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Title/Titill: Can ultrasound on admission in active labor predict labor duration and a spontaneous delivery?

Year/Útgáfuár: 2021

Version/Útgáfa: Post-print (lokagerð höfundar)

Please cite the original version:

Vinsamlega vísið til útgefnu greinarinnar:

Dr Hulda Hjartardottir MD , Ms Sigrún H. Lund PhD , Dr Sigurlaug Benediktsdottir MD , Dr Reynir T. GEIRSSON MD, PhD , Dr Torbjørn M. Eggebø MD, PhD , ´ Can ultrasound on admission in active labor predict labor duration and a spontaneous delivery?, American Journal of Obstetrics & Gynecology MFM (2021), doi: https://doi.org/10.1016/j.ajogmf.2021.100383

Journal Pre-proof

Can ultrasound on admission in active labor predict labor duration and a spontaneous delivery?

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Please cite this article as: Dr Hulda Hjartardóttir MD , Ms Sigrún H. Lund PhD , Dr Sigurlaug Benediktsdóttir MD , Dr Reynir T. GEIRSSON MD, PhD , Dr Torbjørn M. Eggebø MD, PhD , Can ultrasound on admission in active labor predict labor duration and a spontaneous delivery?, *American Journal of Obstetrics & Gynecology MFM* (2021), doi: https://doi.org/10.1016/j.ajogmf.2021.100383

Highlights

Can ultrasound on admission in active labor predict labor duration and a spontaneous delivery?

- **Ultrasound was used to examine nulliparous women on admission in active labor**

- **Assessments of fetal head station, position and cervical dilatation were made**

- **Associations were found between duration of labor and both station and dilatation**

- **Associations were found between spontaneous delivery and station but not dilatation**

- **Neither duration of labor nor spontaneous delivery were associated with head position**

Can ultrasound on admission in active labor predict labor duration and a spontaneous delivery?

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Disclosure statement: The authors report no conflict of interest

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Word count:

Abstract: 500 words

Main text: 3265 words

Can ultrasound on admission in active labor predict labor duration and a spontaneous delivery?

Condensation

Ultrasound at the beginning of the active phase can predict length of labor and mode of delivery in nulliparous women.

Short Title

Ultrasound as an admission test in active labor

AJOG at a Glance (130 words)

     A.   ***Why was the study conducted*?**

- Predicting the length of labor and a spontaneous delivery on admission could be valuable.

- The performance of ultrasound as an admission test using head-perineum distance (HPD), angle of progression (AoP), fetal head position and cervical dilatation was investigated.

B. *What are the key findings*?

- HPD and AoP were associated with spontaneous delivery with an AUC of 0.68 and 0.67 (best cut-off levels ≥45 mm and ≤93°), respectively

- Duration of labor expressed as the HR for spontaneous delivery was 1.90 for HPD (95% CI; 0.83 to 2.60), for AoP the HR was 2.07 (95% CI; 1.15 to 3.72) and for cervical dilatation 3.11 (95% CI; 1.68 to 5.77).

- Fetal head position was not associated with labor duration or mode of delivery.

C. *What does this study add to what is already known*?

- Ultrasound can be used as an admission test in active labor

- Fetal head station was associated with labor duration and spontaneous delivery

- Cervical dilatation was associated with labor duration

- Fetal head position was neither significantly associated with labor duration nor mode of delivery

Structured Abstract

Background

Identifying predictive factors for a normal outcome at admission in the labor ward would be of value for planning labor care, timing interventions and in preventing labor dystocia. Clinical assessments of fetal head station and position at the start of labor have some predictive value but the value of ultrasound methods for this purpose has not been investigated. Studies using transperineal ultrasound before labor onset show possibilities of using these methods to predict outcome.

Objective

To investigate if ultrasound measurements during the first examination in the active phase of labor were associated with the duration of labor phases and the need for operative delivery.

Study Design

This was a secondary analysis of a prospective cohort study at Landspitali University Hospital, Reykjavik, Iceland. Nulliparous women at ≥37 weeks with a single fetus in cephalic presentation and spontaneous labor onset were eligible. The recruitment period was from January 2016 to April 2018.

Women were examined by a midwife on admission and included if in established active phase defined as regular contractions with a fully effaced cervix, open four cm or more. An ultrasound examination was performed by a separate examiner within 15 minutes, both examiners were blinded to the other's results. Transabdominal and transperineal ultrasound were used to assess fetal head position, cervical dilatation and fetal head station expressed as head-perineum distance and angle of progression.

Duration of labor was estimated as the hazard ratio for spontaneous delivery using Kaplan-Meier curves and Cox regression analysis. The hazard ratios were adjusted for maternal age and BMI. The associations between study parameters and mode of delivery were evaluated using receiver-operating characteristic curves.

Results

Median time to spontaneous delivery when head-perineum distance was ≤45 mm was 490 minutes compared to 682 min when >45mm (log rank test, *p*=0.009, but the adjusted HR for shorter HPD was 1.47; 95% CI; 0.83 to 2.60). For angle of progression ≥93° the median duration was 506 minutes compared to 732 min when <93° (log rank test, *p*=0.008, adjusted HR for AoP was 2.07; 95% CI: 1.15 to 3.72). The median time to delivery for non-occiput posterior positions was 506 minutes compared with 677 minutes for occiput posterior positions (log rank test, *p*=0.07, adjusted HR 1.52; 95% CI: 0.96-2.38) Median time to delivery was 429 minutes for dilatation of ≥6 cm and 704 minutes for dilatation of 4-5 cm (log rank test, *p*=0.002, adjusted HR 3.11; 95% CI: 1.68 to 5.77).

Spontaneous deliveries were 75, 16 were instrumental vaginal (one forceps and 15 ventouse) and eight were cesarean deliveries. Head-perineum distance was associated with spontaneous delivery with AUC=0.68 (95% CI; 0.55 to 0.80) and angle of progression with AUC=0.67 (95% CI; 0.55 to 0.80). Ultrasound measurement of cervical dilatation or position at inclusion were not significantly associated with a spontaneous delivery.

