vacuum and forceps deliveries together as research objects cannot give a clear guidance to obstetricians about choosing instruments when an ultrasound parameter over its predictive cut-off. An obstetrician with rare experience of forceps delivery may select vacuum. And the failure of primary vacuum extraction may result in more pulls or be followed by forceps traction, even by caesarean section, which may increase maternal and fetal morbidities [8–10]. According to our clinical experiences, it is more reasonable to investigate vacuum and forceps deliveries respectively, in search of ultrasound predictors of complicated or failed OVD.

The cut-off of AOP1 (127.8°) in our cohort is lower than that suggested by Cuerva et al. [33] (AOP1 as 138°). The difference may be related to the different definition of complicated or difficult forceps delivery that leads to different grouping criteria in the ROC curve analysis. In the study conducted by Cuerva et al. [33], a forceps delivery was classified as complicated when one or more of the following situation happened: three or more tractions, difficult or failed forceps delivery according to the impression of the operator, a third-degree or higher tear, significant bleeding during the episiotomy repair, major tear reported by the obstetrician and confirmed by a drop in the hemoglobin level of $\geq 2.5\text{g/dl}$ following the delivery, and a significant traumatic neonatal lesion. In our study, some complications such as apparent forceps marks, subsequent vaginal laceration and postpartum hemorrhage related to severe perineal tear were removed from the inclusion criteria of complicated group. Because they can be accepted by the patients after informed consent, especially when acute fetal distress occurs and a very urgent forceps traction is needed to save the baby's life.

In previous studies [18, 28–31, 33, 36], several ultrasound parameters (AOP, PD, HD, HPD, HWPD and HRD) and models showed significant values in predicting complicated or failed OVD. However, in the emergency situation such as acute fetal distress, time is limited to make the decision whether an OVD should be performed or not. The ultrasound parameters which can be obtained by ITU easily and rapidly will be more desirable for the clinical decision-making.

The whole shape of fetal skull in the sagittal plane is not always well-visualized during the capture of ITU images. There are some subjectivity in determining the proportion of fetal head beyond IPL, the widest transverse diameter of fetal head and the deepest bony part of fetal head. Therefore, there were some deviations between the real values and the measured values of HRD, HD, HWPD and PD. Besides, measuring HRD is time-consuming, which may cause the delay of obstetrical managements. The mechanism of delivery and the likelihood of successful OVD is associated with the relationship between fetal head skull and maternal pelvis. HPD is affected by the soft tissue thickness in perineum and levels of obesity, and its actual predictive value remains questionable. The measurement of AOP is easy, reproducible and reliable irrespective of the clinician's level of ultrasound experience [37, 38]. Thus, AOP is the best choice to evaluate fetal head station and the difficulty level of OVD according to the existing data. And our findings showed an AOP1 of $> 127.8^\circ$, an AOP2 of $> 171.4^\circ$ and their combination (a combined prediction score of > 1.376) can predict a high probability of successful and safe forceps delivery, which can be helpful in making a quick decision about forceps use.

Our study has several weaknesses. (1) The population in our study is from Southern China, with a shorter height and a smaller pelvic size than those of the population in the European and American countries. It cannot represent the general population. (2) The number of cases in our series was small. (3) Fetuses in occiput posterior position which was found to be an independent risk factor for perineal tears [39] were excluded from our study due to the different delivery mechanism. It is necessary to carry out further studies focusing on different populations, a larger sample size and occiput posterior position.

In conclusion, using the measurements of AOP1 and AOP2 and a new prediction score basing on AOP1 and AOP2 can predict a high probability of safe forceps delivery, and such prediction can be helpful for the obstetricians in clinical decision-making, especially for the beginners without sufficient experiences in forceps operating.

Equation (1):

probability of complicated operative delivery = $1/\{1 + e^{[-(-25.376-0.36AOP2 + 0.508\text{head circumference})]}\}$

Equation (2):

Combined prediction score = $-28.790 + 0.105 \times AOP1(^{\circ}) + 0.094 \times AOP2(^{\circ})$

Data Availability:

The datasets generated during the current study are available from the corresponding author on reasonable request.

Declarations

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Authors' contributions:

Conceptualization: Hui Chen

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Competing interests:

The authors declare no competing interests.

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Figures

Figure 1

Transperineal ultrasound image showing measurement of AOP of fetal head. AOP was defined as the angle between a line through the long axis of the pubic symphysis and another line extending from the inferior margin of the pubic long axis tangentially to the fetal skull's contour.

Figure 2

Transperineal ultrasound image showing measurement of HD of fetal head. HD was defined as the angle resulting from the union of a line across the long axis of the pubic symphysis and a perpendicular line to fetal head widest transverse diameter.

Figure 3

Ultrasound parameters in complicated group and uncomplicated group A. AOP1; B. AOP2

Figure 4

ROC curves of AOP1, AOP2 and their combination