OBSTETRICS

Factors that affect ultrasound-determined labor progress in women undergoing induction of labor

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BACKGROUND: The traditional approach to the assessment of labor progress is by digital vaginal examination; however, it is subjective and imprecise. Recent studies have investigated the role of transperineal ultrasonographic assessment of fetal head descent by measuring the angle of progression and head-perineum distance.

OBJECTIVE: The objective of this study was to evaluate factors that affected labor progress, which were defined by the transperineal ultrasonographic parameters, in women who achieved vaginal delivery.

STUDY DESIGN: This was a prospective longitudinal study performed in 315 women with singleton pregnancy who underwent labor induction at term between December 2016 and December 2017. Paired assessment of cervical dilation and fetal head station by vaginal examination and transperineal ultrasonographic assessment of fetal head descent (parasagittal angle of progression and head-perineum distance) were made serially after the commencement of labor induction until full cervical dilation. The researchers were blinded to the findings of the clinical team's vaginal examination and vice versa. The repeated measure data were analyzed by mixed effect models to identify the significant factors (age $\geq$35 years, obesity, parity, methods of labor induction, and epidural anesthesia) that affected the relationship between parasagittal angle of progression and head-perineum distance against fetal head station and cervical dilation.

RESULTS: The total number of paired vaginal examination and transperineal ultrasonographic assessments among the 261 women (82.9%) with vaginal delivery was 945, with a median of 3 per woman. The median assessment-to-assessment interval was 4.6 hours (interquartile range, 4.3–5.2). Multiparity and mechanical methods of labor induction were associated with a faster rate of fetal head descent, which was determined by head-perineum distance against fetal head station, than nulliparity and the use of a slow-release vaginal pessary, respectively. An additional increase of 0.10 cm in head-perineum distance was observed, for an unit increase in fetal head station in nulliparous women (P=.03) and women who had a slow-release vaginal pessary (P=.02), compared with multiparous women and those who had mechanical methods for labor induction. The use of epidural anesthesia was associated with a slower rate of fetal head descent, which was determined by both parasagittal angle of progression and head-perineum distance, against fetal head station. An additional decrease of 3.66 degrees in parasagittal angle of progression (P=.04) and an additional increase in 0.33 cm in head-perineum distance ($P\leq$.001) were observed for a unit increase in fetal head station in women with the use of epidural anesthesia, compared with those without. Obese women had higher head-perineum distance overall, compared with normal weight women; at different cross-sections of time periods, obesity appeared to be associated with a slower rate of change between head-perineum distance and cervical dilation. Advanced maternal age did not affect transperineal ultrasound-determined labor progress ($P>$.05).

CONCLUSION: Parity, methods of labor induction, the use of epidural anesthesia, and obesity affect labor progress, which has been illustrated objectively by serial transperineal ultrasonographic assessment of fetal head descent.

Key words: angle of progression, AOP, delivery, epidural anesthesia, fetal head station, head-perineum distance, HPD, induction of labor, labor progress, maternal age, obesity, Propess, transperineal ultrasound scan, vaginal examination

Assessment of labor progress was described originally by Dr Emanuel A. Friedman[1,2] in 1955.[3] Serial vaginal examinations of 500 term primigravid parturients, which were performed by a single examiner, were presented in a graphic form.[2] Among the 500 pregnant women, 70% were 20–30 years old, and 40%, 55%, and 1.8% had spontaneous vaginal delivery, operative vaginal delivery, and cesarean delivery, respectively. The normal primigravid cervical-dilation-time curve was characterized by a sigmoid shape and could be divided into 4 phases (latent, acceleration, maximum slope, and deceleration).[2] Recently, several reports have demonstrated that labor progress that is determined by vaginal examination in modern pregnant populations significantly differs from that determined by the Friedman's curve,[4–9] which suggests that the latter might be out of date and requires updating.

Thus far, vaginal examination for determination of cervical dilation, fetal head station and position, and presence of caput succedaneum and molding is the only method for the assessment of labor progress. However, vaginal examination is subjective with significant inter- and intraobserver variability.[10,11] The agreement of assessment of cervical dilation and fetal head station between clinicians is approximately 50%; the degree of agreement decreases as labor progresses.[10,11] In addition, vaginal examination is perceived to be uncomfortable and sometimes painful.[12–16] It can also introduce infection;[17,18] importantly, findings from vaginal examination cannot be recorded electronically. Intrapartum transperineal ultrasound scanning has emerged recently as a noninvasive tool to assess labor progress objectively and to predict mode of delivery.[19–38]

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AJOG at a Glance

Why was this study conducted?

This study assessed a new approach to evaluate labor progress and evaluated factors that affect labor progress, as defined by serial transperineal ultrasonographic parameters of fetal head descent.

Key findings

Multiparity and mechanical methods of labor induction were associated with a faster rate of fetal head descent, which was determined by head-perineum distance against fetal head station, than nulliparity and the use of a slow-release vaginal pessary , respectively. Epidural anesthesia was associated with a slower rate of fetal head descent, which was determined by both parasagittal angle of progression and head-perineum distance, against fetal head station than those without epidural anesthesia. Obese women had higher fetal head engagement and were associated with a slower labor progress at certain time points during labor than nonobese women.

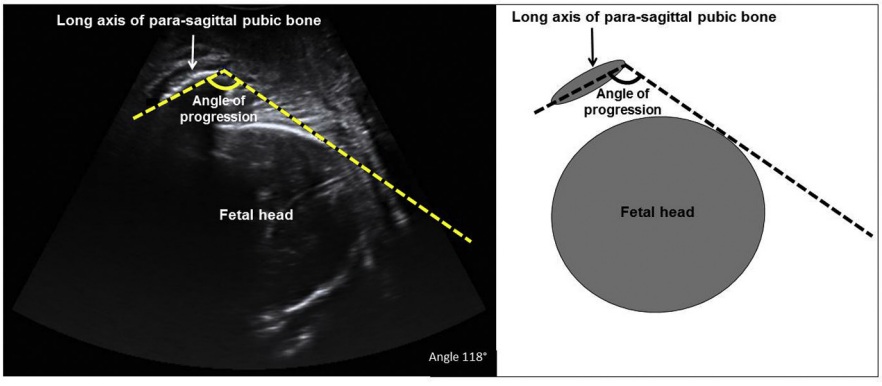
What does this add to what is known?

Serial transperineal ultrasound scanning can evaluate labor progress objectively.

Transperineal ultrasonographic parameters that have been proposed include angle of progression (AOP),[39] head-perineum distance (HPD),[40] and sonographic cervical dilation.[41] The AOP is a measurement of the angle from the leading part of the fetal skull and the symphysis pubis in a mid-sagittal plane.[39] The HPD is the shortest distance from the perineal skin surface to the outmost bony limit of the fetal skull in a transverse view.[40] These 2 parameters are reflective of fetal head station and proved to be predictive of successful vaginal delivery after induction of labor.[32,37] The sonographic cervical dilation is an ultrasonographic measurement of cervical dilation.[41] Our group has conducted a prospective study in 308 singleton pregnant women who were undergoing induction of labor at term and demonstrated that these transperineal ultrasonographic parameters, when assessed before induction of labor, are reproducible but that only the parasagittal (ps)AOP is an independent predictor of cesarean delivery.[37] Studies to date have evaluated only the use of transperineal ultrasonographic parameters as a single assessment in predicting mode of delivery.[19,21,32,37,42–44]

It is well-recognized that several factors, such as maternal age, body mass index (BMI), and parity, affect labor progress as determined by vaginal examination and that these factors should be taken into account when the diagnosis of dystocia is made.[45–52] In the current study, we proposed a new approach to evaluate labor progress; the objective was to evaluate factors that affected labor progress, as defined by serial transperineal ultrasonographic parameters, in women who achieved successful vaginal delivery after induction of labor at term.