Conclusions

Ultrasound examinations showed that fetal head station and cervical dilatation was associated with the duration of labor but measurements of fetal head station were the variables best associated with operative deliveries.

Abbreviations: OP, occiput posterior; HR, hazard ratio; CI, confidence intervals; AUC, area under the curve; HPD, head perineum distance; AoP, angle of progression.

Keywords

Angle of progression, fetal head station, head perineum distance, labor, transperineal ultrasound, delivery time

Introduction

The length of labor is highly individual. Prolonged labor is known to increase the risk of adverse outcomes for the mother and fetus and is associated with a negative birth experience.[1, 2] Slow progress in labor occurs in 13-37% of nulliparous women and dystocia is a frequent indication for cesarean section during labor.[3-5] It would be advantageous to be able to predict which women will deliver vaginally when they enter labor. Various factors have been used to try to predict the need for cesarean section before labor, especially before labor induction[6-9] or in women who have had a previous cesarean section. Very few studies have been done among

women expecting to go into spontaneous labor or when they are admitted to a labor ward.[10-12]

Among the factors investigated are maternal characteristics such as age, height, BMI and

gestational age, but also clinical factors such as cervical dilatation and station and position of the

fetal head. Although cervical dilatation is relatively easily assessed with digital vaginal palpation,

assessments of both head station and position have been shown to be subjective and often

inaccurate.[13-16]

Transabdominal and transperineal ultrasound is increasingly used as an adjunct to

clinical assessment during labor, since fetal head position and descent into the pelvic cavity are

more accurately determined with ultrasound than digitally.[16-18] The International Society of

Ultrasound in Obstetrics and Gynecology (ISUOG) has published guidelines for the use of

ultrasound in labor.[19] We have shown that these methods can be used to follow labor progress

in terms of fetal head station and position.[20, 21] Identifying predictive factors for a normal

outcome early in the labor process would be desirable and of value for planning labor care,

allowing for better targeted interventions and resources when labor dystocia is more likely to

arise. Previous studies using transperineal ultrasound before spontaneous or induced labor have

shown that it is possible to use these methods to predict outcome.[22-24] A prediction model in

normal and prolonged nulliparous labors has even been constructed.[25] We aimed to investigate

how ultrasound assessments during the first examination in the active phase of labor were

associated with duration of labor phases and delivery mode.

Materials and methods

This was a secondary analysis of a prospective cohort study at Landspitali University Hospital in

Reykjavík, Iceland, between January 2016 and April 2018. We examined 99 women with

ultrasound longitudinally through the active phase of labor. The fetal head descent and fetal rotation patterns in this group have been published.[20, 21] In this study we concentrate on the predictive value of the first ultrasound examination.

Women over the age of 18 with a single fetus in cephalic presentation and a spontaneous start of labor at gestational age ≥37 weeks were eligible and recruited in a non-consecutive manner. The study population corresponded to the definition of group 1 in the Robson 10-group classification system (nulliparous women in spontaneous labor).[26] Oral and written information about the study was provided by a midwife on admission to the labor ward and written consent obtained before inclusion.

Active labor was defined by a clinical examination as a fully effaced cervix, open at least four centimeters in the presence of regular contractions in agreement with the actual WHO recommendations.[27, 28] Women were included after the initial examination if they were in established active phase or when the active phase was diagnosed in the women who had been admitted in the latent phase.

A midwife examined cervical dilatation clinically at admission. An ultrasound examination was then done by one of two obstetricians trained in both transabdominal and transperineal scanning within 15 minutes. Results of the ultrasound examination were not revealed to the labor ward staff and the ultrasound examiners were not involved in clinical decisions regarding the laboring women.

The main outcome measure was duration of the active phase of labor estimated as the likelihood for spontaneous delivery and expressed by a hazard ratio (HR). Secondary outcomes were duration of the second stage, duration of active pushing phase and mode of delivery.

Independent test variables were the ultrasound findings of head-perineum distance (HPD), angle of progression (AoP), fetal head position and cervical dilatation. The guidelines at the hospital have no upper limit for the duration of the active phase of labor, but the second stage should not be longer than four hours and active pushing no longer than two hours.

The ultrasound device used was Voluson *i* (GE Medical systems, Zipf, Austria) with a 3.5-7.5- MHz 3D curved multi-frequency transabdominal transducer. The ultrasound examination comprised both a transabdominal and transperineal scan. To determine the fetal head position, the transabdominal approach was used first. For this purpose, views of the fetal spine, orbits, midline structures of the fetal head and the choroid plexus were obtained. When this was not possible, due to deep engagement of the fetal head, the transperineal approach was used to determine position, obtaining views of the midline structures, the thalami and the choroid plexuses. The fetal head position was defined as the position of the occiput marked on a clock face graph with half-hour intervals. The occiput posterior position was categorized as ≥04:00 and ≤08:00 o'clock as described by Akmal et al.[29, 30]

Further, during the transperineal scan, AoP, HPD and cervical dilatation were assessed. AoP was measured in the sagittal plane as the angle between the longitudinal axis of the pubic symphysis and a line from the most inferior edge of the symphysis tangentially to the lowest contour of the fetal head.[31] The HPD was measured in the frontal plane (transverse plane related to perineum) as the shortest distance from the transducer to the fetal skull as previously described.[24, 32] After measuring HPD, the transducer was tilted posteriorly until the cervix could be seen.[33-35] Both the anterior-posterior and transverse diameters of the cervical dilatation were measured and the mean value used for calculations. All measurements were done in-between contractions.

All data were collected and managed using REDCap electronic data capture tools hosted at Landspitali University Hospital.[36] The study was approved by the Landspitali Ethics Committee, reference no. 26/2015.

Statistical analysis

The associations between spontaneous vaginal delivery vs. all operative deliveries related to ultrasound assessed HPD, AoP and cervical dilatation as continuous variables were evaluated using receiver-operating characteristic (ROC) curves. To find the best cut-off levels of HPD and AoP for predicting spontaneous delivery, Youden´s J statistic was employed.

