

Applications of Ultrasound in Prelabor and Labor

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ABSTRACT

Ultrasound is a crucial part of everyday obstetrical practice and becomes more and more important in the management of traditionally clinical aspects of obstetrics, such as management of labor and delivery, offering a possibly more objective method of examination. The rate of labor induction has doubled in the last two decades and more objective methods are needed to assess the possible outcome of an induction and help clinicians in order to counsel women appropriately. Regarding the management of labor there is extensive evidence that clinical assessment during labor is not accurate, with potential consecutive major implications in the decision-making and the prognosis of the delivery mode. Several studies have shown that ultrasound is an objective method of assessing labor and its progress and is very helpful in decision-making for instrumental deliveries. The purpose of this article is to review the evidence available in literature regarding the benefits and the role in general of ultrasonography in prelabor and labor.

Keywords: Ultrasound, Labor, Prelabor, Sonopartogram.

How to cite this article: Iliescu D, Antsaklis P, Paulescu D, Comanescu A, Tudorache S, Antsaklis A, Ceausu I, Novac L, Cernea N, Kurjak A. Applications of Ultrasound in Prelabor and Labor. Donald School J Ultrasound Obstet Gynecol 2012;6(3):257-269.

Source of support: Nil

Conflict of interest: None declared

INTRODUCTION

It is well-established that clinical evaluation during labor is a subjective method, which is not accurate and depends on the experience of the performer. Ultrasound examination on the contrary is a quick, safe, noninvasive method which has been proposed as a more objective alternative for monitoring labor. Sonography has been proposed by different studies as an objective method for planning time and mode of delivery and for intrapartum monitoring, as well as decision-making for instrumental delivery. Aim of this article is to review the evidence regarding the use of ultrasound in assessing labor and delivery.

ULTRASOUND IN PRELABOR

There is an increased use of ultrasound in antenatal monitoring and assessment of labor, which has been supported by recent evidence in the literature. The new ultrasound machines are designed to enable service and allow obstetricians to routinely provide good quality ultrasound services, including prelabor assessments.¹

Ultrasound examination offers valuable information before the beginning of labor, such as placental localization,

presence of neck-cord or vasa previa, fetal presentation, weight, well-being, depiction of prematurity and prolonged pregnancy information. The collateral applicability of ultrasound during labor has also been studied in literature. For example, assessment before epidural catheter placement,²⁻⁸ intrapartum maternal symphyseal separation by transverse suprapubic ultrasound examination,⁹ intrapartum fetal behavior and prediction of adverse perinatal outcome based on amniotic fluid amount or biophysical profile,¹⁰⁻¹⁹ depiction of the molding and caput succedaneum during, but also before labor,²⁰⁻²⁶ maternal^{27,28} and fetal²⁹⁻⁴³ intrapartum pulsed Doppler blood flow assessment, intrapartum myometrial thickness changes,⁴⁴ ultrasound use in the third stage of labor,⁴⁵⁻⁵² or the assessment of the postvoid residual volume in laboring and postpartum women with or without epidural analgesia.⁵³⁻⁵⁶ In the majority of these cases, until now the clinical significance is unclear and remains part of research protocols.

Prediction when Planning Spontaneous Labor

A predictive method which could estimate with good sensitivity the possibility of the mode of delivery (e.g. vaginal delivery or cesarean section) would be beneficial regarding both health economics and also the medical outcome of the pregnancy, such as pelvic floor trauma⁵⁷⁻⁶⁰ or other psychological consequences to the mother⁶¹⁻⁶³ and the perception of personal failure.⁶⁴

According to latest evidence it appears that such estimation could be possible before induction of labor and during labor, but if such predictions are established earlier, they should have a much greater benefit. We should also mention the increasing rate of 'on demand' cesarean section,^{65,66} which frequently is motivated by their desire to avoid a traumatic delivery,^{67,68} studies so far have failed to detect a large proportion of pregnancies at risk of these outcomes.⁶⁹⁻⁷²

Dietz et al studied the correlation between antenatal bladder neck mobility and delivery mode⁷³ and confirmed that it is possible to assess prenatally fetal head engagement with translabial ultrasound.⁷⁴ The quantification of head engagement was performed using two methods: In the first method, a line was drawn through the inferoposterior symphyseal margin and parallel to the main transducer axis.⁷⁵ In the second method, the line of reference was a

vertical line through the central axis of the symphysis pubis, tangential to the symphyseal caudal margin, later named the 'infrapubic line'. Head engagement was defined as the minimum distance between the presenting part and the reference lines described. Later, this measurement was named 'distance of progression'. The authors concluded that the evaluation of head engagement by translabial ultrasound is highly reproducible and comparable to clinical assessment of head engagement (abdominal palpation, full Bishop scores and vaginal assessment).