FIGURE 1
Transperineal ultrasonographic measurement of parasagittal angle of progression



Briefly, a covered convex transducer is placed between the labia majora, below the symphysis pubis, and an image is acquired to include the symphysis pubis and the fetal head. Small lateral movements of the probe are made to align the ultrasound beam in a parasagittal orientation to include the whole length of parasagittal pubic bone and fetal skull. The parasagittal angle of progression is measured between the longitudinal axis of the pubic bone to the lowest convexity of the fetal skull.

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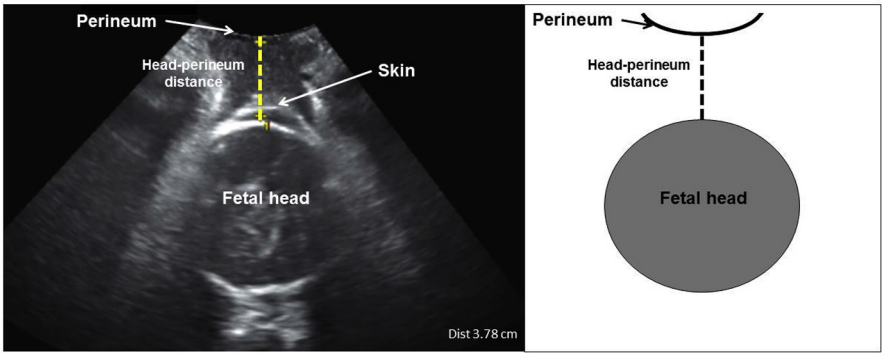
Materials and Methods

This was a prospective longitudinal study performed in women with singleton pregnancy who underwent induction of labor at term in a single maternity unit in Hong Kong SAR, between December 2016 and December 2017. Inclusion criteria for the study were pregnant women with a live fetus in cephalic presentation and intact membranes who underwent induction of labor between 37^{+0} and 42^{+6} weeks gestation for various indications and subsequently delivered vaginally. Written informed consent was obtained from the women who agreed to participate in the study, which was approved by the Institutional Review Board (Joint Chinese University of Hong Kong—New Territories East Cluster Clinical Research Ethics Committee, Reference Numbers CRE-2016.338).

Ultrasound assessment

Transperineal ultrasound assessment was carried out by 6 operators (P.C., A.H.W.K., W.T.T., W.T.L., W.W.Y.C., J.H.), who have had at least 3 year's

FIGURE 2
Transperineal ultrasonographic measurement of head-perineum distance



The head-perineum distance is the distance between the lowest edge of the parasagittal pubic bone and the nearest point of the fetal skull along a line that passes perpendicular to the long axis of the pubic bone by a transperineal ultrasound examination in a transverse view. The transducer is moved and angled until the shortest distance to fetal head is visualized.

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TABLE 1
Characteristics of the study population

Variables	Measure
Mean maternal age, y (interquartile range)	32.1 (29.0–35.4)
≥35, n (%)	76 (29.1)
<35, n (%)	185 (70.9)
Median maternal weight, kg (interquartile range)	67.3 (61.4–75.2)
Median maternal height, cm (interquartile range)	158 (155–162)
Median maternal body mass index, kg/m^2 (interquartile range)	26.9 (24.8–29.6)
≥30, n (%)	58 (22.2)
<30, n (%)	203 (77.8)
Racial origin, n (%)	
Chinese	260 (99.6)
Non-Chinese	1 (0.4)
Parity, n (%)	
Nulliparous	145 (55.6)
Parous	116 (44.4)
Indications for induction of labor, n (%)	
Postterm	126 (48.3)
Diabetes mellitus	47 (18.0)
Hypertension	12 (4.6)
Fetal growth restriction	11 (4.2)
Oligohydramnios	11 (4.2)
Macrosomia	21 (8.0)
Others	33 (12.6)

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obstetric ultrasound scanning experience. Examinations were performed with the woman in a supine position and with an empty bladder. Two-dimensional transperineal scan was performed to assess the psAOP (Figure 1) and HPD (Figure 2) by Voluson P8 ultrasound machine (GE Healthcare, Tiefenbach, Austria), as previously described.[37] Briefly, a covered convex transducer (4C-RS) was placed between the labia majora below the symphysis pubis, and an image was acquired to include the symphysis pubis and the fetal head. Small lateral movements of the probe were made to align the ultrasound beam in a parasagittal orientation to include the whole length of parasagittal pubic bone and fetal skull. The psAOP was measured between the longitudinal axis of the pubic bone to the lowest convexity of the fetal skull.[37] The HPD was measured as the shortest distance from the outer bony limit of fetal skull to skin surface of perineum by a transperineal ultrasound examination in a transverse view. The transducer was moved and angled until the shortest distance to fetal head was visualized. The soft tissue was compressed with firm pressure without creating discomfort for the women.[37]

Paired assessment of fetal head station and cervical dilation by vaginal examination and transperineal ultrasonographic assessment of fetal head descent (psAOP and HPD) were made serially after the commencement of induction of labor until full cervical dilation. Specifically, according to the hospital protocol, vaginal examination was performed every 24 hours during latent phase, and every 4 hours during active phase, respectively.

The ultrasound assessment was not used to guide clinical management, and the clinical team attending to the participant during the induction of labor was not made aware of the transperineal ultrasonographic findings. The researchers were blinded to the findings of the clinical team's vaginal examination.

Maternal characteristics (which included age, weight, height, parity, gestational age, method of induction of

TABLE 1
Characteristics of the study population *(continued)*

Variables	Measure
Median estimated fetal weight, g (interquartile range)	3276 (3001.5–3571.6)
Median Bishop score (interquartile range)	6 (4–6)
Method of induction of labor, n (%)	
Propess[a]	111 (42.5)
Mechanical methods	150 (57.5)
Oxytocin administration, n (%)	
Yes	177 (67.8)
No	84 (32.2)
Median gestation age at delivery, wk (interquartile range)	40 (38.1–41.0)
Mean birthweight, g (interquartile range)	3237 (2967.5–3543.8)
Epidural anesthesia, n (%)	
Yes	9 (3.4)
No	252 (96.6)
Median labor duration, hr (interquartile range)	4.7 (2.8–8.2)
Median induction-to-delivery interval, hr (interquartile range)	10.7 (5.8–26.9)
Median Apgar score (interquartile range)	
At 1 minute	9 (9–9)
At 5 minutes	10 (10–10)
Median arterial blood gas pH (interquartile range)	7.26 (7.20–7.30)

[a] Ferring Pharmaceuticals, Saint-Prex, Switzerland.

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labor, use of epidural anesthesia, and ultrasound findings) were recorded in a secured electronic database. Obesity was defined as a BMI of ≥30 kg/m^2.[53] Gestational age was determined from the first date of the last menstrual period and confirmed by the measurement of crown–rump length in the first trimester or head circumference in the second trimester.