To evaluate differences in the time interval from inclusion to spontaneous vaginal delivery according to fetal head station, position and cervical dilatation, we used Kaplan-Meier methods and Cox regression analyses. The Kaplan-Meier method was used to generate plots for fetal head station categories, for OP vs. non-OP positions and for cervical dilatation <4-5 cm vs. ≥6 cm. The plots were compared with a log rank test. Cox regression analyses were used to calculate hazard ratios (HR) as an estimate of the likelihood ("risk") of spontaneous delivery using the same categories for HPD, AoP, cervical dilatation and occiput positions for comparison. Cesarean sections and operative vaginal deliveries were censored.

We used the statistical software package R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Results

Study population

One hundred women were included, but one woman withdrew her consent. The study

population characteristics and labor outcomes are given in Table 1. Clinically assessed cervical

dilatation at inclusion was four cm in 26 women, five in 30, six in 19, seven in 16 and eight in six

women and in two women the dilatation was nine and ten cm. At inclusion, 49 women had

confirmed rupture of membranes.

Spontaneous delivery

In all, 75/99 women achieved a spontaneous delivery, and 24 were delivered operatively; eight

with a cesarean and 16 with an instrumental vaginal delivery. All but one of the operative

deliveries were owing to prolonged first or second stage of labor (further details can be found in

a longitudinal study describing the patterns of fetal head descent).[21] Of the 52 women that had

a fetus in the OP position at inclusion, 35 (67%) delivered spontaneously compared with 40/47

(85%) women who had a fetus in a non-OP position (p=0.06). The ROC curve analyses for the

associations between HPD and AoP at inclusion in prediction of a spontaneous delivery are

shown in Figure 1. HPD was associated with spontaneous delivery with AUC=0.68 AUC (95% CI:

0.55 to 0.80) and AoP with 67% AUC=0.67 (95% CI: 0.55 to 0.80). The best cut-off level for

predicting spontaneous delivery was HPD of ≤45mm and AoP of ≥93°. These levels were also

used for stratification into groups for comparison of labor duration. Ultrasound measurement of

cervical dilatation was not associated with a spontaneous delivery, with an AUC of 0.50 (95% CI,

0.38-0.63). The test characteristics of ultrasound measurements in predicting spontaneous

delivery are presented in Table 2.

Duration of labor

At inclusion fetal station expressed as ultrasound measured HPD was ≤45 mm in 60 women and >45 mm in 39. The estimated median time in active labor when HPD was ≤45 mm was 490 minutes vs. 682 min if the HPD >45 mm (log rank test, *p*=0.009). The probability of being delivered is illustrated with Kaplan-Meier curves (1-survival) in Figure 2. The HR for a spontaneous vaginal delivery showed a shorter duration of labor associated with smaller HPD (HR=1.90 (95%CI, 1.16 to 3.11), but the association was not significant after adjusting for maternal age and BMI (HR =1.47, 95% CI, 0.83-2.60).

Fetal station expressed as AoP was ≥93° in 69 women and <93° in 30 women. The estimated median time in active labor was 506 min in the former vs. 732 min in the latter group (log rank test, *p*=0.008) and the probability of being delivered is shown in Figure 3. The HR for a spontaneous delivery associated with wider AoP values was 2.06 (95% CI, 1.19 to 3.56) and remained significant after adjusting for maternal age and BMI; HR 2.07 (95% CI, 1.15 to 3.72).

Of the fetuses 52/99 were in the OP position at inclusion. The estimated median time in active labor was not significantly associated with fetal position at inclusion, i.e. 506 min in non-OP positions vs. 677 min in OP positions (log rank test, *p*=0.07). The HR for a spontaneous delivery associated with non-OP positions illustrated as a Kaplan-Meier plot (1-survival) in Figure 4 was 1.51 (95% CI, 0.96 to 2.38) and it did not change after adjusting for maternal age and BMI; HR 1.54 (95% CI, 0.97 to 2.46).

Ultrasound assessment of cervical dilatation showed that 64 women had dilatation of 4-5 cm, 23 women were dilated ≥6 cm and in 12 women dilatation could not be measured. Dilatation could be assessed in 40/49 with ruptured membranes versus 45/48 with intact membranes, *p*=0.26. The estimated median duration of active labor was 429 min for dilatation

of ≥6 cm and 704 for dilatation of 4-5 cm (log rank test, *p*=0.002). The HR for spontaneous

delivery associated with greater dilatation illustrated as a Kaplan-Meier plot (1-survival) in

Figure 5 was 2.45 (95% CI, 1.38-4.36) and after adjusting for maternal age and BMI the HR was

3.11 (95% CI, 1.68-5.77).

Duration of the second stage

The estimated median duration of the second stage was 92 minutes if HPD was ≤45 mm at

inclusion vs. 109 minutes if HPD was >45 mm (*p*=0.06). The HR for a spontaneous delivery

related to smaller HPD values was 1.61 (95%CI, 0.97 to 2.64), but the association was not

significant after adjusting for maternal age and BMI (HR =1.50, 95% CI, 0.85-2.65). The estimated

median duration of the second stage was 93 minutes if the AoP was ≥93 degrees at inclusion vs.

124 minutes if AoP was <93 degrees (p=0.04). For larger AoP values the HR for spontaneous

delivery was 1.76 (95% CI, 1.02 to 3.04) and was 1.59 (95% CI, 0.88 to 2.88 after adjusting for

maternal age and BMI.

Occiput position and cervical dilatation at inclusion were not associated with the

estimated duration of the second stage.

The estimated median duration of the active second stage was 62 min if AoP was ≥93

degrees at inclusion vs. 75 min if AoP was <93 degrees (p=0.03). For larger AoP values the HR for

spontaneous delivery was 1.86 (95% CI, 1.05 to 3.32) and after adjusting for age and BMI it was

1.97 (95% CI 1.06 to 3.68). None of the other parameters examined were associated with the

estimated duration of active pushing (Table 3).

Comment

Principal Findings

Fetal head station measured with ultrasound as HPD and AoP in the early active phase of labor was associated with both the time remaining in labor and with the duration of the second stage. HPD and AoP were associated with a spontaneous delivery with AUC=0.68 and 0.67, respectively. Ultrasound assessed cervical dilatation in the early active phase of labor was significantly associated with labor duration, but not with delivery mode. Fetal head position at the first examination in the active phase was neither associated with duration of labor nor delivery mode.