In 2006, the same center proposed the development of a combined model for prediction of delivery mode.⁷⁶ In a prospective observational study with 202 term nulliparous women, they identified that factors, such as maternal age, history of cesarean section, Bishop score and bladder position on Valsalva had an ability of up to 87% to discriminate between normal vaginal delivery and operative delivery. The initial ultrasound parameters taken into account were Anterior vaginal wall relaxation determined by translabial ultrasound after bladder emptying,⁷⁷ the descent of the bladder wall (the lowest point reached by any part of the bladder) observed on maximal Valsalva maneuver, ultrasound engagement of the fetal head and cervical length determined translabially. However, more studies are needed in order to confirm the data and to test the consecutive effect on maternal and neonatal outcomes.

Prediction when Planning Induction of Labor

The rate of labor induction in developed societies has doubled in the last two decades, reaching more than one fifth of pregnancies in total.^{78,79}

Ultrasound assessment was demonstrated to be helpful in establishing the indication for labor induction. The main reasons for induction of labor are postterm pregnancy diabetes and preeclampsia.⁸⁰ Besides the crucial role of dating in early pregnancy, the traditional approach in the management of prolonged pregnancy was reconsidered by the research performed by Rao et al,⁸¹ reporting that combined ultrasound-based assessment of cervical length and fetal well-being at the end of the 40th week or during the 41st week of gestation, delays induction and results in spontaneous onset of labor and delivery in more than 80% of cases of prolonged pregnancy.

Regarding the prediction of the outcome when planning induction of labor, because of the 20% rate of cesarean section related to failed induction, failure to progress in labor or fetal distress,⁸²⁻⁸⁴ a variety of maternal and fetal factors as well as screening tests have been suggested to predict successful labor induction. Certain characteristics of the woman [parity, age, weight, height and body mass index (BMI)], and of the fetus (birth weight and gestational age)⁸⁵

proved to be useful. However, in most clinics, and in most of the patients, the Bishop score⁸⁶ for more than 4 decades is still the 'gold standard' for assessing the prognostic of induction of labor, although is considered a subjective evaluation with limitations.⁸⁷

Transvaginal cervical length⁸⁸⁻⁹⁰ or angle measurement⁹¹ improved the prediction rate of the outcome of induction. Preinduction measurement of the cervical length increases the odds of cesarean section by about 10% for each 1 mm increase above 20 mm and the odds are about 75% lower in multiparae compared with nulliparae with the same cervical length.^{88,89} Also the initial position of the fetal occiput was debated, with contradictory results.⁹²⁻⁹⁶ The biochemical markers (phIGFBP-1) in cervical secretions were assessed in preinduction but did not seem to improved the prediction of induction outcome.⁹⁰

Results from 2006 showed that ultrasound assessment of fetal head-perineum distance was predictive of labor outcome for women with prelabor rupture of membranes at term.⁹⁶ In 2008, Eggebø et al in a prospective study of 275 women admitted for induction of labor⁹⁷ aimed to compare this distance (measured by transperineal ultrasound as the shortest distance from the outer bony limit of the fetal skull to the skin surface of the perineum) with maternal factors, Bishop score and ultrasound measurements of cervical length, cervical angle and occiput position (assessed by transabdominal ultrasound imaging). Regarding the ultrasound assessment of fetal head-perineum distance, a cut-off <40 mm before induction of labor was found as a predictive factor for successful induction with a 62% predictive value, similar to that of ultrasonographically measured cervical length <25 mm (61%), cervical angle >90° (63%), Bishop score >6 (61%) and BMI >30 (60%).

The superiority of clinical⁹⁸⁻¹⁰⁰ or ultrasound^{88,89,101-104} evaluations is still debatable, and a large meta-analysis¹⁰⁵ concluded that further research is needed because both techniques appear to offer similar results. Most likely a combined approach using combinations of maternal factors, sonographic and clinical assessments would offer the expected outcome.^{76,89,95,102}

ULTRASOUND IN LABOR

Extensive evidence indicates that clinical assessment during labor is not accurate, with potential consecutive major implications in the decision-making and the prognosis of the delivery mode. According to many studies, imaging methods are superior in establishing fetal head position, station and progression during labor. What is more, it has been proved that digital pelvic estimations of fetal head level in the pelvic canal and its progression are poorly reproducible between clinicians,¹⁰⁶ while in studies with birth simulators,¹⁰⁷ it was shown that the accuracy of diagnosing clinically the pelvic station was low.

Friedman's data and definitions have proved useful in standardizing the management of patients in labor but were never intended to be applied without thought. In 2002, Zhang et al¹⁰⁸ analyzed retrospective data from 1162 nulliparous women, with singleton vertex term pregnancy, who delivered vaginally after spontaneous onset of labor. The authors' average labor curve differed markedly from the Friedman curve and they concluded that the pattern of labor progression in contemporary practice differs significantly from the Friedman curve, suggesting that progress of labor is population-based and depends on various management choices (e.g. epidural analgesia, active management during labor, etc.). Recent studies suggest that the use of ultrasound may overcome these problems by providing a series of objective evaluations of fetal head position and progression during labor and thus, offer a better prediction of spontaneous or successful instrumental vaginal delivery.