Induction of labor

Induction of labor was performed according to the management protocol of the hospital. The Bishop score was determined by an experienced obstetrician. Labor was induced with amniotomy followed by oxytocin if the cervix was favorable (Bishop score, >6). If the cervix was unfavorable, labor was induced with 10 mg dinoprostone slow-release vaginal pessary (Propess; Ferring Pharmaceuticals, Saint-Prex, Switzerland). In women with previous cesarean section, intracervical balloon (Cook Cervical Ripening balloon; Cook Medical LLC, Bloomington, IN) was used. The women with unfavorable cervix were reassessed 24 hours later; if the cervix remained unfavorable, a further 10 mg of Propess was given, and, if the cervix was favorable, amniotomy was carried out. If the woman remained in latent phase after 12 hours of oxytocin infusion or if there were ≥2 episodes that the cervix failed to dilate at a rate of 1 cm per hour when the cervix was >3 cm dilated, a cesarean delivery was indicated because of no progress of labor. Data on pregnancy and labor outcomes were retrieved from computerized medical records and were also recorded in the database.

Statistical analysis

The repeated measure data were analyzed by mixed effect models to capture the correlations of changes in psAOP and HPD over time with assumed covariance structures. To identify the factors (age ≥35 years, obesity, parity, methods of induction of labor, and epidural anesthesia) that affected the relationship between psAOP and HPD against fetal head station and cervical dilation in women who achieved vaginal delivery, the significance of the interaction term between each of the variables and fetal head station or cervical dilation were determined. Probability values of <.05 were considered to be statistically significant. Statistical analysis was performed SAS software (version 9.4; SAS Institute Inc, Cary, NC).

Results

Maternal characteristics

Three hundred forty five pregnant women were recruited. We excluded 30 cases because of incomplete data in 27 cases and 3 women went into labor before induction. Of the remaining 315 cases, 261 women (82.9%) achieved vaginal delivery. Characteristics of the study population are presented in Table 1. Median of maternal age and BMI were 32.1 years (interquartile range, 29.0–35.4 years) and 26.9 kg/m^2 (interquartile range, 24.8–29.6 kg/m^2), respectively. Frequencies of nulliparity, maternal age ≥35 years, obesity, and the use of epidural anesthesia were 55.6% (n=145), 29.1% (n=76), 22.2% (n=58), and 3.4% (n=9), respectively. There were no significant differences in labor duration and induction-to-delivery interval between women with age ≥35 years vs those with age <35 years (P=.31, P=.13), and between obese women vs nonobese women (P=.27, P=.38; Table 2). Multiparous women had significantly lower labor duration and induction-to-delivery interval compared with nulliparous women (P<.001 for both). Women with the use of a mechanical method for induction of labor had significantly lower labor duration and induction-to-delivery interval than those with the use of Propess (P=.001 for both). Last, the usage of epidural anesthesia was associated with longer duration of labor and induction-to-delivery interval than those without its use (P=.006, P=.001; Table 2).

TABLE 2
Labor duration and induction-to-delivery interval

Group	Labor duration, hr[a]	*P* value	Induction-to-delivery interval, hr[b]	*P* value
Age, y		.306		.126
<35 (n=185)	5.65 (3.04–9.99)		12.31 (6.40–28.37)	
≥35 (n=76)	4.85 (2.75–11.85)		9.31 (5.16–23.23)	
Body mass index, kg/m^2		.272		.380
<30 (n=203)	5.28 (2.90–9.65)		11.13 (5.88–24.98)	
≥30 (n=58)	6.11 (3.22–12.55)		12.01 (6.51–31.92)	
Parity		<.001		<.001
Nulliparous (n=145)	7.90 (4.73–13.56)		19.05 (10.71–38.17)	
Multiparous (n=116)	3.29 (2.28–5.90)		6.67 (4.08–10.73)	
Labor induction		<.001		<.001
Propess[c] (n=111)	7.45 (4.60–13.37)		28.82 (16.42–42.20)	
Mechanical method (n=150)	3.97 (2.67–7.46)		6.67 (4.45–10.96)	
Epidural anesthesia		.006		.001
No (n=252)	5.27 (2.94–9.71)		10.93 (5.97–24.90)	
Yes (n=9)	16.03 (8.30–21.12)		44.97 (25.22–57.21)	

Data presented as median (interquartile range).

[a] Time interval from active phase of labor to delivery; [b] Time interval from starting process of induction-to-delivery; [c] Ferring Pharmaceuticals, Saint-Prex, Switzerland.

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Paired vaginal examination and transperineal ultrasound assessment

After the commencement of induction of labor, the total number of paired vaginal examination and transperineal ultrasonographic assessments in women with vaginal delivery was 945, with a median of 3 (interquartile range, 2–4) per woman. The median assessment-to-assessment interval was 4.6 hours (interquartile range, 4.3–5.1 hours).

Factors that affect labor progress

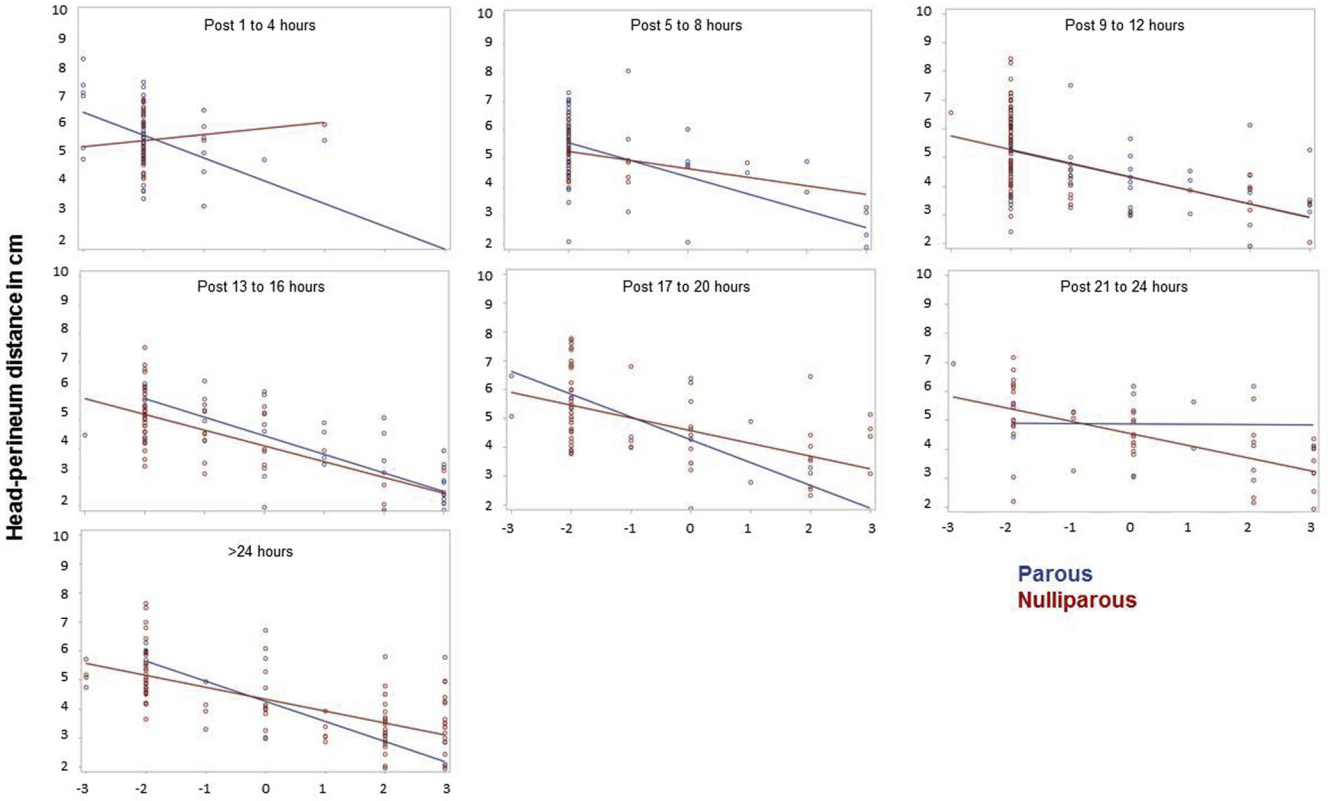
Changes in transperineal ultrasound parameters against fetal head station