Results in context

The prediction of mode of delivery in nulliparous women using clinical factors on admission in labor has been investigated.[10, 11, 37-39] Turcot et al. found that cervical dilatation on admission could predict operative delivery but less than one third of women had a cervical dilatation ≥4 cm at inclusion.[39] Janssen et al. found that less advanced cervical dilatation and higher fetal station predicted cesarean delivery and a model developed based on these and a few other factors predicted cesarean delivery with AUC=0.71.[11] However, in their study only one quarter of the women were included at >4 cm. Wilkes et al. found that a change in cervical dilatation and station 2 h after admission was better in predicting cesarean delivery than the initial dilatation and station.[38] de Souza et al. studied nulliparous and multiparous women in both spontaneous and induced labor at less than 7 cm dilatation and a prediction model based on clinical factors on admission predicted cesarean delivery with AUC=0.78, but that prediction was better when using information obtained during labor.

The value of transperineal ultrasound in predicting labor outcomes has previously been investigated before the onset of labor and in laboring women.[22-25, 40-42] In these studies the cohorts have comprised mixed groups of parous and nulliparous women and labors with

spontaneous and induced labors. Marsoosi et al. studied 70 nulliparous and parous women and suggested that AoP might predict vaginal delivery when measured on admission in active labor.[40] Chor et al. studied hourly changes of several clinical and ultrasound parameters in nulliparous women in both induced and spontaneous labor and found that changes in progression distance could be of use for predicting cesarean delivery due to non-progressive labor.[42] Chan et al. studied nulli- and multiparous women in active, induced and spontaneous labor and suggested that a combination of AoP and HPD could be used to predict time to a normal spontaneous delivery.[41] Torkildsen et al studied women in prolonged labor and found HPD and AoP to predict vaginal delivery with AUC of 0.81 and 0.76 respectively.[5] Eggebø et al. studied nulliparous women in prolonged labor and found that a model combining maternal factors known to be associated with delivery mode with ultrasound factors could be useful in predicting vaginal delivery.[25] Fetal head position was found to be of value in predicting cesarean delivery in nulliparous women with a prolonged first stage in another study by Eggebø et al. but did not predict operative vaginal delivery nor remaining time in labor.[43] Comparisons with these studies suggest that the value ultrasound in assessing fetal head station and reliably confirming position may be greater in predicting operative delivery when labor is prolonged than at the outset of a spontaneous labor.

Ultrasound AoP and HPD are different but interrelated methods for assessing fetal head station. We included both in our study and found good correlation between the methods as shown before.[44] Both methods may be associated with the duration of labor and delivery mode because there was only modest variation of the respective predictive values and their confidence limits. Both approaches have in previous studies been found to be of value to indicate the likelihood of successful descent of the fetal head through the birth canal and thus vaginal delivery.[5, 31, 32, 45-48]

Ultrasound measurements of cervical dilatation are more challenging than assessment of position and measurements of HPD and AoP, especially after rupture of the membranes. Objective measurements are possible after training, and good repeatability has been shown.[33] Ultrasound cannot replace clinical assessment of cervical dilatation at late stages, but has the potential to be used as an admission test.[35]

Clinical Implications

Our results show the expected variation of duration of the active phase of labor and that cervical dilatation at admission is associated with the duration of labor. In addition, we show that assessing the fetal head station with ultrasound has a role as it is not only associated with duration of the active phase and the second stage but also with spontaneous vaginal delivery. We can confirm suggestions from previous studies that the position of the fetal head at the diagnosis of the active phase does not seem to have an effect on the duration of labor or the mode of delivery.[17, 22]

Based on our results, measuring HPD and AoP on admission in the active phase of labor could identify those women who are at low risk of intervention and assessed as being more likely to have shorter durations of labor. These women could then be reassured and offered a low risk environment but other women who are assessed as having a higher risk, based on measurements showing high fetal head station, could be observed more closely for signs of slow progress in terms of fetal descent and cervical dilatation. They could also be better informed of more realistic expectations of labor duration and offered more effective pain relief as soon as active labor is diagnosed. Other supportive measures could also be ensured, such as one-to-one midwifery care. Our results do not suggest that we have, as yet, a reliable method to find those women who ultimately will need an operative delivery as progress is so individual. Given the late

occurrence of fetal head descent and rotation observed in our longitudinal study of the same group of women[20] it is possible that change over time is a better predictor of outcome than a spot assessment at admission, as suggested by other researchers.[38, 39, 49, 50]

Research Implications

We investigated the association between ultrasound and spontaneous vaginal deliveries instead of cesarean delivery as we only had eight such deliveries. Results based on such small numbers could be subject to greater errors so this should be studied in larger groups. It is possible that fetal head station is more strongly associated with cesarean delivery than all operative deliveries. If confirmed the results could be used to construct a labor admission test helping to stratify risk along with other demographic and pregnancy risk factors.

Strengths and Limitations

A strength of our study was the homogenous group of spontaneously laboring nulliparous women recruited and assessed when the active phase was diagnosed. We were also able to report on ultrasound measurements of cervical dilatation as well as fetal position and station using methods that can be regarded as established. The ultrasound examiners were fetal medicine experts, which is a strength in documenting the potential value of ultrasound, but also a potential limitation for external validation. At the present time, only few obstetricians and midwives are trained in these methods, but that is likely to change. In 2018 WHO changed the definition of the active phase of labor, and recommended that cervical dilatation should be at least five cm at the start of the active phase.[51] We used the WHO criteria recommended at the time when the study was planned and executed; regular contractions, cervix effaced and dilatation of ≥4 cm.[27] Women were also recommended to stay at home until contractions were

regular.

That women had varying degrees of cervical dilatation at inclusion could be considered a limitation. We had no way of knowing the actual length of the active phase among most of the women because they were already in established labor on admission. On the other hand, this reflects the reality of labor and we were keen to observe whether outcomes could be predicted at the time of the ultrasound examination. Other limitations were the observational design and the size of the cohort. The low cesarean section rate in this population was in line with usual audits from our hospital, but differs from many other departments, which may limit the external validation.