Cervical Changes (Effacement and Dilatation)

Monitoring labor has to do with assessment of cervical dilatation, head position and head descent. On the contrary, assessment of cervical dilatation throughout labor is not possible with current ultrasound technology. So, a technique that would make it possible for the entire labor to be monitored independently from the clinical transvaginal examination would be very useful. The technical difficulties encountered by the transperineal/translabial ultrasonography are related to the poor visualization of the cervix during labor, due to the poor echogenicity, relative small thickness after the effacement, the impossibility to obtain acceptable resolution at a considerable depth without a sonographic 'window' and because of the fetal presentation protruding through the cervical os during dilatation.¹

Cervical effacement was studied by Ziliani et al¹⁰⁹ in 86 early (latent phase) labor term pregnancies with intact membranes by transperineal sonography and showed a progressive shortening of the cervical canal concomitant with the opening of a funnel-shaped internal cervical os. Then both orifices fused, completing the process of effacement, followed in all nulliparous and parous patients by cervical dilatation of the external os (stationary during initial phase but quickly evolving after the completion of effacement).

In 2003, Saito et al¹¹⁰ investigated 73 uncomplicated parturient women at term. The cervical length was evaluated before, during and after a uterine contraction by transvaginal ultrasound in the first stage of labor and the degree of cervical shortening during the contraction was determined. The cervix was shortened by approximately 50% during a

uterine contraction in the normal course of labor in both nulliparous and parous women, significantly greater than in false labor, prolonged latent phase and protracted active phase. These data suggest that the impact of uterine contraction on real-time ultrasound cervical shortening/effacement could help in differentiating inefficient uterine contractions from normal ones and thus, to predict the subsequent course of labor.

Fetal Head Position in Labor

Leopold's maneuvers followed by transvaginal digital examination are currently performed for intrapartum assessment of the fetal head position and station, and the clinical obtained data are considered crucial in monitoring the progress of labor and the decision-making for instrumental vaginal delivery or cesarean section.^{111,112}

However, clinical examination is considered experience-dependent and highly subjective. Intrapartum sonographic depiction of fetal head position has been proposed since 1989 by Rayburn et al¹¹³ in a study with 86 laboring women presenting an arrest of >7 cm cervical dilatation and found that ultrasound techniques improved diagnosis of fetal head position, especially in differentiating between persistent posterior or anterior occipital positions. The clinical examination alone was often inexact, especially in cases of failure of adequate progression during late labor associated with scalp edema or caput formation.

The concept that intrapartum ultrasonographic assessment of fetal head position is feasible and more precise than the clinical transvaginal assessment was sustained by other authors in the following decades. Later, the station level and progression of the fetal head were found better evaluated by ultrasound than clinically.

Ultrasound Accuracy in Assessment of Fetal Head Position

Studies that compared digital examination and transabdominal ultrasound of the fetal head position show an agreement of more than 70% between the two techniques, but only for the second stage of labor and with a 45° variation tolerated.

Kreiser et al (2001) in a study with 44 women showed that the error rate in detecting fetal occiput position in the second stage of labor was significantly lower when they used combined transabdominal and transperineal sonography (6.8%), compared to vaginal examination (29.6%). Parity, maternal body mass index or fetal weight had no influence on the error rate of vaginal examination for fetal occiput position.¹¹⁴

Sherer et al (2002)¹¹⁵ found that intrapartum ultrasound increases the accuracy of fetal head position assessment

during active labor and may serve as an educational tool for physicians in training. Digital examinations performed by senior residents or attending physicians, and followed by transverse suprapubic transabdominal ultrasound assessment, in 102 consecutive patients during active labor showed an overall high rate of error (76%) in clinical determination of fetal head position. Attending physicians showed an almost two-fold higher success rate in depicting correct fetal head position by physical examination *vs* residents in the $\pm 45^\circ$ analysis. The same authors concluded that intrapartum ultrasound increases the accuracy of fetal head position assessment in the second stage of labor as well, demonstrating a high rate of error (65%) in transvaginal digital determination of fetal head position.¹¹⁶

Akmal et al (2002) reached similar conclusions and proposed the application of intrapartum suprapubic ultrasound as a more precise examination in the detection of fetal head position, because the routine digital examination during labor failed to identify the correct fetal position by more than 45° in the majority of the 496 examined cases in the second stage of labor.¹¹⁷ Thus, the use of digital pelvic examination failed to determine the fetal head position in 34% of women in labor and, of those in whom the position was determined, the findings of the digital and sonographic examinations were in agreement in only 49.4% of cases.¹¹⁷

