OBSTETRICS

Fetal descent in nulliparous women assessed by ultrasound: a longitudinal study

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Hulda Hjartardóttir, MD; Sigrún H. Lund, PhD; Sigurlaug Benediktsdóttir, MD; Reynir T. Geirsson, MD, PhD; Torbjørn M. Eggebø, MD, PhD

BACKGROUND: Ultrasound measurements offer objective and reproducible methods to measure the fetal head station. Before these methods can be applied to assess labor progression, the fetal head descent needs to be evaluated longitudinally in well-defined populations and compared with the existing data derived from clinical examinations.

OBJECTIVE: This study aimed to use ultrasound measurements to describe the fetal head descent longitudinally as labor progressed through the active phase in nulliparous women with spontaneous onset of labor.

STUDY DESIGN: This was a single center, prospective cohort study at the Landspitali - The National University Hospital of Iceland, Reykjavik, Iceland, from January 2016 to April 2018. Nulliparous women with a single fetus in cephalic presentation and spontaneous labor onset at a gestational age of ≥37 weeks, were eligible. Participant inclusion occurred during admission for women with an established active phase of labor or at the start of the active phase for women admitted during the latent phase. The active phase was defined as an effaced cervix dilated to at least 4 cm in women with regular contractions. According to the clinical protocol, vaginal examinations were done at entry and subsequently throughout labor, paired each time with a transperineal ultrasound examination by a separate examiner, with both examiners being blinded to the other's results. The measurements used to assess the fetal head station were the head-perineum distance and angle of progression. Cervical dilatation was examined clinically.

RESULTS: The study population comprised 99 women. The labor patterns for the head-perineum distance, angle of progression, and cervical dilatation differentiated the participants into 75 with spontaneous deliveries, 16 with instrumental vaginal deliveries, and 8 cesarean deliveries. At the inclusion stage, the cervix was dilated 4 cm in 26 of the women, 5 cm in 30 of the women, and ≥6 cm in 43 women. One cesarean and 1 ventouse delivery were performed for fetal distress, whereas the remaining cesarean deliveries were conducted because of a failure to progress. The total number of examinations conducted throughout the study was 345, with an average of 3.6 per woman. The ultrasound-measured fetal head station both at the first and last examination were associated with the delivery mode and remaining time of labor. In spontaneous deliveries, rapid head descent started around 4 hours before birth, the descent being more gradual in instrumental deliveries and absent in cesarean deliveries. A head-perineum distance of 30 mm and angle of progression of 125° separately predicted delivery within 3.0 hours (95% confidence interval, 2.5—3.8 hours and 2.4—3.7 hours, respectively) in women delivering vaginally. Although the head-perineum distance and angle of progression are independent methods, both methods gave similar mirror image patterns. The fetal head station at the first examination was highest for the fetuses in occiput posterior position, but the pattern of rapid descent was similar for all initial positions in spontaneously delivering women. Oxytocin augmentation was used in 41% of women; in these labors a slower descent was noted. Descent was only slightly slower in the 62% of women who received epidural analgesia. A nonlinear relationship was observed between the fetal head station and dilatation.

CONCLUSION: We have established the ultrasound-measured descent patterns for nulliparous women in spontaneous labor. The patterns resemble previously published patterns based on clinical vaginal examinations. The ultrasound-measured fetal head station was associated with the delivery mode and remaining time of labor.

Key words: angle of progression, cesarean delivery, fetal head position, fetal head station, head-perineum distance, transabdominal ultrasound, transperineal ultrasound

Introduction

Proper descent of the fetal head during labor is a prerequisite for vaginal delivery. How this process is followed and assessed, is fraught with difficulty because the landmarks on the fetal head and in the pelvis can be hard to identify. Clinical vaginal examination is prone to considerable subjectivity by the individual examiner. The spinal plane is not an actual anatomic plane in the pelvis, but an imaginary plane with only 2 anatomic reference points, the ischial spines,[1] which are, moreover, not in the pelvic midline where the station of the fetal head is gauged. The leading bony reference point on the fetal head should be easier to identify, but the presence of molding and caput succedaneum can make the examiner erroneously consider the head to have descended to a lower level than actually true. Therefore, other methods of assessment have been suggested.[2–5]

Knowledge of fetal head descent during labor comes mainly from the classic series of studies by Friedman and coworkers in 1965,[6–8] describing the patterns of descent based on clinical, digital estimations of the fetal head station in the pelvic cavity. This work was essential for the World Health Organization (WHO) partograph and the WHO has recommended the partograph, until 2018, with an alert line of 1 cm cervical dilatation per hour and an action line displaced by 4 hours as suggested by Philpott et al.[9–12]

Cite this article as: Hjartardóttir H, Lund SH, Benediktsdóttir S, et al. Fetal descent in nulliparous women assessed by ultrasound: a longitudinal study. Am J Obstet Gynecol 2021;224:378.e1-15.

0002-9378/$36.00

https://doi.org/10.1016/j.ajog.2020.10.004

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AJOG at a Glance

Why was this study conducted?

The clinical methods used for assessing the fetal head station are subjective and have limited accuracy. Ultrasound measurement is an objective means for assessing the fetal head station. This study therefore aimed to describe the fetal head descent in nulliparous women with spontaneous labor onset.

Key findings

The ultrasound-assessed fetal head stations at both the first and last examination were significantly associated with the delivery mode. Both a head-perineum distance of 30 mm and an angle of progression of 125° independently predicted delivery within 3.0 hours (95% confidence interval, 2.5—3.8 and 2.4—3.7 hours, respectively). The fetal head station remained unchanged early during the active phase of labor but showed a pattern of rapid descent during the last 4 hours of labor, regardless of the initial cervical dilatation or occiput position.

What does this add to what is known?

The ultrasound patterns for fetal head descent in nulliparous women were described. The head-perineum distance and angle of progression predicted the remaining time to delivery. The longitudinally measured head-perineum distance and angle of progression independently produced similar labor patterns.

There has been a renewed focus on the progression of labor in recent years, revisiting the classic Friedman cervix dilatation and descent curves[13—16] in the light of changes in obstetrical practices and populations.[17—20] Less attention has been paid to the descent of the fetal head than to cervical dilatation, although this was an integral part of the labor curves presented by Friedman and his coworkers.[13,14,17—20] The fetal head station and position remain the qualities by which progress during the second stage of labor are judged. Recent clinical studies of fetal head descent have been conducted to compute mathematical models relating cervical dilatation to the fetal head station.[21—23] The patterns of descent from these studies were obtained and described using the accepted clinical methods. Ultrasound measurements have been suggested to be a more objective and accurate method for assessing the fetal head station and as having the potential to replace clinical methods.[23—40] This study aimed to use ultrasound measurement methods to describe fetal head descent longitudinally throughout the active phase of labor in nulliparous women with a spontaneous onset of labor at term.