Conclusions

We found that ultrasound assessments of fetal head station on entry to the labor ward in the active phase were associated with labor duration and the duration of the second stage and to be modestly associated with spontaneous delivery. Cervical dilatation assessed with ultrasound at the same time was associated with the duration of labor but not with spontaneous delivery. Ultrasound assessments of fetal head position were neither associated with labor duration nor the mode of delivery. Ultrasound can be used to categorize women into low- and high-risk groups, but it cannot, reliably, define a subset of women needing operative delivery.

Acknowledgements

References

1. Allen VM, O'Connell CM, Baskett TF. Maternal and perinatal morbidity of caesarean delivery at full cervical dilatation compared with caesarean delivery in the first stage of labour. BJOG 2005;112:986-90.

2. Cheng YW, Shaffer BL, Bryant AS, Caughey AB. Length of the first stage of labor and associated perinatal outcomes in nulliparous women. Obstet Gynecol 2010;116:1127-35.

3. Gifford DS, Morton SC, Fiske M, Keesey J, Keeler E, Kahn KL. Lack of progress in labor as a reason for cesarean. Obstet Gynecol 2000;95:589-95.

4. Kjaergaard H, Olsen J, Ottesen B, Dykes AK. Incidence and outcomes of dystocia in the active phase of labor in term nulliparous women with spontaneous labor onset. Acta Obstet Gynecol Scand 2009;88:402-7.

5. Torkildsen EA, Salvesen KA, Eggebo TM. Prediction of delivery mode with transperineal ultrasound in women with prolonged first stage of labor. Ultrasound Obstet Gynecol 2011;37:702-8.

6. Peregrine E, O'Brien P, Omar R, Jauniaux E. Clinical and Ultrasound Parameters to Predict the Risk of Cesarean Delivery After Induction of Labor. Obstet Gynecol 2006;107.

7. Hernández-Martínez A, Pascual-Pedreño AI, Baño-Garnés AB, Melero-Jiménez MR, Tenías-Burillo JM, Molina-Alarcón M. Predictive model for risk of cesarean section in pregnant women after induction of labor. Arch Gynecol Obstet 2016;293:529-38.

8. Levine LD, Downes KL, Parry S, Elovitz MA, Sammel MD, Srinivas SK. A validated calculator to estimate risk of cesarean after an induction of labor with an unfavorable cervix. Am J Obstet Gynecol 2018;218:254.e1-54.e7.

9. Rane SM, Pandis GK, Guirgis RR, Higgins B, Nicolaides KH. Pre-induction sonographic measurement of cervical length in prolonged pregnancy: the effect of parity in the prediction of induction-to-delivery interval. Ultrasound Obstet Gynecol 2003;22:40-4.

10. de Souza HCC, Perdoná GSC, Marcolin AC, et al. Development of caesarean section prediction models: secondary analysis of a prospective cohort study in two sub-Saharan African countries. Reproductive Health 2019;16:165.

11.   Janssen PA, Stienen JJC, Brant R, Hanley GE. A Predictive Model for Cesarean Among Low-Risk Nulliparous Women in Spontaneous Labor at Hospital Admission. Birth 2017;44:21-28.

12.   Murphy K, Shah L, Cohen WR. Labor and delivery in nulliparous women who present with an unengaged fetal head. J Perinatol 1998;18:122-5.

13.   Dupuis O, Silveira R, Zentner A, et al. Birth simulator: reliability of transvaginal assessment of fetal head station as defined by the American College of Obstetricians and Gynecologists classification. Am J Obstet Gynecol 2005;192:868-74.

14.   Buchmann E, Libhaber E. Interobserver agreement in intrapartum estimation of fetal head station. Int J Gynaecol Obstet 2008;101:285-89.

15.   Chan YT, Ng KS, Yung WK, Lo TK, Lau WL, Leung WC. Is intrapartum translabial ultrasound examination painless? J Matern Fetal Neonatal Med 2016;29:3276-80.

16.   Sherer DM, Miodovnik M, Bradley KS, Langer O. Intrapartum fetal head position I: comparison between transvaginal digital examination and transabdominal ultrasound assessment during the active stage of labor. Ultrasound Obstet Gynecol 2002;19:258-63.

17.   Gardberg M, Laakkonen E, Salevaara M. Intrapartum sonography and persistent occiput posterior position: A study of 408 deliveries. Obstetrics and Gynecology 1998;91:746-49.

18.   Akmal S, Kametas N, Tsoi E, Hargreaves C, Nicolaides KH. Comparison of transvaginal digital examination with intrapartum sonography to determine fetal head position before instrumental delivery. Ultrasound in Obstetrics & Gynecology 2003;21:437-40.

19.   Ghi T, Eggebø T, Lees C, et al. ISUOG Practice Guidelines: intrapartum ultrasound. Ultrasound in Obstetrics & Gynecology 2018;52:128-39.

20.   Hjartardottir H, Lund SH, Benediktsdottir S, Geirsson RT, Eggebø TM. When does fetal head rotation occur in spontaneous labor at term: results of an ultrasound-based longitudinal study in nulliparous women. Am J Obstet Gynecol 2020.

21.   Hjartardóttir H, Lund SH, Benediktsdóttir S, Geirsson RT, Eggebø TM. Fetal descent in nulliparous women assessed by ultrasound: a longitudinal study. Am J Obstet Gynecol 2020.

22.   Eggebo TM, Heien C, Okland I, Gjessing LK, Romundstad P, Salvesen KA. Ultrasound assessment of fetal head-perineum distance before induction of labor. Ultrasound in Obstetrics & Gynecology 2008;32:199-204.

23.   Levy R, Zaks S, Ben-Arie A, Perlman S, Hagay Z, Vaisbuch E. Can angle of progression in pregnant women before onset of labor predict mode of delivery? 2012;40:332-37.

24. Eggebo TM, Gjessing LK, Heien C, et al. Prediction of labor and delivery by transperineal ultrasound in pregnancies with prelabor rupture of membranes at term. Ultrasound Obstet Gynecol 2006;27:387-91.