In women who had successful vaginal delivery after induction of labor at term, parity and methods of induction of labor significantly affected the association between HPD, but not psAOP, and fetal head station, taking account of repeated measures from individuals; multiparity and induction of labor by mechanical methods (amniotomy or intracervical balloon) had steeper slopes of HPD against fetal head station than nulliparity and induction of labor by Propess, respectively. Objectively, an additional increase of 0.10 cm in HPD was observed for an unit increase in fetal head station in nulliparous women (P=.03) and women who had Propess (P=.02), compared with multiparous women and those who had mechanical methods for induction of labor (Figures 3 and 4; Table 3). The use of epidural anesthesia was associated with a slower rate of fetal head descent, which was determined by both psAOP and HPD, against fetal head station. Specifically, an additional increase in 0.33 cm in HPD (P<.01) and an additional decrease of 3.66 degrees in psAOP (P=.04) were observed for a unit increase in fetal head station in women with the use of epidural anesthesia, compared with those without (Figures 5 and 6; Table 3). Maternal age of ≥35 years and obesity did not significantly affect the association of psAOP and HPD against fetal head station (Table 3).

Changes in transperineal parameters against cervical dilation

In women who had successful vaginal delivery after induction of labor at term, obesity and methods of induction of labor (but not maternal age, parity, and the use of epidural anesthesia) significantly affected the association between HPD and cervical dilation, taking account of repeated measures from individuals. Obesity was associated with an additional decrease of 0.05 cm in HPD for an unit increase in cervical dilation, compared with normal weight women (P=.03; Table 4; Figure 7). However, the effect of obesity on the relationship between HPD and cervical dilation appeared to be more complex: obese women had higher HPD overall compared with normal weight women. At different cross-sectional time periods, obesity appeared to be associated with a

FIGURE 3
Changes in head-perineum distance against fetal head station: parity



Changes in head-perineum distance against fetal head station between nulliparous women (*blue line*), taking into account repeated measures from individuals.

cm, centimeters.

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slower rate of change between HPD and cervical dilation. The use of Propess was associated with an additional increase of 0.04 cm (P=.05) in HPD for an unit increase in cervical dilation, compared with those with the use of mechanical methods for induction of labor (Table 4; Figure 8). None of the factors affected the association of psAOP against cervical dilation (Table 3).

Figures 9 and 10 illustrate serial measurements of psAOP and HPD from the commencement of induction of labor until full cervical dilation.

Comment

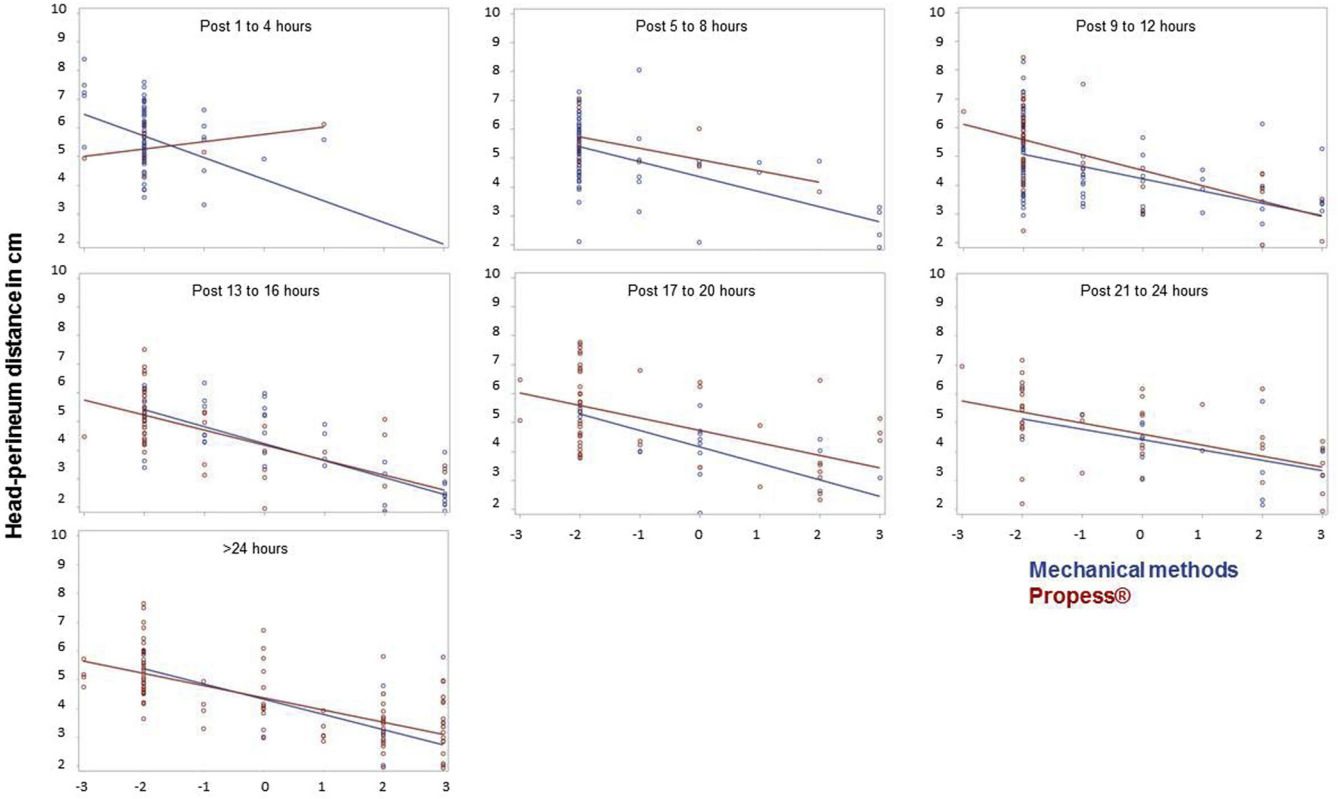
Principal findings of the study

With regard to women who achieve vaginal delivery after induction of labor at term, (1) multiparity and mechanical methods of induction of labor are associated with a faster rate of fetal descent, as represented by HPD against fetal head station, than nulliparity and the use of Propess, respectively; (2) the use of epidural anesthesia is associated with a slower rate of fetal head descent, as represented by psAOP and HPD against fetal head station, than those without the use of epidural anesthesia; (3) obese women have higher HPD, and at different cross-sectional of time periods during labor, obesity is associated with a slower rate of fetal head descent, as determined by HPD against cervical dilation; and (4) advanced maternal age does not affect progress of labor defined by the transperineal ultrasonographic assessment.