Materials and Methods

We performed a prospective cohort study at the Landspitali - The National University Hospital of Iceland, Reykjavík, Iceland, from January 2016 to April 2018. The study population comprised 100 nulliparous women with spontaneous onset of labor, a single fetus in the cephalic presentation, and a gestational length of ≥37 weeks who were included nonconsecutively. The study population corresponded to the definition of group 1 in the Robson 10-group classification system.[41] One woman withdrew her consent and was excluded. All the women received oral and written information about the study on admission to the labor ward and written consent was obtained before inclusion. Inclusion occurred on admission for women with an established active phase of labor or at the start of the active phase for women admitted during the latent phase of labor. An active phase was defined at the time of recruitment as a fully effaced cervix, dilated to at least 4 cm, in the presence of regular contractions in accordance with the actual WHO recommendations.[9,10] All examinations were performed as paired clinical and ultrasound examinations throughout labor. Two obstetricians trained in transperineal scanning conducted the ultrasound examinations shortly before or after the clinical assessments (within 15 minutes). Cervical dilatation was examined clinically. The ultrasound examiners and clinical staff were blinded to each other's results. The ultrasound examiners were not involved in the clinical decisions during the labors.

The midwife caring for each woman performed a clinical examination at recruitment and thereafter as clinically indicated in accordance with the local hospital guidelines that recommended vaginal examinations at least every 4 hours. If the cervical dilatation was not satisfactory, defined as crossing the WHO partogram action line, the first option to augment labor progression was to rupture the membranes in case they were intact, with subsequent reassessment after 2 hours. Following a diagnosis of slow progression with ruptured membranes, a low-dose oxytocin infusion was used with subsequent reassessment after 4 hours. With no change in cervical dilatation after a period of 4 hours with adequate contractions, cesarean delivery was considered. An examination was also performed if the woman felt the urge to push, or at the midwife's discretion. No upper limit for the duration of the active phase existed at the hospital, but the duration of the second stage of labor for a nullipara should not be longer than 4 hours with or 3 hours without epidural analgesia. The active pushing phase should not be longer than 2 hours. Signs of fetal distress on cardiotocography monitoring were investigated further with fetal scalp pH or lactate samples.

During each examination, the midwife judged the cervical dilatation in centimeters and the fetal head station using the scale of −5 to +5 cm above and below the ischial spines. All the ultrasound examinations were performed by 2 experienced ultrasound examiners (H.H. and S.B.), and the findings were recorded on a separate sheet of paper. A GE Voluson i ultrasound machine (GE Medical Systems, Zipf, Austria) with a 3.5 to 7.5 MHz 3D curved multifrequency transabdominal transducer was used for both the transabdominal and transperineal scans.

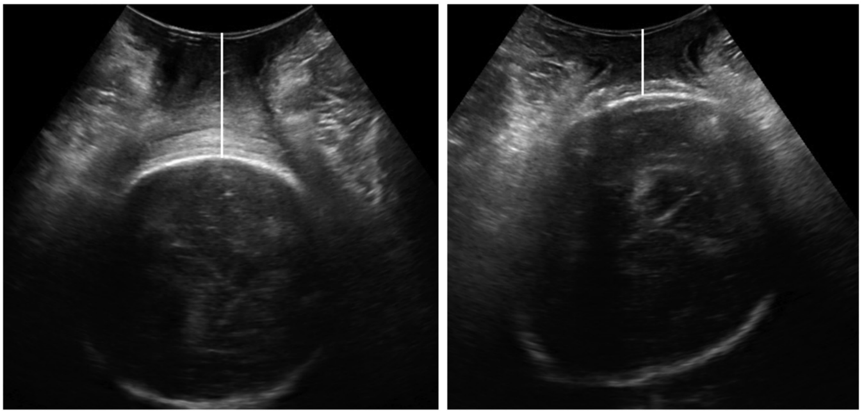
The fetal head descent was assessed by a transperineal ultrasound. The measurements obtained were the head-perineum distance (HPD) and angle of progression (AoP). The HPD was measured in the frontal plane (transverse plane related to the perineum) as the shortest distance from the transducer to the fetal skull (Figure 1, Video 1). The soft tissue was compressed with the transducer until it met resistance against the pubic bone.[28,42] The AoP was measured in the sagittal plane as the angle between the longitudinal axis of the pubic symphysis and a line from the inferior edge of the symphysis tangentially to the fetal head contour (Figure 2, Video 2).[43]

The fetal head position was determined using both the transabdominal and the transperineal approach. The transabdominal examination was preferred whenever reference structures could be visualized. The position of the occiput was marked on a clockface-like graph with half-hourly markings. The fetal head position was categorized as occiput anterior (OA; $\geq$10 and $\leq$2 o'clock), left occiput transverse (LOT; >2 and <4 o'clock), occiput posterior (OP; $\geq$4 and $\leq$8 o'clock), and right occiput transverse (ROT; >8 and <10 o'clock) positions, as described previously by Akmal et al.[44,45] The fetal spine, orbits, midline structures, and choroid plexus were used to determine the position. The epidural analgesia used at the hospital consisted of intermittent doses of 2.5 mg/mL bupivacaine and 5μg/mL sufentanil.

The main objective of this study was to describe the labor patterns for HPD and AoP in nulliparous women and investigate whether these differed by the delivery mode. Furthermore, this study aimed to build prediction models to estimate the time to delivery by HPD and AoP for women who deliver vaginally.

All ultrasound measurements were done online in the labor room and stored on the ultrasound device. The results and summaries of the outcome of the labors were later transferred into a database using the REDCap electronic data capture tools hosted at the hospital.[46] The study was approved by the Landspitali Ethics Committee under-reference number 26/2015.

FIGURE 1
Measurement of the head-perineum distance



Transverse transperineal images (frontal plane related to woman) illustrating the measurement of the head-perineum distance (41 mm in the left image and 21 mm in the right image).