Souka et al (2003) tested in 148 parturient women the feasibility of transabdominal ultrasound for determining fetal head position in laboring women and compared to digital examination. The overall fetal head position assessment by digital examination was accurate in 31% of the cases in the first stage and 66% of the cases in the second stage of labor. In the second stage, it was three times more likely for the assessment not to be possible digitally, if the occiput was posterior.¹¹⁸

Chou et al (2004) published the data from 88 second stage labor assessments. The fetal head positions were clinically and sonographically evaluated and then compared with the actual position at spontaneous vaginal delivery or at cesarean delivery. Digital transvaginal examination was correct in 71.6% of cases, whereas intrapartum ultrasound examination prediction was concordant with the outcome in 92%.¹¹⁹

In 2005, Dupuis et al¹²⁰ by examining 110 patients during the second stage of labor found agreement between the clinical and ultrasound evaluations in 70% of cases, which increased to 80% when a difference of up to 45° in the head rotation was acceptable, but the presence of caput succedaneum and fetal head position with occiput posterior or transverse were associated with a significantly higher rate of clinical error (50%).

Potential Advantages of Ultrasound use in Guiding Instrumental Delivery by Fetal Head Position Determination

Evaluating fetal head position in 64 instrumental deliveries, Akmal et al¹²¹ reported a failure in correct identification of the fetal head position by more than 45° in 27% of the vaginal digital examinations. The accuracy of clinical digital evaluation was worse in lateral/posterior positions of the occiput (54%) comparing to occiput-anterior position (83%). The results were even worse when the fetal head was in station 0/above (33%) than in the clinical locations below station 0 (77%), emphasizing the importance of ultrasound during the second stage of labor and especially before instrumental vaginal delivery.

Wong et al¹²² demonstrated that the accuracy of vacuum cup placement prior to vacuum extraction can be improved using transabdominal ultrasonographic assessment of the fetal head position in a study of 50 prolonged second stage labors.

Therefore, in time, transabdominal ultrasonography was proven to be a simple, quick and efficient way of increasing the accuracy of the assessment of fetal head position during both first and second stages of labor and should be performed routinely before instrumental delivery.

Ultrasound Assistance in Occipitoposterior Prediction at Delivery

Roughly, 5% of all fetuses are delivered in occipitoposterior position. This presentation is associated with increased rates of cesarean or instrumental delivery, and as a result with increased perinatal morbidity and severe maternal perineal trauma.¹²³⁻¹²⁸

Previous studies have demonstrated that clinical assessment of the fetal occiput is inaccurate both in the first and second stage of labor and the results are worse when the occiput is posterior,¹¹⁴⁻¹²² therefore, serial ultrasound evaluations were proposed during the first and second stages of labor to demonstrate, if the occipitoposterior position at delivery is in fact a persistence of this fetal head position or is developing through a malrotation during labor from an initially occipitoanterior position.

Souka et al¹¹⁸ assessed ultrasonographically the rotation of the fetal head in normal and obstructed labor; occipitoposterior position was found highly unlikely when labor begins in the occipital anterior position. Persistent occipital posterior position was found developing through failure to rotate from an initial occipital posterior or transverse position.

Previously (1998), Gardberg et al¹²⁹ had concluded that in 68% of the cases, persistent occiput posterior position develops through a malrotation during labor from an initially occipitoanterior position and only 32% of persistent cases were occipitoposterior (dorsoposterior) at the onset of labor.

However, both studies offered a small number of occiput posterior deliveries,¹³⁰ not enough to offer statistical significance, and there are also some differences in the design of the two studies, at the assessment timing: Souka et al examined women during the first and second stages of active labor, whereas Gardberg et al examined almost half of the patients before the onset of labor and the rest of them in the first phase of active labor. Akmal et al¹³⁰ in a cross-sectional study involving transabdominal sonography meant to determine fetal occipital position in 918 singleton pregnancies with cephalic presentation during active term labor. The authors demonstrated that the majority of occiput posterior positions during labor rotate to the anterior position even at fully dilated cervix: The occiput was posterior in 33, 34 and 19% of fetuses at the respective cervical dilatations of 3 to 5, 6 to 9 and 10 cm and this persisted at delivery in only 21.5, 31.7 and 43.8% of cases. Also the vast majority of occiput posterior positions at delivery were found consecutive of persistence of this position during labor rather than malrotation from an initial transverse or anterior occiput. Thus, 70%, 91% and 100% of occipitoposterior deliveries were in this position at 3 to 5, 6 to 9 and 10 cm of cervical dilation, respectively. The study confirmed previous reports regarding the high incidence of cesarean section and oxytocin use in occipitoposterior deliveries.