25. Eggebo TM, Wilhelm-Benartzi C, Hassan WA, Usman S, Salvesen KA, Lees CC. A model to predict vaginal delivery in nulliparous women based on maternal characteristics and intrapartum ultrasound. Am J Obstet Gynecol 2015;213:6.

26. Robson MS. Classification of caesarean sections. Fetal Matern Med Rev 2001;12:23-39.

27. World Health Organization. The Partograph : the application of the WHO partograph in the management of labour, report of a WHO multicentre study, 1990-1991*Safe Mother*, 1994.

28. Mathai M, Engelbrecht SM, Bonet M, Organisation mondiale de la s, Unicef. *Managing complications in pregnancy and childbirth : a guide for midwives and doctors.*2017; 94.

29. Akmal S, Tsoi E, Kametas N, Howard R, Nicolaides KH. Intrapartum sonography to determine fetal head position. J Matern Fetal Neonatal Med 2002;12:172-7.

30. Akmal S, Tsoi E, Howard R, Osei E, Nicolaides KH. Investigation of occiput posterior delivery by intrapartum sonography. Ultrasound Obstet Gynecol 2004;24:425-8.

31. Barbera AF, Pombar X, Perugino G, Lezotte DC, Hobbins JC. A new method to assess fetal head descent in labor with transperineal ultrasound. Ultrasound in Obstetrics & Gynecology 2009;33:313-19.

32. Kahrs BH, Usman S, Ghi T, et al. Sonographic prediction of outcome of vacuum deliveries: a multicenter, prospective cohort study. Am J Obstet Gynecol 2017;217:69.e1-69.e10.

33. Benediktsdottir S, Eggebo TM, Salvesen KA. Agreement between transperineal ultrasound measurements and digital examinations of cervical dilatation during labor. BMC Pregnancy Childbirth 2015;15:273.

34. Hassan WA, Eggebo TM, Ferguson M, Lees C. Simple two-dimensional ultrasound technique to assess intrapartum cervical dilatation: a pilot study. Ultrasound Obstet Gynecol 2013;41:413-8.

35. Wiafe YA, Whitehead B, Venables H, Dassah ET, Eggebø TM. Intrapartum ultrasound assessment of cervical dilatation and its value in detecting active labor. J Ultrasound 2018;21:233-39.

36. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing

translational research informatics support. Journal of Biomedical Informatics 2009;42:377-81.

37.   Abitbol MM, Bowen-Ericksen M, Castillo I, Pushchin A. Prediction of difficult vaginal birth and of cesarean section for cephalopelvic disproportion in early labor. The Journal of Maternal-Fetal Medicine 1999;8:51-56.

38.   Wilkes PT, Wolf DM, Kronbach DW, Kunze M, Gibbs RS. Risk factors for cesarean delivery at presentation of nulliparous patients in labor. Obstet Gynecol 2003;102:1352-57.

39.   Turcot L, Marcoux S, Fraser WD. Multivariate analysis of risk factors for operative delivery in nulliparous women. Am J Obstet Gynecol 1997;176:395-402.

40.   Marsoosi V, Pirjani R, Mansouri B, et al. Role of 'angle of progression' in prediction of delivery mode. 2015;41:1693-99.

41.   Chan YTV, Ng VKS, Yung WK, Lo TK, Leung WC, Lau WL. Relationship between intrapartum transperineal ultrasound measurement of angle of progression and head–perineum distance with correlation to conventional clinical parameters of labor progress and time to delivery. The Journal of Maternal-Fetal & Neonatal Medicine 2015;28:1476-81.

42.   Chor CM, Poon LCY, Leung TY. Prediction of labor outcome using serial transperineal ultrasound in the first stage of labor. The Journal of Maternal-Fetal & Neonatal Medicine 2019;32:31-37.

43.   Eggebo TM, Hassan WA, Salvesen KA, Torkildsen EA, Ostborg TB, Lees CC. Prediction of delivery mode by ultrasound-assessed fetal position in nulliparous women with prolonged first stage of labor. Ultrasound Obstet Gynecol 2015;46:606-10.

44.   Tutschek B, Torkildsen EA, Eggebo TM. Comparison between ultrasound parameters and clinical examination to assess fetal head station in labor. Ultrasound Obstet Gynecol 2013;41:425-9.

45.   Tutschek B, Braun T, Chantraine F, Henrich W. A study of progress of labour using intrapartum translabial ultrasound, assessing head station, direction, and angle of descent. BJOG 2011;118:62-9.

46.   Ghi T, Contro E, Farina A, Nobile M, Pilu G. Three-dimensional ultrasound in monitoring progression of labor: a reproducibility study. Ultrasound Obstet Gynecol 2010;36:500-06.

47.   Molina FS, Terra R, Carrillo MP, Puertas A, Nicolaides KH. What is the most reliable ultrasound parameter for assessment of fetal head descent? Ultrasound Obstet Gynecol 2010;36:493-9.

48.   Eggebø TM, Hassan WA, Salvesen KÅ, Lindtjørn E, Lees CC. Sonographic prediction of vaginal delivery in prolonged labor: a two-center study. Ultrasound Obstet Gynecol 2014;43:195-201.

49.   Souka AP, Haritos T, Basayiannis K, Noikokyri N, Antsaklis A. Intrapartum ultrasound for the examination of the fetal head position in normal and obstructed labor. J Matern Fetal Neonatal Med 2003;13:59-63.

50.   Melmed H, Evans M. Predictive value of cervical dilatation rates. I. Primipara labor. Obstet Gynecol 1976;47:511-5.

51.   World Health Organization. *WHO recommendations: intrapartum care for a positive childbirth experience.* Geneva, Switzerland:2018 World Health Organization;

Legends for tables and figures.

Legend for Table 1:

Characteristics of the study population of 99 nulliparous women with a singleton fetus at term, examined with ultrasound early in the active phase of labor.