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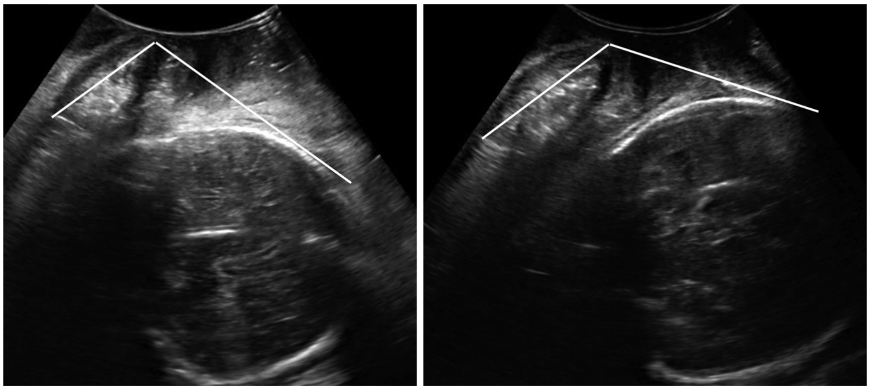
Statistical analysis

To establish the labor patterns, the time of delivery was used as a fixed reference point. From that point, the time was calculated backward. Labor curves, with the 95% confidence intervals (CIs) shaded, were constructed with a fourth degree polynomial model for each of the measurement variables, namely cervical dilatation, HPD, and AoP for the whole group, and also according to the delivery mode, namely spontaneous delivery, instrumental deliver, and cesarean delivery. For spontaneous deliveries, the labor curves were constructed according to both epidural use and oxytocin augmentation and stratified by the fetal head position and cervical dilatation at the first examination. We compared the HPD and AoP measurements to the cervical dilatation and time remaining to delivery for women delivering vaginally using a mixed effects model. For descriptive purposes we used an HPD measurement of 36 mm and an AoP of

FIGURE 2
Measurement of the angle of progression



Sagittal transperineal images illustrating the measurement of the angle of progression (110 degrees in the left image and 130 degrees in the right image).

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TABLE 1
Characteristics of the study population

Maternal characteristics	Cesarean delivery (n=8)	Instrumental delivery (n=16)	Spontaneous delivery (n=75)
Maternal age, y	31 (24—40)	28 (20—38)	26 (18—38)
BMI at first visit, kg/m^2	26 (23—36)	25 (17—35)	22 (17—36)
Gestational age, wk	40.5 (37.3—41.6)	40.5 (38—41.7)	39.9 (37—41.9)
Labor characteristics			
Oxytocin augmentation	7 (88)	12 (75)	22 (29)
Epidural analgesia	7 (88)	11 (69)	43 (57)
Length of labor, h	12.8 (8.9—26)	10.2 (4.7—18.9)	7.8 (1.4—24.3)
Newborn characteristics			
Birthweight, g	3790 (3200—4310)	3890 (2750—4540)	3520 (2480—5000)
Apgar score at 1 min	8.5 (5—10)	8 (2—9)	9 (2—10)
Apgar score at 5 min	10 (9—10)	9 (8—10)	10 (5—10)

Data are presented as median (range) or number (percentage).

BMI, body mass index.

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116° as representing the midpelvic or spinal plane based on previously published studies.[47,48] The Shapiro-Wilk test for normality was used for the AoP and HPD measurements. The AoP measurements were not normally distributed, and therefore we estimated the differences in the median cervical dilatation, AoP, and HPD by the mode of delivery with the Kruskal-Wallis test. The correlation between HPD and AoP was estimated from a Spearman's correlation coefficient and also the correlation between the clinical fetal head station and the HPD and AoP, respectively.

The data were analyzed with the statistical software package R Core Team (The R Foundation, Vienna, Austria) (2018; https://www.R-project.org/).

Results

Study population

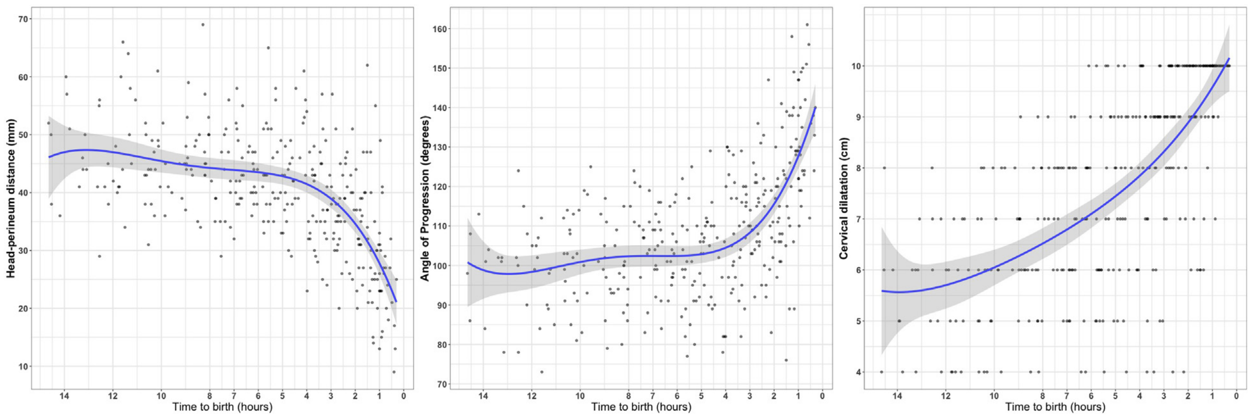
The final study population comprised 99 women: 75 had a spontaneous delivery, 15 delivered with vacuum extraction, 1 with forceps, and 8 with a cesarean delivery. At inclusion, the cervix was dilated to 4 cm for 26 women, 5 cm for 30 women, and ≥6 cm for 43 women. The characteristics of the study population, classified according to the delivery mode, are given in Table 1. The mean duration of the active phase of labor for women with spontaneous delivery was 8.4 (95% CI, 7.3—9.4) hours, 10.5 (95% CI, 8.3—12.7) hours for instrumental deliveries, and 14.3 (95% CI, 9.7—18.8) hours for the cases ending with a cesarean delivery. A total of 345 paired examinations were done, varying from 1 to 8 examinations for each woman depending on the length of labor, with an average of 3.6 examinations for each woman. Two women were only examined once, 97 women were examined at least twice, 66 women were examined 3 times, 49 women were examined 4 times, 24 women were examined 5 times, 15 women were examined 6 times, and 3 women had 8 examinations. Six cesarean deliveries were performed owing to an arrest of cervical dilatation, 1 for arrest of descent during the second stage of labor, and 1 for fetal distress during the second stage of labor (after a prolonged first stage). Details of these labors are given in Supplemental Table 1. One ventouse delivery was performed owing to fetal distress, whereas the other instrumental deliveries were all performed after a prolonged second stage of labor or arrest of descent.

Labor patterns

Figure 3 is a scatterplot illustrating the variation and mean change in the HPD, AoP, and cervical dilatation from inclusion to delivery. Figure 4 shows the pattern of descent for the same data that were classified according to the mode of delivery into spontaneous, instrumental, and cesarean deliveries. The patterns of descent show that on average the fetal head was stationed above the midpelvic plane, which is >36 mm for HPD and <116° for AoP during the early stages of the active phase, but began to descend just before full cervical dilatation was reached. In spontaneous deliveries we observed a steep and continuous descent represented by decreasing HPD measurements and increasing AoP measurements. The descent began on average at a cervical dilatation of 7 cm, around 6 hours before birth, and became more accelerated at a cervical dilatation of around 8 cm, 4 hours before birth. A more gradual descent was seen in the labor curves for instrumental vaginal deliveries and virtually no descent in the cases ending with cesarean delivery. Individual descent curves for women with a spontaneous delivery are shown in Supplemental Figure 1 and illustrate the large individual variation.