Results in context

This is the first study to report on factors that affect labor progress that is determined by serial transperineal ultrasonographic assessment of fetal head descent in women who deliver vaginally. We have demonstrated that women at ≥35 years old have similar fetal head descent rate compared with those at <35 years old. Although there are no previous studies that have evaluated the relationship between maternal age and labor progress, our results are similar to those of 2 studies that evaluated the association of maternal age and labor length.[54,55] In 1965, Friedman and Sachtleben[54] determined the length of labor in 3329 nulliparous women and demonstrated that there were no differences in the length of labor between women who were <18 years old and those who were >35 years old. Sokol et al[55] reported the same observation that advanced maternal age was not associated with the length of labor. However, other studies demonstrated

FIGURE 4
Changes in head-perineum distance against fetal head station: Propess vs mechanical methods



Changes in head-perineum distance against fetal head station between women with the use of Propess (Ferring Pharmaceuticals, Saint-Prex, Switzerland; *red line*) and the use of mechanical methods of induction of labor (*blue line*), taking into account repeated measures from individuals.

cm, centimeters.

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TABLE 3
The effect of different characteristics on the association between transperineal ultrasound parameters and fetal head station

Ultrasound parameters	Variable	Estimate (standard error)	*P* value[a]
Parasagittal angle of progression	Age ≥35 y	−0.08 (0.81)	.92
	Obesity	−0.20 (0.84)	.82
	Propess[b]	0.07 (0.74)	.92
	Nulliparity	0.04 (0.81)	.96
	Epidural anesthesia	−3.66 (1.74)	.04
Head-perineum distance	Age ≥35 y	0.02 (0.05)	.74
	Obesity	−0.07 (0.05)	.15
	Propess[b]	0.10 (0.04)	.02
	Nulliparity	0.10 (0.04)	.03
	Epidural anesthesia	0.33 (0.10)	<.01

[a] $P<.05$, statistically significant; [b] Ferring Pharmaceuticals, Saint-Prex, Switzerland.

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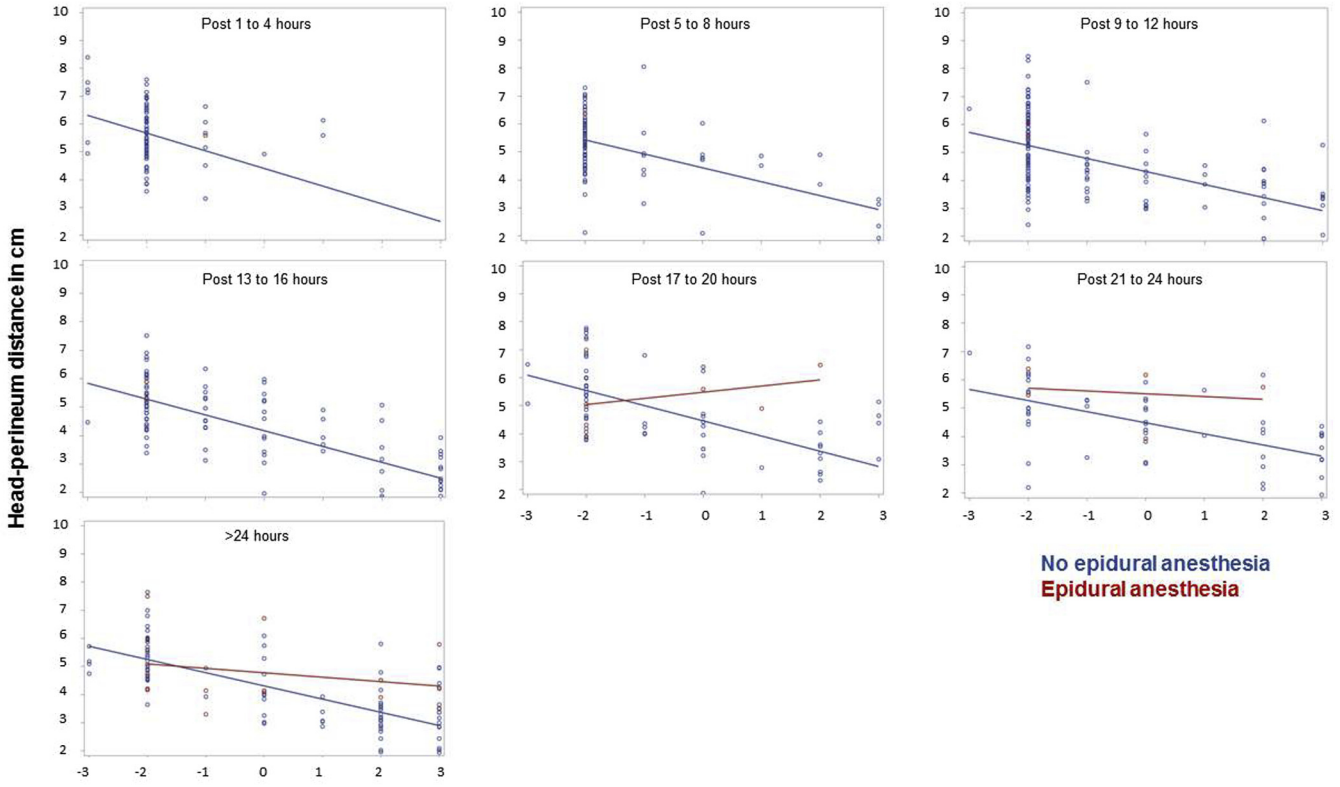
FIGURE 5
Changes in head-perineum distance against fetal head station: epidural anesthesia



Changes in head-perineum distance against fetal head station between women with (*red line*) and without epidural anesthesia (*blue line*), taking into account repeated measures from individuals.

cm, centimeters.