In 2005, Lieberman et al¹³¹ aimed to evaluate the changes of fetal head position during labor in a prospective cohort study of 1562 labors. Ultrasound evaluations were stored at enrollment, epidural administration and during advanced labor (>8 cm), and their analysis showed that, from the occipitoposterior positions in advanced labor, only 20% remained occipitoposterior at delivery. Changes in fetal head position were common and in 36% of the cases the occipitoposterior position was found on at least one ultrasound examination. Also, the labors accompanied by epidural anesthesia presented a higher incidence of occipitoposterior position at delivery (12.9% vs 3.3%), although at enrollment the occipitoposterior position's incidence was similar (23.4%) as the group of women who did not receive epidural anesthesia (26%).

Fetal Head Progression during Labor

Ultrasound Evaluation of Fetal Head Engagement

Engagement of the fetal head is essential in assessing the progression of labor. The presence of caput or molding may

impair the correct clinical vaginal assessment, as this is an indirect evaluation of fetal head engagement during the vaginal palpation of the presented part at the level of maternal ischial spines.

Dietz et al in 2005 proposed the evaluation of fetal head engagement, using the symphysis pubis as reference,⁷⁴ measuring the minimum distance between the presenting part and the 'infrapubic line'.

In a prospective study in 2003, Sherer and Abulafia¹³² supported the use of intrapartum transabdominal assessment of fetal head engagement, by demonstrating a high rate of agreement (85.6%) between transvaginal digital assessment (fetal head positioned at least at maternal ischial spine station 0) and ultrasound determination on transverse suprapubic plane (fetal biparietal diameter below the maternal pelvic inlet), in 119 nulliparous and 103 multiparous pregnant women, and found no influences related to the examiner experience, maternal age, gravidity, maternal body mass index, gestational age, cervical dilatation, effacement, membrane status, ischial spine station of the fetal head, fetal head position at ultrasound assessment, birth weight and mode of delivery. The authors agreed with the concept proposed in 1993 by Knight et al that vaginal findings may be misleading¹³³ and proposed the direct sonographic assessment of engagement of the fetal head at the pelvic inlet as a potential more precise evaluation irrespective of caput succedaneum formation or the presence of significant molding.

Sonographic depiction of fetal head engagement was performed as follows. The pelvic inlet was assessed by placing the transducer transabdominally in a transverse fashion immediately above the maternal symphysis pubis and directed cephalad toward the maternal sacral promontory. The sacral promontory, although not visible sonographically, was considered to be positioned between L5 and S1, at a level previously marked. Utilizing midline intracranial structures (cavum septi pellucidi, falx cerebri and thalami) the level of the BPD was ascertained. When the BPD was located below the line extending between the superior aspect of the maternal symphysis pubis and the maternal sacral promontory (demarcating the pelvic inlet), the fetal head was considered to be engaged.

In the same study,¹³³ the relative cephalad angulation of the transversely positioned suprapubic transducer toward the maternal promontory was considered to define the engagement, knowing that the whole pelvis is tilted forward and accordingly with the woman in the standing position the plane of the pelvic inlet creates an angle of between 50° and 60° with the horizontal; therefore, the cranium was considered to be not engaged when the BPD was visualized at an angle above the pelvic inlet.

Ultrasound Evaluation of Fetal Head Progression

Many studies provided sonographic data regarding fetal head progression in an infrapubic or translabial approach, aligned in the midsagittal plane, and the settings of the machine adjusted for widest insonation angle, maximum depth and lowest output frequency, so that the pubic symphysis and fetal skull contour could be visualized almost entirely on the screen. Also the patient in a semirecumbent position with her legs flexed may be invited to push (push test) to dynamically check the progression of the fetal head within the birth canal. Care should be taken when performing the technique to exclude caput succedaneum from any of the presented measurements (Fig. 1).

Dietz et al in 2005⁷⁴ proposed a translabial ultrasound technique to assess fetal head engagement. Later studies used the so called ‘distance of progression’ or ‘head

progression’, that is the minimal distance between the ‘infrapubic line’ and the presenting part (lowest part of the fetal skull) (Fig. 2).

In 2006, Henrich et al¹³⁴ using the midsagittal infrapubic translabial insonation considered the widest fetal head diameter and its movement with regard to the infrapubic line and the long axis of the symphysis during pushing. The ‘head direction’ was later defined as the angle between the infrapubic line and the major longitudinal axis of fetal (perpendicular to the BPD) and three types of head direction were determined: ‘head-up’ (when the line drawn perpendicular to the widest diameter of the fetal head points ventrally at an angle of $>30^\circ$), ‘head-down’ (when this angle is $<0^\circ$) and ‘horizontal’ (all other angles).^{135,136} In the same, three-dimensional reconstruction from a computed tomographic assessment of a normal female pelvis