The pattern of clinically-assessed cervical dilatation shows a linear slope

FIGURE 3
Labor curves of descent using ultrasound and dilatation assessed clinically



Labor curves showing the fetal head station measured with ultrasound as the head-perineum distance measured in millimeters (left image), angle of progression measured in degrees (middle image), and cervical dilatation assessed clinically in centimeters (right image) over time in nulliparous women with spontaneous onset of labor. The birth is at 0 hours and the time from birth was calculated backward. The 95% confidence intervals are shaded.

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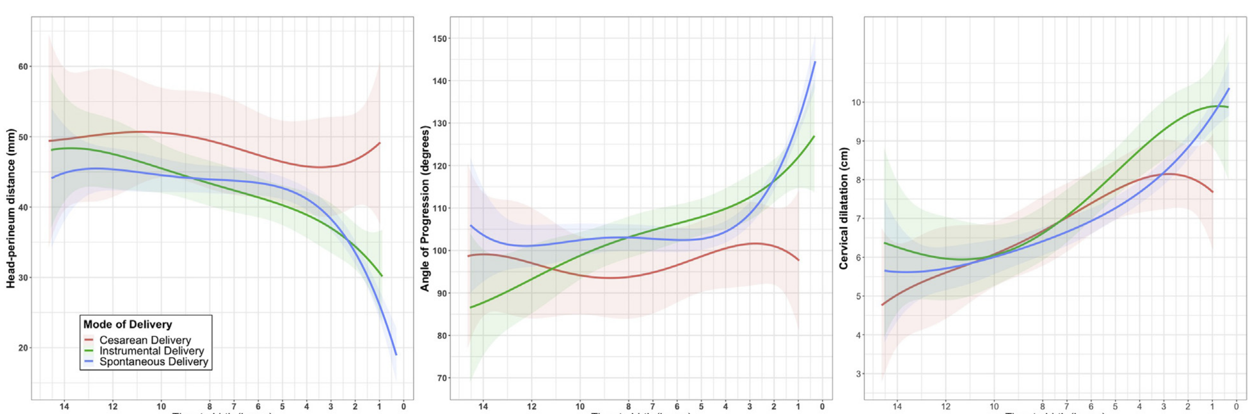
which was steepest for spontaneous deliveries and slightly less steep in the cases ending with instrumental vaginal deliveries (Figure 4). A similar slope tapering off and then stopping at a mean of 8 cm cervical dilatation, around 4 hours before delivery, was seen in the cases ending with a cesarean delivery. Individual dilatation curves are shown in Supplemental Figure 1.

Both the HPD and AoP measurements at the first and last examination showed a higher fetal head station at the first and last measurement in women ending with an operative delivery, and this was even more pronounced in women needing a cesarean delivery (Table 2). Mixed effects models comparing the cervical dilatation and the fetal head station measurements on the basis of the HPD and AoP in women delivering vaginally showed that the relationship was not linear and that a second degree model had a better fit (P value for comparisons of first and second degree models was <.001). At a cervical dilatation of 8 cm, the prediction for the HPD measurement was 40 mm (95% CI, 39–42) and for the AoP it was 106° (95% CI, 104–108). At full cervical

FIGURE 4
Labor curves of descent and dilatation by mode of delivery



Labor curves showing the fetal head station measured with ultrasound as the head-perineum distance measured in millimeters (left image), angle of progression measured in degrees (middle image), and cervical dilatation assessed clinically in centimeters (right image) over time in nulliparous women with spontaneous onset of labor, stratified by mode of delivery. The birth is at 0 hours and time from the birth was calculated backward. The 95% confidence intervals are shaded.

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TABLE 2
Cervical dilatation and ultrasound measurements of fetal head station at first and last examination differentiated into mode of delivery

Measurements at first examination	Cesarean delivery (n=8)	Instrumental delivery (n=16)	Spontaneous delivery (n=75)	*P* value
Cervical dilation, cm	5 (4–7)	5 (4–8)	5 (4–10)	.48
Angle of progression, degrees	88 (73–105)	95 (78–112)	102 (81–128)	.01
Head-perineum distance, mm	56 (34–66)	47 (35–57)	43 (24–64)	.02
Measurements at last examination				
Cervical dilation, cm	8 (6–10)	10 (5–10)	10 (5–10)	.01
Angle of progression, degrees	104 (76–123)	114 (99–155)	123 (82–161)	.01
Head-perineum distance, mm	47 (33–62)	36 (14–51)	30 (9–57)	.001

Data are presented as median (range).

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dilatation this model predicted the HPD to be 29 mm (95% CI, 28–31) and the AoP to be 126° (95% CI, 124–129) (Supplemental Table 2).

A prediction of time remaining to delivery based on the HPD and AoP values using mixed effect models showed that for women delivering vaginally, an HPD measurement of 40 mm predicted delivery in 5.5. hours (95% CI, 5.1–6.1 hours) and for an AoP of 110° the corresponding values were 5.2 hours (95% CI, 4.7–5.7 hours). An HPD of 30 mm and AoP of 125° both predicted delivery within 3.0 hours (95% CI for HPD, 2.5–3.8; 95% CI for AoP, 2.4–3.7 hours). Detailed information is shown in Table 3.

Figure 5 illustrates the HPD and AoP descent curves differentiated by the ultrasound-assessed fetal positions at the first measurement in the women who delivered spontaneously. The fetal head station was highest for fetuses in an OP position. The pattern of rapid descent was similar for all the positions and seemed to occur around 4 hours before birth. Oxytocin augmentation was used in 41% of women and these women had a slower descent (Figure 6). Figure 7 shows the HPD and AoP descent patterns for women who received epidural analgesia. Descent was only slightly slower in the 62% of women who received epidural analgesia. The descent patterns for women included with 4 to 5 cm cervical dilatation were not different compared with those included at a more advanced cervical dilatation (Figure 8).

TABLE 3
Predicted time to delivery according to the head-perineum distance and angle of progression in women delivering vaginally

Head-perineum distance (mm)	Predicted time to delivery (h)	95% confidence interval (h)
60	10.5	9.4–11.6
50	8.0	7.3–8.8
40	5.5	5.1–6.1
30	3.0	2.5–3.8
20	0.6	0.0–1.6
Angle of progression (°)		
80	9.5	8.7–10.4
95	7.4	6.7–8.0
110	5.2	4.7–5.7
125	3.0	2.4–3.7
140	0.8	0.0–1.8

Data are presented as number or median (range).