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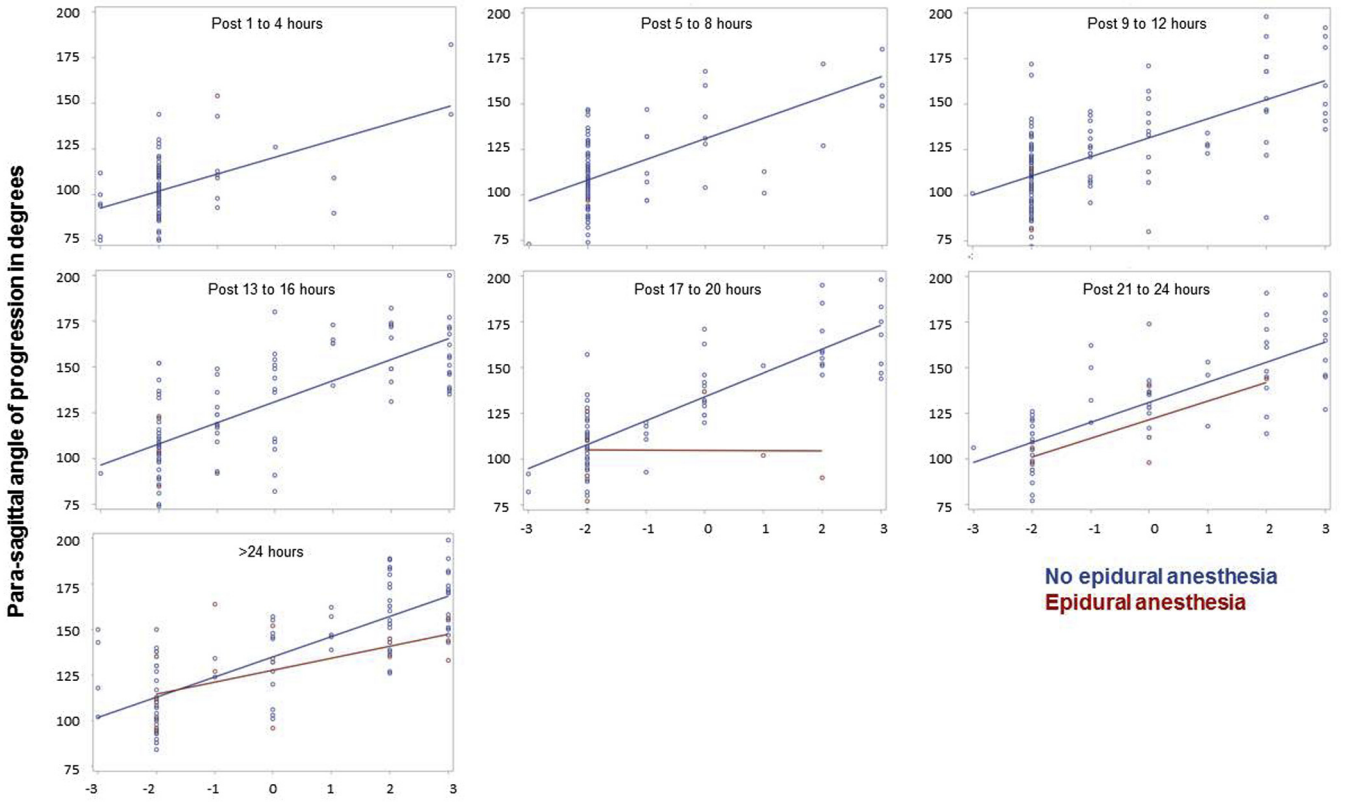
that the length of labor was associated with maternal age.[47,50] Greenberg et al[47] conducted a retrospective cohort study that included 31,976 births and reported that nulliparous women at age >39 years had longer first and second stage of labor than those at age <20 years, after adjustment for the use of epidural, type of labor onset, ethnicity, BMI, neonatal birthweight, and gestational age. In the subgroup of women who had induced labor, a longer duration of the first stage of labor was observed in women with advanced maternal age at up to 35–39 years, in comparison with those at <20 years. In contrast, a study by Zaki et al[50] demonstrated that, in 120,442 women, the length of first stage of labor decreased with increasing maternal age, especially in multiparous women.

Regarding the use of epidural anesthesia, we report that it is associated with a slower fetal head descent based on transperineal ultrasonographic assessments. Controversy revolves around the relationship between epidural anesthesia and labor progress.[56–68] Our results are similar to the results of the study by Alexander et al[61] study in which the authors determined the effects of epidural anesthesia, compared with meperidine, in a cohort of 196 nulliparous women with similar clinical characteristics who achieved spontaneous vaginal delivery at term. The authors demonstrated that the durations of active phase of labor (7.9 vs 6.3 hours) and second stage (60 vs 48 minutes) were longer in women who received epidural anesthesia compared with those given boluses of meperidine. On the contrary, duration of the first stage of labor was also reported to be shorter[69,70] or no different[71–76] in pregnant women who received epidural anesthesia compared with those who received opioid analgesia. Underlying mechanisms that are responsible for the longer duration of labor that is associated with epidural anesthesia include a decrease in maternal plasma oxytocin concentration and uterine activity measured by electromyography.[77-80] Such a decrease leads to reduced plasma concentrations of prostaglandin $F_{2\alpha}$, a hormone known to increase uterine activity.[78,81–84] In addition, epidural anesthesia can block nervous impulses that arise from the birth canal and reduces uterine contractions, which contribute to the reduced release of prostaglandin $F_{2\alpha}$.[84]

Our results have demonstrated that the relationship between obesity and labor progress is a complex one. Obese women have higher fetal head engagement, as illustrated by a higher HPD, and

FIGURE 6
Changes in parasagittal angle of progression against fetal head station: epidural anesthesia



Changes in parasagittal angle of progression against fetal head station between women with (*red line*) and without epidural anesthesia (*blue line*), taking into account repeated measures from individuals.

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TABLE 4
The effect of different characteristics on the association between transperineal ultrasound parameters and cervical dilation

Ultrasound parameters	Variable	Estimate (standard error)	*P* value[a]
Parasagittal angle of progression	Age ≥35 y	−0.31 (0.35)	.36
	Obesity	0.28 (0.37)	.45
	Propess[b]	0.32 (0.32)	.31
	Nulliparity	0.20 (0.35)	.56
	Epidural anesthesia	−0.53 (0.74)	.47
Head-perineum distance	Age ≥35 y	0.01 (0.02)	.69
	Obesity	−0.05 (0.02)	.03
	Propess[b]	0.04 (0.02)	.05
	Nulliparity	0.02 (0.02)	.40
	Epidural anesthesia	0.09 (0.05)	.07

[a] $P<.05$, statistically significant; [b] Ferring Pharmaceuticals, Saint-Prex, Switzerland.

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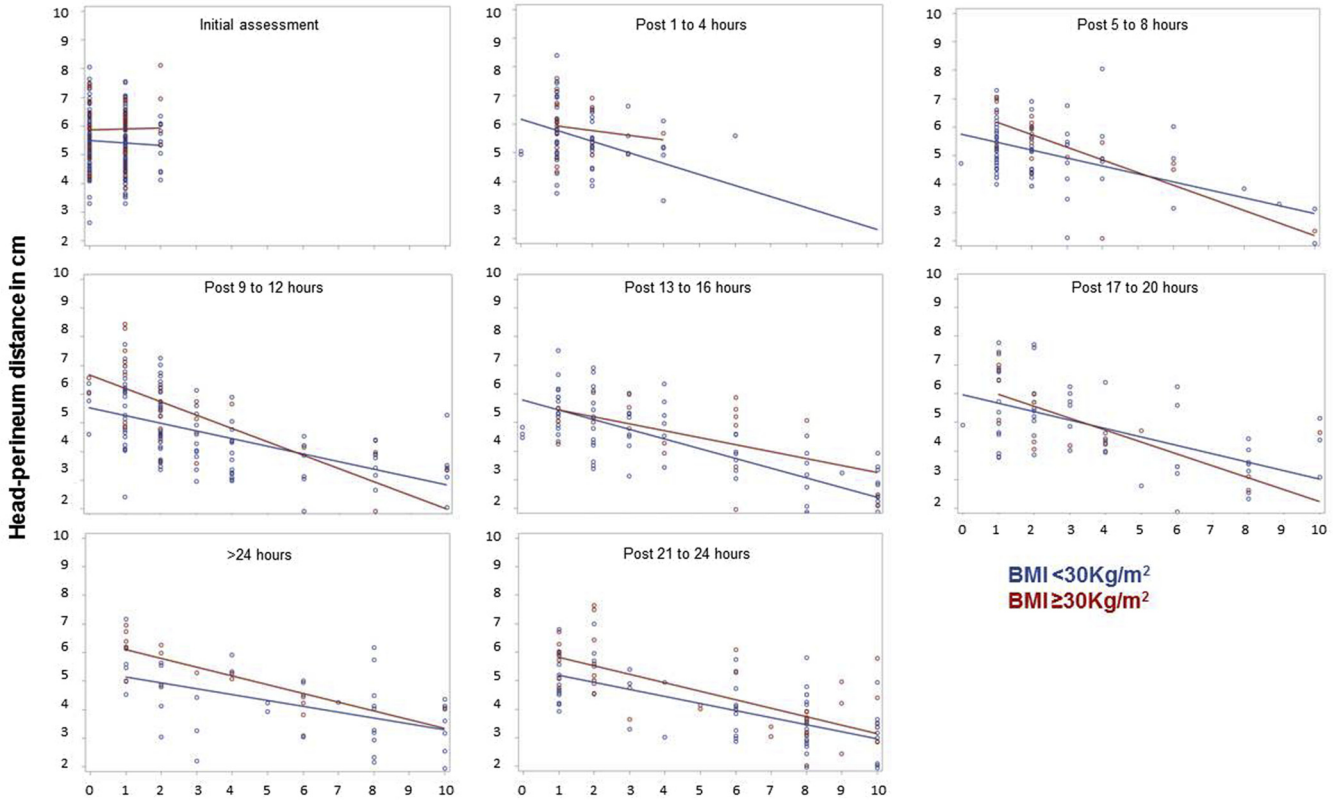
FIGURE 7
Changes in head-perineum distance against cervical dilation: body mass index