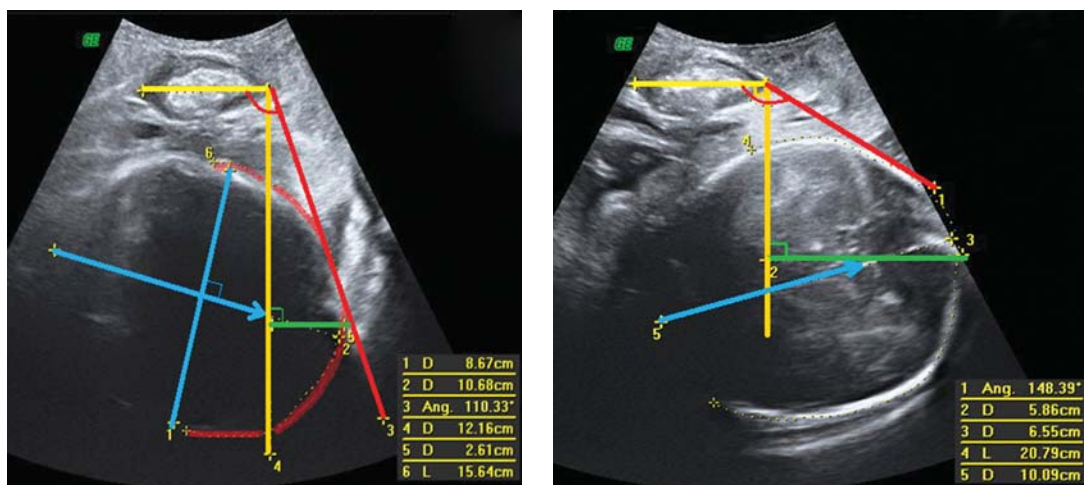


Fig. 1: Normal progression in midsagittal infrapubic approach; the settings of the machine adjusted for widest insonation angle and maximum depth, so that the pubic symphysis and fetal skull contour could be visualized almost entirely on the screen. Serial evaluations of progression angle (red) showing the increase of angle from 110 to 148° in 30 minutes; head progression (green) in the same period is increasing from 26 to 65 mm; evolution of fetal head direction (blue) from ‘head-down’ to ‘head-up’. Longitudinal axis of pubic symphysis and infrapubic line are figured in yellow



Fig. 2: Lack of progression in midsagittal infrapubic approach. Serial evaluations with stationary angle of progression (red) $<110^\circ$; stationary head progression/distance of progression (green) <20 mm; persistent head-down direction: Line drawn perpendicular to the widest diameter of the fetal head (blue) points ventrally at an angle of $<0^\circ$ (downward direction). Longitudinal axis of pubic symphysis and infrapubic line are figured in yellow

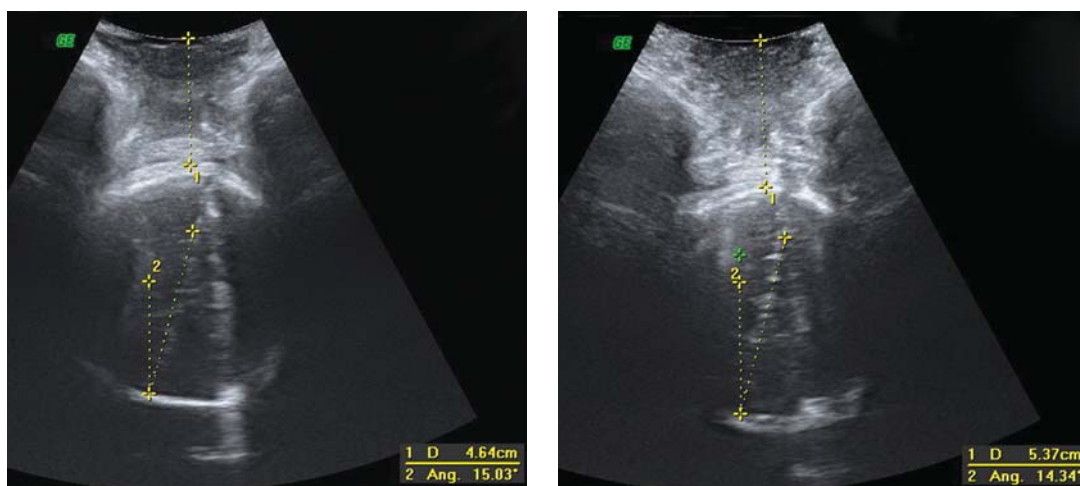


Fig. 3: Transverse infrapubic translabial incidence. Evaluation of fetal head rotation with stationary 'midline angle' (Ang), approximately 15°. Lack of fetal head progression with stationary head to perineum distance (D), approximately 5 cm

demonstrated that a line parallel to the infrapubic line and 3 cm caudal to it indicates the level of the ischial spines. This finding was considered important in estimation of the head station. Head progression and head direction proved to be useful in the pilot study of 20 patients (Fig. 3), aimed to assess the prognosis for operative vaginal delivery: During push-test, the 'head-up' direction and objective descent of the fetal head diameter below the infrapubic line, resulted in successful operative delivery. Lack of passage below the infrapubic line and horizontal or downward head direction were considered poor prognostic signs.