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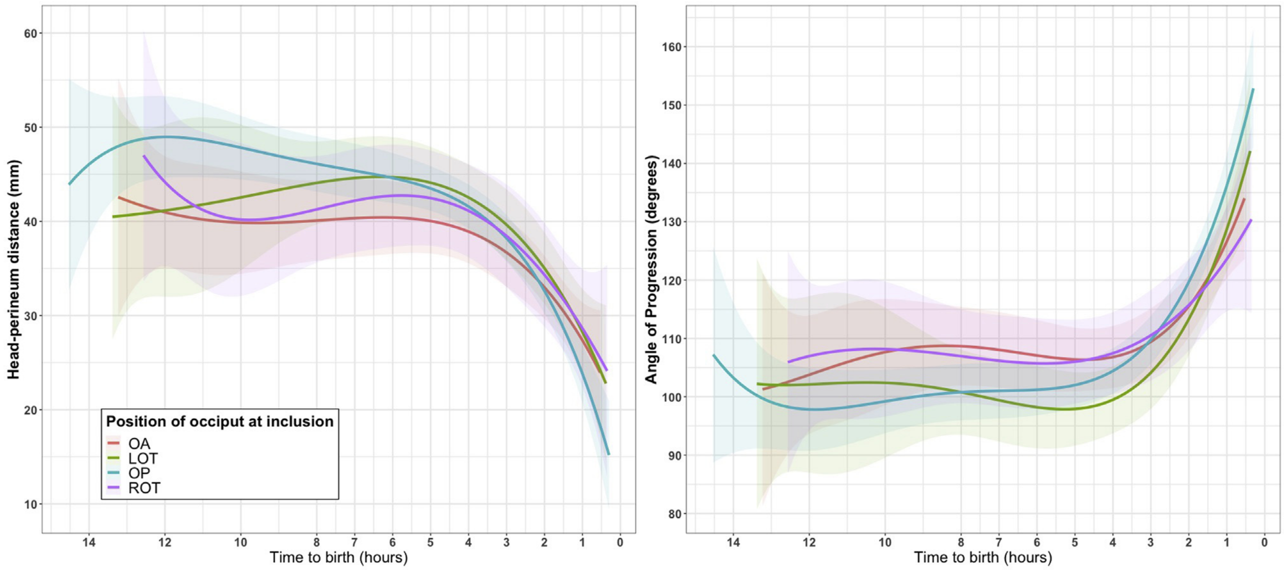
The HPD and AoP are independent methods but are correlated ($r = -0.80$; $P<.001$) and gave similar mirror image patterns. The correlation between the clinically-assessed fetal head station and the HPD was $r=-0.75$; $P<.001$ and between the fetal head station and the AoP was $r=0.75$; $P<.001$. The association between the clinically-assessed fetal head station and ultrasound measurements is shown in Supplemental Figure 2.

Comment

Principal findings

The results of this study described longitudinally assessed fetal head descent using ultrasound measurements among nulliparous women in spontaneous labor. We were able to create curves for the fetal head descent, stratified by mode of delivery, and for spontaneous deliveries we created curves stratified by both the

FIGURE 5
Labor curves of head descent stratified by occiput position at inclusion



Labor curves showing patterns of fetal head station measured with ultrasound as the head-perineum distance measured in millimeters (left image) and angle of progression measured in degrees (right image) over time in nulliparous women with spontaneous onset of labor at term and also delivering spontaneously, stratified by the fetal occiput position at inclusion. The birth is at 0 hours and time from the birth was calculated backward. The 95% confidence intervals are shaded.

LOT, left occiput transverse; *OA*, occiput anterior; *OP*, occiput posterior; *ROT*, right occiput transverse.

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occiput position and cervical dilatation at inclusion, and for epidural use and oxytocin augmentation. We found a significant association between the measured AoP and HPD at the first and last examination and the mode of delivery. The AoP and HPD measurements could be used to predict the time to vaginal delivery and we have related them to the degree of cervical dilatation. These results confirm the feasibility of following fetal head descent during labor by ultrasound.

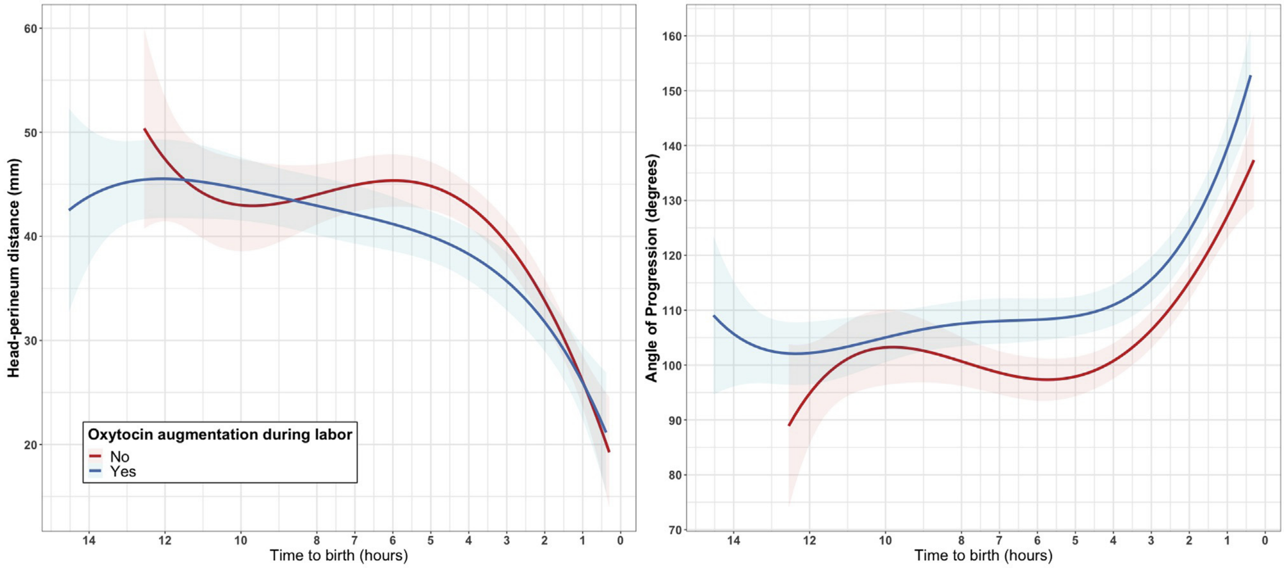
Clinical significance

Reducing the number of vaginal examinations during labor is important, both because of the discomfort and pain associated with them and to reduce the risk of infection.[49,50] Compared with clinical vaginal examinations, measuring the HPD and AoP is easy, noninvasive, and causes little discomfort, as confirmed by acceptability studies.[51–54] Ultrasound images can be stored and used as an objective documentation. The idea of a sonopartogram has already been advanced.[55] Being able to predict both the outcome of labor and the time remaining in labor is important for both the woman in labor and her care provider. By describing the labor patterns for the AoP and HPD, and their associations with the mode of delivery, time remaining in labor and the cervical dilatation, we have shown that a transperineal ultrasound is a feasible method to follow the progression of labor and can complement clinical vaginal examinations.