Changes in head-perineum distance against cervical dilation between women with body mass index of ≥30 kg/m^2 (*red line*) and those with body mass index of <30 kg/m^2 (*blue line*), taking into account repeated measures from individuals.

BMI, body mass index; *cm*, centimeters.

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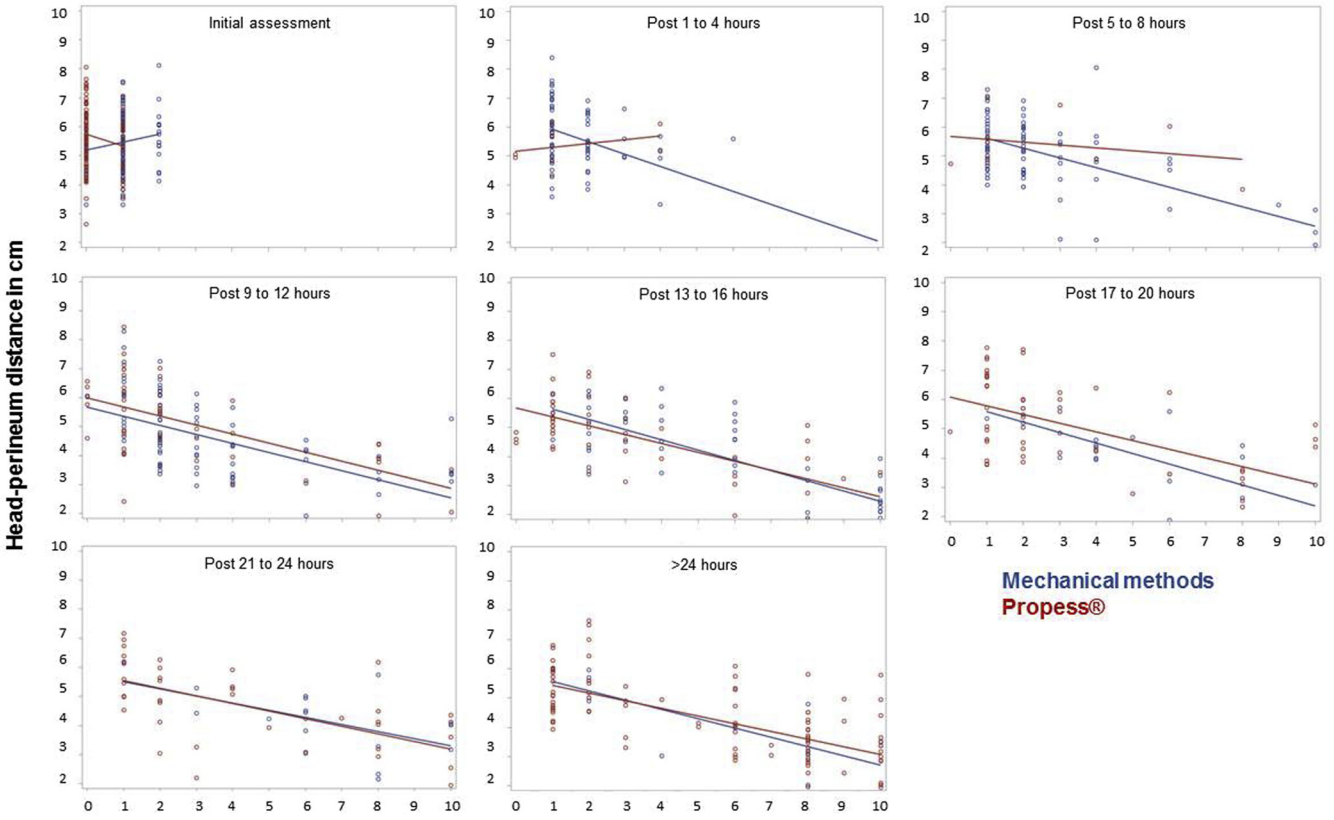
obesity is associated with a slower labor progress at certain time points during labor, than with nonobese women, as illustrated by the fetal head descent (HPD) against cervical dilation. These results are similar to those observed in previous studies.[45,49,85–89] A study of 118,978 singleton pregnancies demonstrated that, in both nulliparous and multiparous women, median durations of first stage of labor were 5.4, 5.7, 6.0, 6.7, and 7.7 hours in women with BMI of <25, 25.0–29.9, 30.0–34.9, 35.0–39.9, and ≥40 kg/m^2, respectively.[49] Norman et al[87] demonstrated that pregnant women with BMI ≥30 kg/m^2 had longer duration and slower progression (changes in cervical dilation) of the first stage of labor in both nulliparous and multiparous women, compared with those with BMI <30 kg/m^2. Importantly, the differences in labor progress were observed until 6 cm, which suggests that the first stage of labor began at 6 cm in obese women.[87] Proposed mechanisms that underlie slow labor progress in obese women include reduced myometrial contraction, disrupted cervical ripening, and altered placental preparation for labor.[90-93] For example, myometrial strips that were obtained from obese women who underwent elective cesarean delivery at term contracted with less force and lower frequency than those obtained from normal weight women.[94] This effect is mediated by high cholesterol level, adipokines, particularly leptin, and inflammatory cytokines in obese women.[94] However, some studies have reported contradictory results on maternal BMI and labor progress,[95–97] which can be attributed to differences in the definition of active phase of labor and duration of labor (first stage of labor only vs both first and second stage of labor).

Last, we have also shown that multiparous women and mechanical methods for induction of labor (amniotomy and intracervical balloon) are associated with faster fetal head descent, which has been determined by transperineal ultrasonographic assessments. Such findings are consistent with previous studies.[98-103] The effects of maternal factors on rates of change in fetal head descent (psAOP or HPD) in relation to cervical dilation are not observed as evidently, compared with fetal head station. This finding is not surprising because both psAOP and HPD are reflective of fetal head station, rather than cervical dilation.