In a similar study, Ghi et al¹³⁷ showed that when the fetal head was directed downward on the sonogram, the station assessed clinically was most frequently $\leq +1$ (77.2%); when the direction was horizontal, the station was most frequently $\leq +2$ (89.8%) and when the fetal head was directed upward, the station was usually $\geq +3$ (88.5%). Roughly, in fetuses with a persistent head-down direction the presenting part was above the midpelvis and cesarean section would be the most appropriate choice. The horizontal direction of the fetal head was diagnosed in almost all cases (90%) with a midpelvis position of the presenting part, and in case of persistence, further management depends on the clinician's experience or clinic's protocol. Finally, a head-up direction indicated that the head was in the lower third of the pelvis in almost all cases (89%).¹³⁷

In 2009, Barbera et al¹³⁸ proposed the measurement of a new parameter of transperineal ultrasound the angle of progression as an objective, accurate and reproducible method for assessing the descent of the fetal head during labor, after studying 88 term laboring patients with a singleton fetus in cephalic presentation. The angle of progression was measured between the long axis of the pubic symphysis and a line extending from its most inferior portion

tangentially to the fetal skull and values of at least 120° measured during the second stage of labor were always associated with subsequent spontaneous vaginal delivery. A significant linear association was found between clinical digital assessments of station and the measurements of head descent angle. However, because of the large standard deviations for each station, the prediction intervals of the progression angle were found with important overlap, thereby compromising any precision in predicting the angles from clinical station assessment. In turn, the clinical station as assessed by digital examination presented important variations at any given progression angle, which still represents a more objective evaluation. The authors also observed that larger progression angles during the second stage of labor were associated with significantly decreased time to delivery. They also noted, a good repeatability and reproducibility of the technique (intraobserver variability = 2.9° and interobserver error = 1.24°).¹³⁸

Kalache et al¹³⁹ using the same technique¹³⁸ in 26 term women with prolonged second stage of labor and occipito-anterior position, showed a strong relationship between the angle of progression and the indication of cesarean section delivery. Authors found that the estimated probability of either an easy and successful vacuum extraction or spontaneous vaginal delivery for an angle of progression of 120° was 90%.

Also in 2009, Barbera et al established the progression angles in midsagittal transperineal sectional plane corresponding for each clinical station (-5 to +5), using 70 nonpregnant women computed tomography scans studied with the aid of a geometric model.¹⁴⁰ Then, in 88 laboring patients, the correlation between digitally assessed fetal head station and the progression angles as established for each station was proven to be poor, especially at stations below zero (0 station - 18%, +1 - 16%, +2 - 2.6%, +3 - 0%),

where the correct digital assessment has important clinical impact. Only allowing a variation of ± 2 cm, the agreement reached 92, 56, 39 and 40% respectively. As the safe indication of forceps (low) requires according ACOG recommendations the fetal descend at the +2 station, the findings suggest that it is imperative to develop objective methods in the evaluation of the fetal head during the second stage of labor.

Not all the sonographic measurements were proposed in the midsagittal transperineal sectional plane. In 2008, Eggebø et al⁹⁶ suggested that fetal head-perineum distance may be of use in the prediction of labor outcome before labor induction⁹⁶ and also in women with prelabor rupture of membranes at term,⁹⁷ knowing also that the measurement is reproducible.⁹⁷ Because the birth canal is curved, the authors suggested that there is an association, but not a direct relationship, between fetal head-perineum distance and fetal head station. However, a potential source of error in the measurement may appear because of the different degree in compression of the soft tissue, but again, the authors have found the interobserver and intraobserver variability of the method to be acceptable.⁹⁷

A prospective comparative study including the angle of progression,^{138,139} linear measurements^{74, 96} and the semi-subjective assessment of head direction¹³⁴ were already suggested in order to answer the question regarding the best method in ultrasound labor assessment.^{136,139} Therefore, further investigation will be necessary to clarify the potential role of the described parameters of progression in the management of prolonged or normal second stage of labor. Also, we believe that extensive studies should be carried with respect to various clinical situations, as the mentioned studies included only pregnancies with the fetus in the occipitoanterior position. In the occipitoposterior position, fetuses are known to have head elongation due to vertex molding and should therefore be analyzed separately.

Ultrasound Evaluation of Fetal Head Rotation

Volume reconstruction with surface rendering of the fetal skull was used by Fuchs et al in 2008 to demonstrate internal rotation of the fetal head.¹⁴¹ An easier technique to evaluate the head rotation was proposed in 2009 the study mentioned above by Ghi et al¹³⁷ by the visualization of falx cerebri in transverse infrapubic insonation. The authors investigated the ability of ultrasound to diagnose fetal station in the second stage of labor in 60 uncomplicated pregnancies at term, with fetuses in vertex presentation by serial digital examinations and translabial sonography. The direction of the head was noted and categorized as downward, horizontal or upward as previously presented¹³⁴ and by rotating the

transducer in the transverse plane the rotation of the head was evaluated by the appreciation of the angle between the anterior-posterior axis of maternal pelvis and cerebral midline echo - so-called 'midline angle'. Failure to visualize the cerebral midline or a rotation $\geq 45^\circ$ was associated with a station $\leq +2$ in 95.1% examinations. Conversely, a rotation of $<45^\circ$ was associated with a station $\geq +3$ in 69.2% examinations. The probability of a station +3 cm or more was particularly high when an upward direction of the head was seen in combination with a rotation of $<45^\circ$ (95.2%). Inter- and intraobserver variability suggested good reproducibility of the method and the comparisons between clinical and sonographic findings demonstrated a statistically significant relationship.