Research implications

Friedman published the graphic analysis of labor in 1954[13] and the patterns of cervical dilatation and fetal descent in 1965.[6–8] Although Friedman considered both cervical dilatation and fetal descent to be of equal clinical importance, there has since been a universal emphasis on following labor progress based on the assessments of cervical dilatation in preference to fetal head descent. Vaginal delivery requires full cervical dilatation, but it is equally important to achieve fetal head descent down to the pelvic floor. Labor, moreover, does not end at full dilatation. Clinical palpation of the fetal head station is subjective and has limited reliability.[5,53,56,57] The American College of Obstetricians and Gynecologists' classification of the clinical assessment of fetal station has therefore been questioned owing to the inaccuracy of the method.[58] Researchers studying fetal descent have also called for a more objective measure of the fetal head station than offered by a clinical examination.[8,23] Ultrasound methods also have limitations with interobserver and interdevice variability,[53,59] but are more accurate than clinical examinations. The use of ultrasound has therefore been encouraged as a more objective method in recent years.[47,53,60] The objective nature of the AoP has also been correlated to anatomic landmarks, using magnetic resonance imaging and computed tomography techniques.[48,61]

FIGURE 6
Labor curves of head descent startified by use of oxytocin



Labor curves showing the patterns of fetal head station measured with ultrasound as the head-perineum distance measured in millimeters (left image) and angle of progression measured in degrees (right image) over time in nulliparous women with spontaneous onset of labor at term and also delivering spontaneously, stratified by oxytocin augmentation during labor. The birth is at 0 hours and time from the birth was calculated backward. The 95% confidence intervals are shaded.

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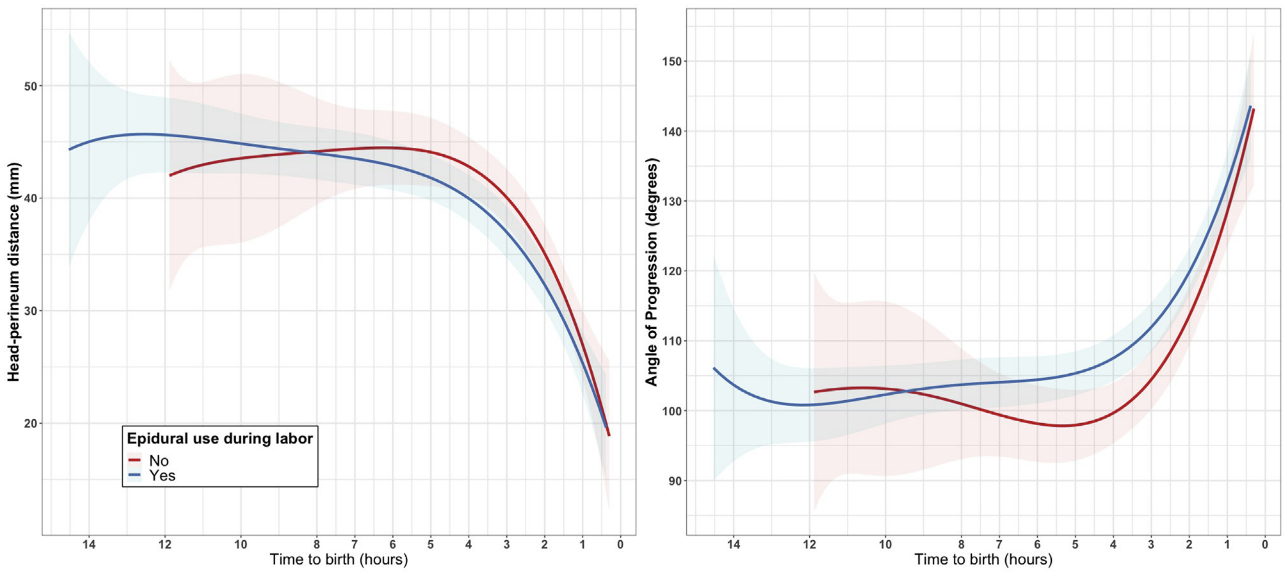
Visual comparisons show that the ultrasound descent pattern is similar in shape to the clinical curves published by Friedman.[8] The ultrasound-assessed fetal head station was slightly higher and above the midpelvis level initially. In the original clinical data, the fetal head was, on average, considered to have advanced below the maternal spinal plane when the active phase of labor had been reached.[8] There are fundamental methodological differences between comparing the clinical assessment of the spinal plane and the results obtained when using the HPD and AoP values to determine fetal head descent, but attempts have been made to relate the 2.[1,47,48,61,62] Another variation is the relationship between cervical dilatation and rapid descent. The descent started, on average, at 4 cm dilatation according to Friedman's curves and reached its maximum rate of descent at an average of 6 cm dilatation. We found rapid descent to start around 7 to 8 cm dilatation but in both cases leading to delivery around 4 hours later. The duration of the active phase of labor was shorter in Friedman's curves: 4.9 hours vs 8.4 hours in this study. This difference may be caused by different definitions for the start of the active phase of labor. By Friedman's definition the active phase begins at variable degrees of cervical dilatation, but we defined the start of the active phase at a dilatation of 4 cm in accordance with the actual WHO recommendations. The difference observed may also be caused by changes in the obstetrical population or practice.[21–23] Taking into account that the forces which drive the rapid and progressive descent may contrive to build up to a decisive turning point later in the cervical dilatational process of labor. This may be more important than the actual cervical dilatation and calls for more time to be allowed during an otherwise normal labor.

We found that second degree models described the relationship between the cervical dilatation and ultrasonically-measured fetal head station better than the linear models in women delivering vaginally. This differs from the findings of Hamilton et al[23] who found a linear relationship between the cervical dilatation and clinically-assessed fetal head station.

When the fetal head was in the OP position at the first measurement, the fetal head station was higher throughout the early part of the active phase of labor. However, this did not seem to affect the pattern of rapid descent toward the end of labor, which was similar for all the initial occiput positions in women delivering spontaneously.

We defined active labor as regular contractions with a fully effaced and 4 cm dilated cervix, which, at the time, was the WHO definition of active labor. Since then the WHO has changed its definition to a 5 cm dilatation[63] and Zhang et al[17] recommended a dilatation of 6 cm as the start of the active phase. As we used the time of delivery as the reference point and then calculated

FIGURE 7
Labor curves of head descent stratified by epidural use



Labor curves showing the patterns of the fetal head station measured with ultrasound as the head-perineum distance measured in millimeters (left image) and angle of progression measured in degrees (right image) over time in nulliparous women with spontaneous onset of labor at term and also delivering spontaneously, stratified by the use of epidural analgesia. The birth is at 0 hours and time from the birth was calculated backward. The 95% confidence intervals are shaded.