FIGURE 8
Changes in head-perineum distance against cervical dilation: Propess vs mechanical methods



Changes in head-perineum distance against cervical dilation between women with the use of Propess (Ferring Pharmaceuticals, Saint-Prex, Switzerland; *red line*) and the use of mechanical methods of induction of labor (*blue line*), taking into account of repeated measures from individuals.

cm, centimeters.

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Clinical implications

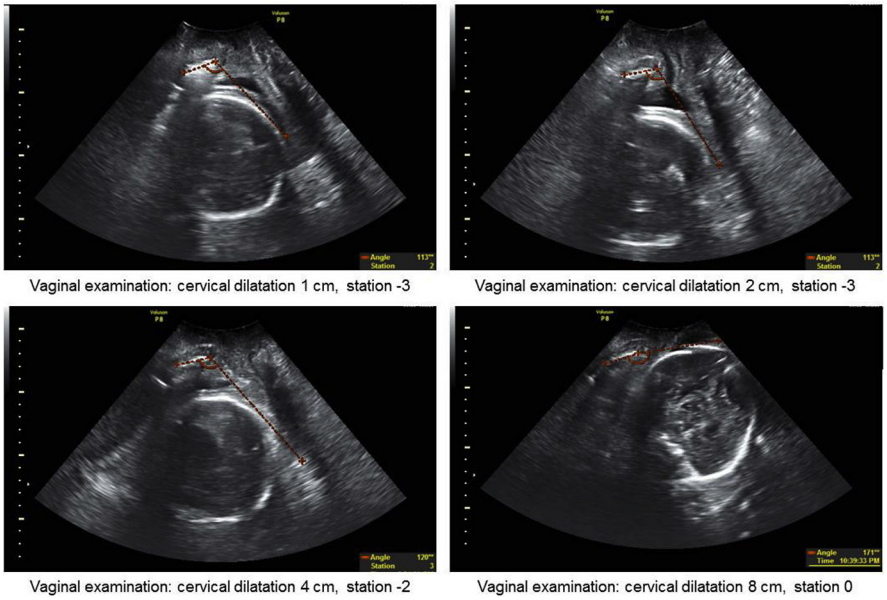
In current clinical practice, clinicians are required to assess and document cervical dilation, fetal head station, and position as indicators of labor progress that essentially guide labor management. A growing body of evidence suggests that ultrasound scanning has a potential role in the management of labor. Thus far, ultrasound scanning in labor has been shown to have a role in (1) precise identification of fetal position,[25,27,35] (2) diagnosis of the presence of caput succedaneum and its extent,[104] (3) determination of the fetal head station,[23] 4) documentation of the degree of labor progress during the second stage of labor to predict mode of delivery,[20,28,29,36] and (5) prediction of labor outcome in women who undergo induction of labor.[19,21,32,37,38,42] It would be ideal if we could accurately predict who will deliver vaginally without complications and who will require an operative delivery (cesarean or operative vaginal delivery). This ultimately will reduce morbidity, improve safety, optimize use of resources, and improve satisfaction of women during labor and delivery[105,106].

Our findings confirm previous observations that parity, methods of induction of labor, the use of epidural anesthesia, and obesity affect labor progress.[49,54,55,61,87,107,108] Hence, such factors should be considered when the diagnosis of labor dystocia is made. In addition, we have proposed a new approach in evaluating labor progress by serial transperineal ultrasonographic measurements of psAOP and HPD, which reflect fetal head descent. The observations from our study in which several maternal and labor characteristics that affect the rates of fetal head descent in women who achieve successful vaginal delivery after induction of labor potentially can guide clinicians to decide whether slower labor progress is due to these factors and therefore to adjust management accordingly.

Research implications

To date, the use of a partogram is an integral part of labor management. Future research is needed to evaluate whether transperineal ultrasonographic parameters of fetal head descent can be incorporated within the existing partogram in a larger population [41] and to determine whether the integrated partogram should be stratified according to parity, BMI, method of labor induction, and the use of epidural anesthesia.

FIGURE 9
Serial measurements of parasagittal angle of progression



Serial measurements of parasagittal angle of progression from the commencement of induction of labor until full cervical dilation.

cm, centimeters.

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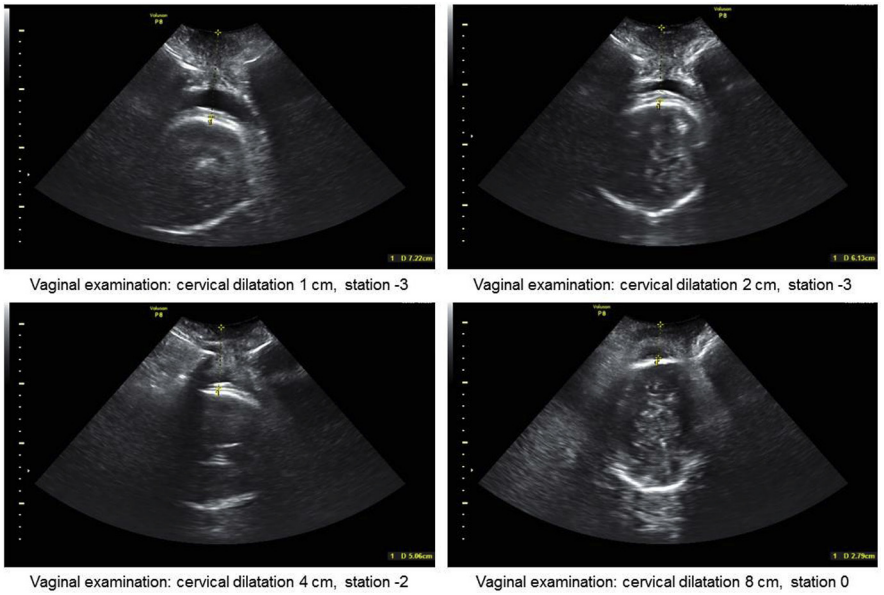
FIGURE 10
Serial measurements of head-perineum distance



Serial measurements of head-perineum distance from the commencement of induction of labor until full cervical dilation.

cm, centimeters.

Chaemsaithong et al. Labor progress by transperineal ultrasound. Am J Obstet Gynecol 2019.

Strengths and limitations

Strengths of our study include (1) the application of a standardized protocol for induction of labor and labor management, (2) the assessment of effect of different factors on labor progress, rather than labor length, with the former having the ability to guide labor management, (3) blinding of clinicians and researchers to each other's assessment, and (4) objective assessment and quantification of labor progress by serial transperineal ultrasonographic measurement of psAOP and HPD.

Main limitations of this study were that our study population included mainly Chinese women and that we chose to evaluate labor progress in those who underwent induction of labor because this would allow for acquisition of transperineal ultrasonographic parameters from the beginning of labor. Our results might not be generalizable in other ethnic populations and do not represent labor progress in women with spontaneous onset of labor. We did not use 3-dimensional ultrasonography because the aim of the effort was to introduce simple 2-dimensional ultrasound assessment of labor progress, which potentially could be adopted by physicians, midwives, and nurses.

Conclusion

In conclusion, we have demonstrated that nulliparity, induction of labor by Propess, the use of epidural anesthesia, and obesity are associated with a slower labor progress that is illustrated objectively by serial transperineal ultrasonographic assessment of fetal head descent. ■

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