Most studies so far has been obtained with standard two-dimensional ultrasound but intentions to implement three-dimensional (3D) ultrasound technology were expressed for a more accurate alignment of anatomic landmarks of maternal and fetal structures.

Molina et al¹³⁵ compared digital and ultrasound assessment of occipital position and evaluated the repeatability of the measurements (head direction, angle of the middle line, progression distance and angle of progression) in 50 women in the second stage of labor after transperineal acquisition of three-dimensional blocks of the fetal head. In agreement with previous studies, they found that digital pelvic examination is not accurate in determining the fetal head position during labor, as in 66% cases it failed to identify the correct fetal head position by more than 45° . The percentage of correct identification of the fetal head position by digital examination increased with cervical dilatation. All four 3D ultrasound measurements that were acquired were found to be reproducible, with the best correlations being for the progression angle, offering the highest intraclass correlation coefficients for the same observer (0.94; 95% CI, 0.90-0.97) and for different operators (0.84; 95% CI, 0.73-0.91). The progression angle was also the measurement with the smallest limits of agreement (LOA) in the Bland-Altman test, for intraobserver (bias 0.9; LOA, -9.2% to 11.1%) and interobserver (bias 1.5; LOA, -15.4 to 18.3%) variability.

The results regarding the repeatability of measurements in the mentioned study were very similar to those obtained using 2D ultrasound equipment in the study of Dückelmann et al¹⁴² who demonstrated that ultrasound experience or fetal head station did not affect the reliability of progression angle measurement.

Ultrasound has an established role in the management and assessment of labor,¹⁴³ as it has been demonstrated that it improves obstetrical abilities and decisions. Transperineal

ultrasound was a good predictor of labor outcome in late third-trimester when planning spontaneous labor, by evaluation of head engagement (position of fetal head in relation to pubic symphysis), or bladder position on Valsalva. Transvaginal and transperineal sonography proved to be useful when planning induction of labor by cervical measurements (length, angle), or head to perineum distance, and has been shown to have a significant association with the induction-to-delivery interval and the risk for cesarean section. Regarding the management of labor there is extensive evidence that digital pelvic examination is experience-dependent, highly subjective and poorly reproducible and does not provide accurate assessment of the position and progression of the fetal head during the first and second stage of labor. Intrapartum ultrasound on the contrary, becomes an important examination for the assessment of fetal head position, and for the decision-making before instrumental vaginal delivery.

Regarding fetal head progression during labor, ultrasound provides important information regarding the assessment of fetal head engagement, irrespective of caput succedaneum or the presence of significant molding. The fetal head progression in an infrapubic or translabial midsagittal approach was demonstrated as a quick, objective and reproducible way of increasing the accuracy of the assessment compared to clinical digital evaluation with linear and angular measurements been proposed (distance of progression, head direction, angle of progression and head-perineum distance). During the fetal head descend, ultrasound was found useful in evaluation of fetal head rotation by surface rendering of the fetal skull, or by appreciation of the 'midline angle' between the anterior-posterior axis of maternal pelvis and cerebral midline echo in the perineal transverse plane. Therefore, the application of ultrasound in labor may serve not only to monitor the progress of labor but also for performing a safe operative delivery and can also help in the prediction of whether a vaginal delivery would be successful.

Recently, three-dimensional assessment software designed for labor measurements was developed and all the measurements mentioned above may be calculated based on a single 3D volume scan, stored, superimposed and displayed with previous set of measurements in order to visually appreciate any significant changes in fetal head progression and rotation during labor.

The cesarean section rate continuous to increase, reaching an all-time high in some countries. A significant part of this rise is due to the so-called unjustified cesarean sections, that is the ones without a clear indication. Therefore, efforts should be made to describe the value of every available objective parameter in obstetric practice, in

order to form a system that would assess labor and its progress objectively. The aim of such a system would be to avoid unnecessary cesarean sections and on the contrary justify any decisions for instrumental delivery or cesarean section, especially now that medicolegal issues play a key role in medicine. Bigger studies are needed in order to draw safe results. The development of a sonopartogram that will aim to monitor labor and delivery objectively and to increase the clinicians' confidence in the decision-making regarding the mode of delivery may be the answer to many of these problems.

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