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backward, similar to the methodology used by Zhang et al,[17] we do not believe these differences in definition have any bearing on the patterns of descent supported by our findings of almost identical descent patterns for women included at 4 to 5 cm cervical dilatation compared with those included at a dilatation of ≥6 cm.

To get a complete picture of nulliparous women in spontaneous labor we did not exclude women with advanced dilation on admission. This represents the reality of spontaneous labors. Excluding these women would have resulted in a selected population of women having slow labors.

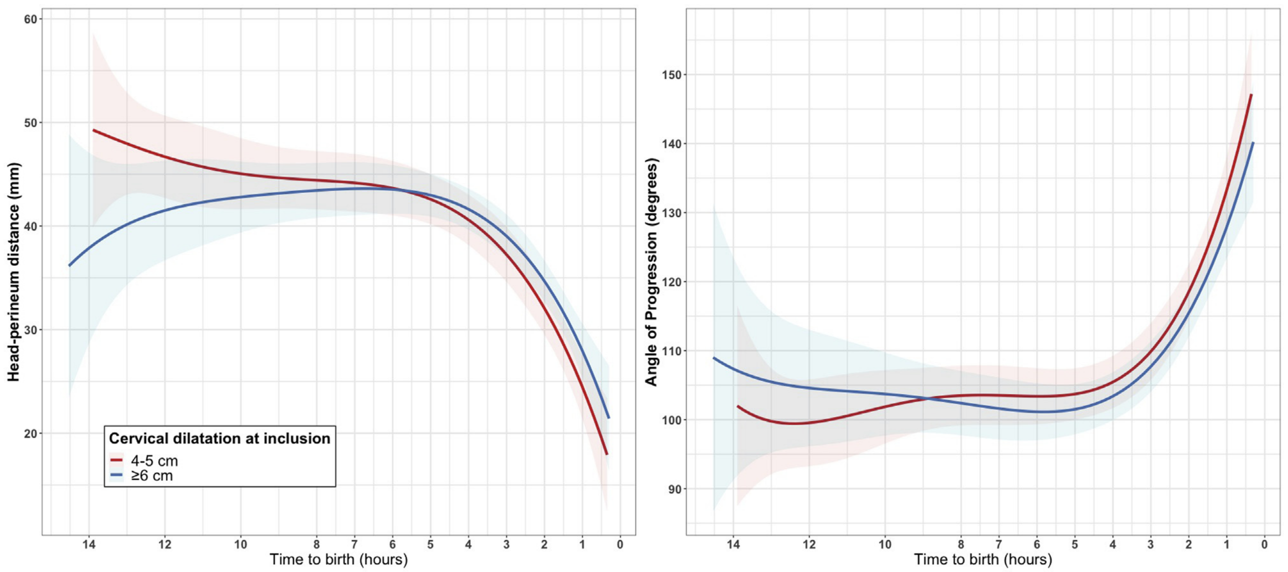
We decided to do paired clinical and ultrasound examinations, and to follow the hospital protocol for vaginal examinations during labor, namely at least every 4 hours, as we felt that this would be sufficient to construct labor patterns for the whole group. Having a strict protocol of more frequent examinations would have given us more accurate knowledge of the clinical progression for each individual woman.

Studies have shown conflicting results about the effects epidural analgesia has on the progression of labor.[64–78] In our study group, 62% of the women were given epidural analgesia. There were no differences between the fetal head levels during the early part of the active phase of labor associated with epidural use in women delivering spontaneously, but the curve of fetal head descent was slightly more sloping in these women. This is in line with the results of a recent study using ultrasound methods to monitor fetal head descent.[36] A study following women in induced labors with ultrasound measurements of the fetal head descent, has also demonstrated different patterns of labor progression in women who delivered vaginally and those needing cesarean delivery.[79]

Oxytocin augmentation was used in 41% of the women and a slower descent was observed in these labors. This is not surprising because a slow progress is the indication for oxytocin augmentation. Although it would be ideal to study only spontaneous, unstimulated labors, it would be unethical to withhold treatment for labor inertia. The protocol for augmentation used was the agreed upon protocol at our hospital and the cesarean delivery rate in the study corresponds to the 8% cesarean delivery rate for group 1 in the Robson 10-group classification system at our hospital. We therefore think that the internal validity was good. However, the external validity may be limited by a relatively low overall cesarean delivery rate of 15.3% in Iceland.[80] Similar studies should be performed in other countries and other populations. In our cohort, only 1 cesarean delivery was performed because of fetal distress but this was at full dilatation following slowly progressing dilatation with oxytocin augmentation.

We reported both the HPD and AoP measurements for research purposes because these methods are

FIGURE 8
Labor curves of head descent stratified by cervical dilatation at inclusion



Labor curves showing the patterns of the fetal head station measured with ultrasound as the head-perineum distance measured in millimeters (left image) and angle of progression measured in degrees (right image) over time in nulliparous women with spontaneous onset of labor at term and also delivering spontaneously, stratified by the cervical dilatation at inclusion. The birth is at 0 hours and time from the birth was calculated backward. The 95% confidence intervals are shaded.

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complimentary and reinforce the results when considered together. Although there are methodological differences between the 2, with the AoP using the symphysis as a reference point and the HPD representing the remaining distance for the fetal head to pass to the pelvic outlet, they have been shown to be well correlated.[81] The methods were also correlated in our study and showed similar labor pattern curves, suggesting that these measurements could be used interchangeably. The correlation between the ultrasound measurements and clinical assessments in our study was good at high stations, but not at low stations (Supplemental Figure 2).

Strengths and limitations

The strengths of this study were the prospective, longitudinal design and a well-defined population of spontaneously laboring nulliparous women recruited during the active phase of labor. The ultrasound examiners were both fetal medicine specialists, which adds to the quality of the examinations. This could also be considered a weakness because the results might not be directly applicable to the average labor ward staff. It has, however, been shown that these skills are easily obtained.[60] The nonconsecutive nature of inclusion may be considered a limitation, but the participants were recruited on the given days when the ultrasound examiners were available and we are not aware of any selection bias. The small sample size, especially regarding the operative delivery numbers, limits the generalizability of the results and further studies in both parous and nonparous women in spontaneous and induced labor are needed.

Conclusions

We used tested, objective, intrapartum ultrasound methods to describe the pattern of fetal head descent in nulliparous women delivering at term. The patterns resemble previously published clinical patterns. Ultrasonically measured fetal head station was associated with the mode of delivery and with the remaining time in labor. The results of this study may encourage further studies on fetal descent as measured with ultrasound in other well-defined groups of women in labor and in other settings. ■

Acknowledgments

The authors thank the midwives in the labor ward at the Landspitali - National University Hospital of Iceland for their help with the recruitment, clinical examinations, and data collection. We thank Helga Birna Gunnarsdottir, the project manager at the Landspitali - National University Hospital of Iceland, for help with setting up the database.