Characteristics	Median (range) or n (%)
Age	27.0 (18-40)
Body mass index (kg/m^2)	23.3 (16.7-36.3)
Oxytocin augmentation	41 (41.4)
Epidural analgesia	61 (61.6)
Spontaneous delivery	75 (75.8)
Ventouse delivery	15 (15.2)

Forceps delivery	1 (1.0)	
Cesarean section	8 (8.1)	
Blood loss (ml)	400 (100-2000)	
Episiotomy	13 (13.3)	
Degrees of perineal tear		
None	19 (19.2)	
1°	22 (22.2)	
2°	53 (53.5)	
3°	5 (5.1)	
Birthweight (g)	3540 (2480-5000)	
Apgar score at 1 min	9 (2-10)	
Apgar score at 5 min	10 (5-10)	
Gestational age (days)	280 (259-293)	

Legend for Table 2:

Test characteristics of ultrasound measurements of head-perineum distance and angle of progression in predicting spontaneous vaginal delivery

	Sensitivity	FPR	PPV	NPV	PLR	NLR
Head-perineum distance (mm)						
≤40	0.33 (0.23, 0.45)	0.12 (0.03, 0.32)	0.89 (0.72, 0.98)	0.30 (0.19, 0.42)	2.67	0.76
≤46	0.67 (0.45, 0.84)	0.33 (0.16, 0.55)	0.87 (0.75, 0.94)	0.41 (0.26, 0.58)	2.08	0.46
≤50	0.80 (0.69, 0.88)	0.75 (0.53, 0.90)	0.77 (0.66, 0.86)	0.29 (0.11, 0.52)	1.07	0.80

≤60	0.97 (0.91, 1.00)	0.95 (0.79, 1.00)	0.76 (0.66, 0.84)	0.33 (0.01, 0.91)	1.02	0.64

Angle of progression (°)

≥110	0.24 (0.15, 0.35)	0.04 (0.00, 0.21)	0.95 (0.74, 1.00)	0.29 (0.19, 0.40)	5.76	0.79
≥100	0.57 (0.45, 0.69)	0.33 (0.16, 0.55)	0.84 (0.71, 0.93)	0.33 (0.20, 0.48)	1.72	0.64
≥93	0.79 (0.68, 0.87)	0.54 (0.33, 0.74)	0.82 (0.71, 0.90)	0.41 (0.22, 0.61)	1.45	0.47
≥90	0.87 (0.77, 0.93)	0.71 (0.49, 0.87)	0.79 (0.69, 0.87)	0.41 (0.18, 0.67)	1.22	0.46
≥80	1.00 (0.95, 1.00)	0.88 (0.68, 0.97)	0.78 (0.69, 0.86)	1.00 (0.29, 1.00)	1.14	0.00

FPR, false-positive rate; PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio

Legend for Table 3:

Cox regression analysis for risk ("likelihood") of a spontaneous delivery in nulliparous women examined at the diagnosis of the active phase of labor

Parameter	Unadjusted HR	95% CI	Adjusted HR	95% CI
Active phase				
Non-occiput posterior	1.51	0.96-2.38	1.54	0.97-2.46
HPD ≤45 mm	**1.90**	**1.16-3.11**	1.47	0.83-2.60
AoP ≥93°	**2.06**	**1.19-3.56**	**2.07**	**1.15-3.72**
Cervical dilatation examined with ultrasound ≥ 6 cm	**2.45**	**1.38-4.36**	**3.11**	**1.68-5.77**

Second stage

|				
Non-occiput posterior	1.40	0.89-2.21	1.43	0.89-2.29
HPD ≤45 mm	1.61	0.97-2.64	1.50	0.85-2.65
AoP ≥93°	**1.76**	**1.02-3.04**	1.59	0.88-2.88
Cervical dilatation examined with ultrasound ≥ 6 cm	1.57	0.91-2.70	1.76	0.98-3.16
Active second stage				
Non-occiput posterior	1.45	0.92-2.28	1.54	0.97-2.46
HPD ≤45 mm	1.55	0.94-2.55	1.52	0.87-2.65
AoP ≥93°	**1.86**	**1.05-3.32**	**1.97**	**1.06-3.68**
Cervical dilatation examined with ultrasound ≥ 6 cm	1.43	0.83-2.47	1.50	0.84-2.68

HR with CI not crossing 1.0 were assumed significant

CI, confidence interval; HR, hazard ratio; HPD, head-perineum distance; AoP, angle of progression
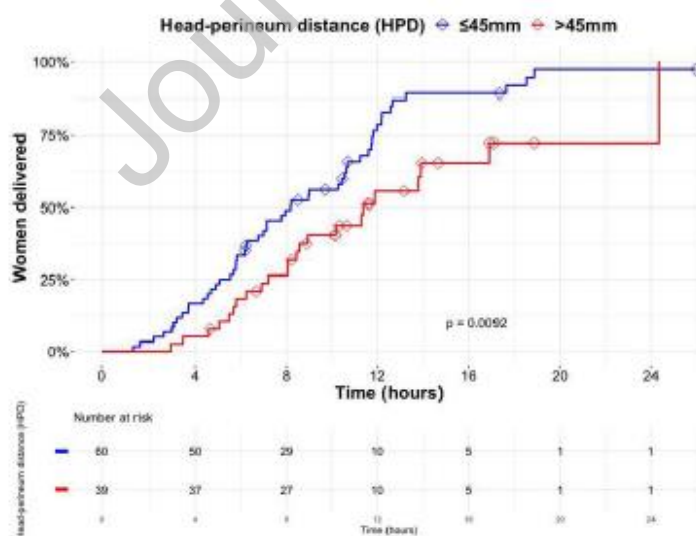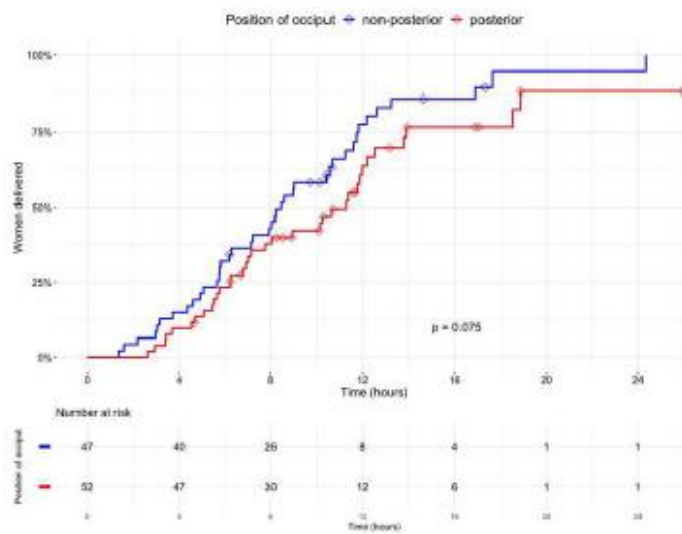
Legend for Figure 1:

Receiver-operating characteristic (ROC) curves for angle of progression and head-perineum distance measurements in the prediction of spontaneous vaginal delivery in nulliparous women on admission in active spontaneous labor at term.
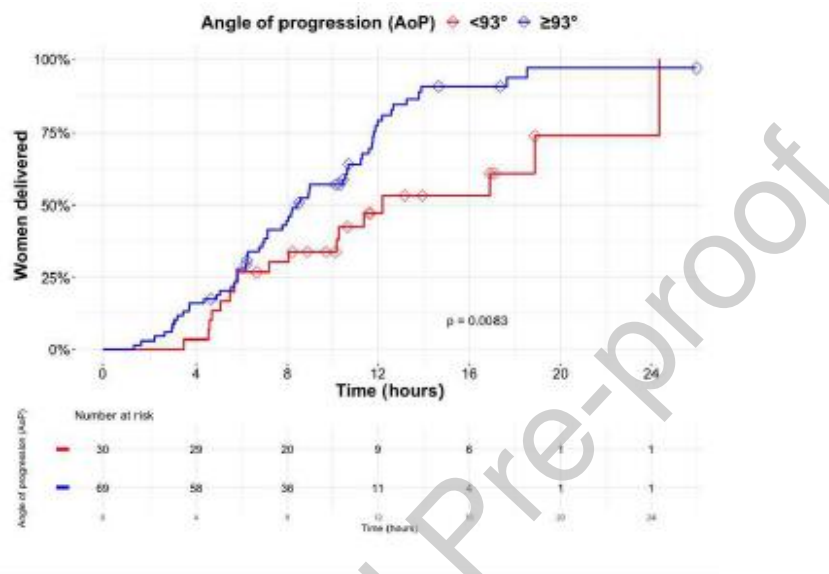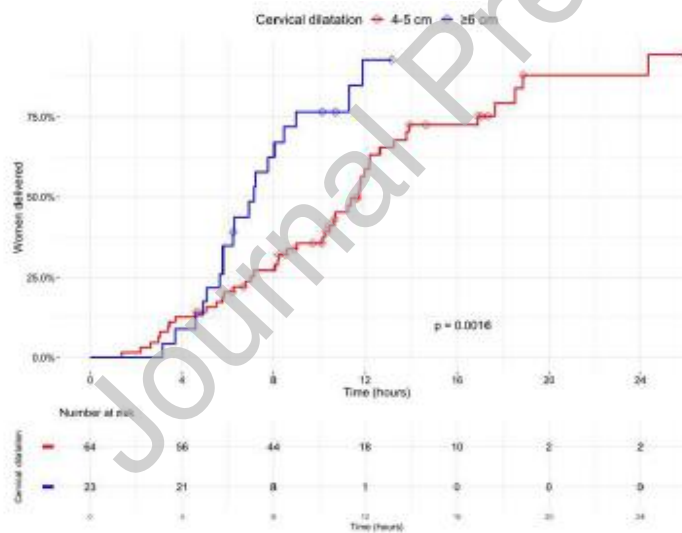

Legend for Figure 2:

Kaplan-Meier curves of time from the first examination in the active phase to delivery in 99 nulliparous women in spontaneous labor. The curves are stratified as to head-perineum distance ≤45mm and >45mm. Cases with operative delivery were censored (diamonds on survival lines).
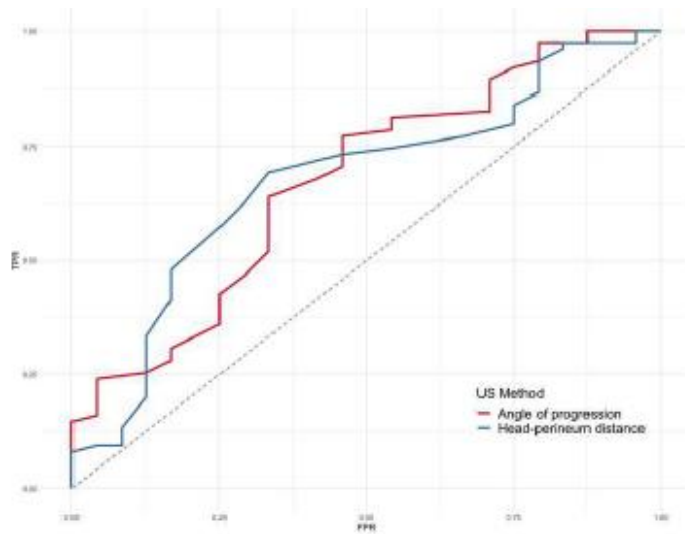
Legend for Figure 3:

Kaplan-Meier curves of time from the first examination in the active phase to delivery in 99 nulliparous women in spontaneous labor. The curves are stratified as to angle of progression ≥93° and <93. Cases with operative delivery were censored (diamonds on survival lines).

Legend for Figure 4

Kaplan-Meier curves of time from the first examination in the active phase to delivery in 99 nulliparous women in spontaneous labor. The curves are stratified as to non-occiput posterior and occiput posterior positions. Cases with operative delivery were censored (diamonds on survival lines).

30

Legend for Figure 5

Kaplan-Meier curves of time from the first examination in the active phase to delivery in 99 nulliparous women in spontaneous labor. The curves are stratified as to ultrasound assessed cervical dilatation of 4-5 cm and ≥6 cm. Cases with operative delivery were censored (diamonds on survival lines).