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Author and article information

From the Department of Obstetrics and Gynecology, Landspitali - The National University Hospital of Iceland, Reykjavik, Iceland (Drs Hjartardóttir, Benediktsdóttir, and Geirsson); Faculty of Medicine, University of Iceland, Reykjavik, Iceland (Drs Hjartardóttir, Benediktsdóttir, and Geirsson); deCODE genetics, Reykjavik, Iceland (Dr Lund); National Center for Fetal Medicine, Department of Obstetrics and Gynecology, St. Olavs Hospital, Trondheim University Hospital, Trondheim, Norway (Dr Eggebø); Department of Obstetrics and Gynecology, Stavanger University Hospital, Stravanger, Norway (Dr Eggebø); and Institute of Clinical and Molecular Medicine, Norwegian University of Science and Technology, Trondheim, Norway (Dr Eggebø).

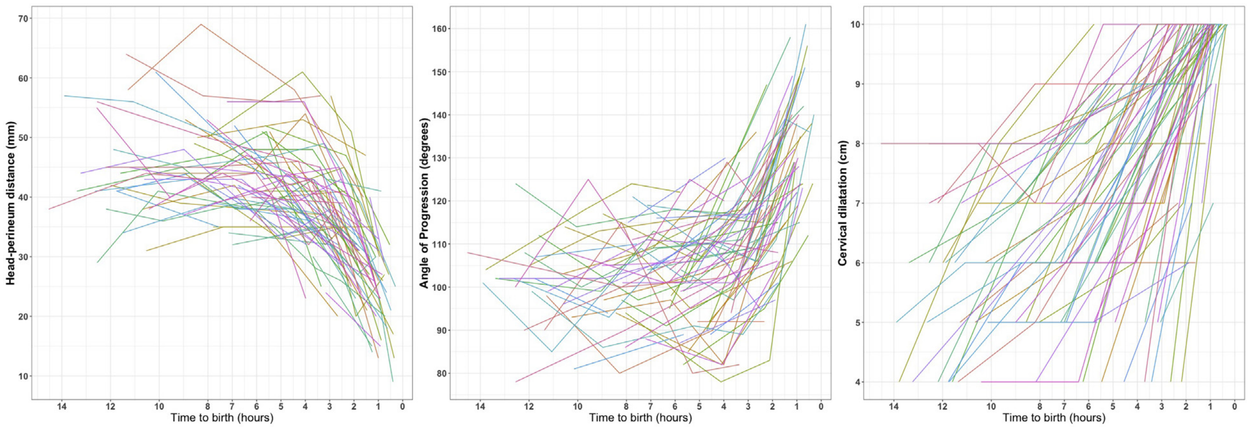
Received Sept. 4, 2020; revised Sept. 25, 2020; accepted Oct. 2, 2020.

The authors report no conflict of interest.

The study was supported by grant number 185435-052 from the Icelandic Centre for Research.

Corresponding author: Hulda Hjartardóttir, MD. huldahja@landspitali.is

SUPPLEMENTAL FIGURE 1
Individual patterns of head descent and cervical dilatation



Labor curves showing the individual patterns of fetal head station as measured with an ultrasound as the head-perineum distance measured in millimeters (left image), angle of progression measured in degrees (middle image), and cervical dilatation assessed clinically in cm (right image) over time in nulliparous women with spontaneous onset of labor at term. Only the curves of women who delivered spontaneously are shown. The birth is at 0 hours and time from the birth was calculated backward.

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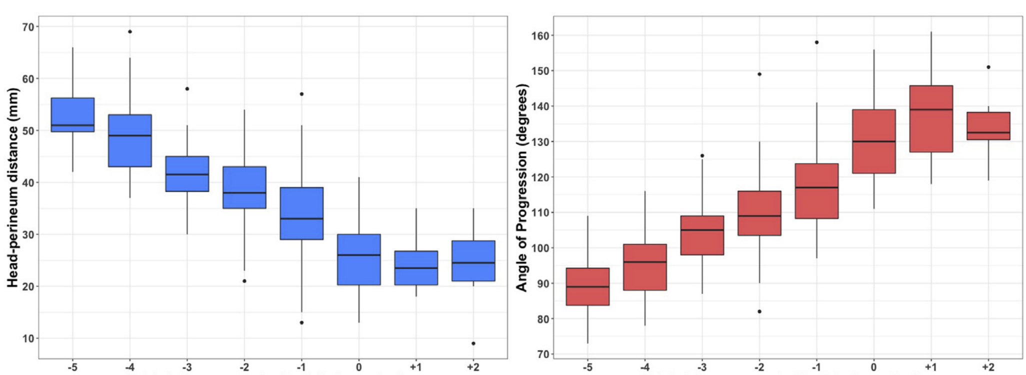
SUPPLEMENTAL FIGURE 2
Association between ultrasound and clinical methods to assess fetal station



A boxplot showing the association between the clinically assessed fetal head station and the fetal head station as measured with ultrasound as the head-perineum distance measured in mm (left image) and the angle of progression measured in degrees (right image).

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SUPPLEMENTAL TABLE 1
Details of the labors for women needing a cesarean delivery

Case	Cervical dilation at inclusion (cm)	Cervical dilatation at delivery (cm)	Occiput position at inclusion	Occiput position at delivery	HPD at inclusion (mm)	HPD at last examination (mm)	AoP at inclusion (°)	AoP at last examination (°)	Length of active phase of labor I (h:min)	Length of second stage (h:min)	Indication
1	4	6	OA	OA	43	34	98	122	17:15		FP
2	5	6	OP	OP	48	47	91	89	10:06		FP
3	6	10	OP	OP	59	49	79	110	08:40	04:53	FP
4	5	8	OP	OP	60	40	84	107	13:55		FP
5	7	9	OP	OP	60	55	84	89	11:35		FP
6	4	10	ROT	OP	52	46	98	100	14:24	00:38	FD
7	5	6	OP	OP	66	62	73	76	11:20		FP
8	4	8	OP	OP	34	33	105	123	25:22		FP

AoP, angle of progression; *FD*, fetal distress; *FP*, failure to progress; *HPD*, head-perineum distance; *OA*, occiput anterior; *OP*, occiput posterior; *ROT*, right occiput transverse.

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SUPPLEMENTAL TABLE 2

The predicted ultrasound-measured fetal head station at each centimeter of cervical dilatation

Cervical dilatation (cm)	Predicted HPD (mm)	95% CI (mm)	Predicted AoP (°)	95% CI (°)
4	44	42–47	102	98–105
5	46	44–47	99	96–101
6	45	44–47	98	96–100
7	44	42–45	101	98–103
8	40	39–42	106	104–108
9	36	34–37	115	113–117
10	29	28–31	126	124–129

Data are presented as number or median (range).

AoP, angle of progression; *CI*, confidence interval; *HPD*, head-perineum distance.

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