



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

ARCHIVIO ISTITUZIONALE DELLA RICERCA

Alma Mater Studiorum Università di Bologna Archivio istituzionale della ricerca

Fetal head progression and regression on maternal pushing at term and labor outcome

This is the final peer-reviewed author's accepted manuscript (postprint) of the following publication:

Published Version:

Youssef A., Brunelli E., Azzarone C., Di Donna G., Casadio P., Pilu G. (2021). Fetal head progression and regression on maternal pushing at term and labor outcome. *ULTRASOUND IN OBSTETRICS & GYNECOLOGY*, 58(1), 105-110 [10.1002/uog.22159].

Availability:

This version is available at: <https://hdl.handle.net/11585/860216> since: 2024-09-04

Published:

DOI: <http://doi.org/10.1002/uog.22159>

Terms of use:

Some rights reserved. The terms and conditions for the reuse of this version of the manuscript are specified in the publishing policy. For all terms of use and more information see the publisher's website.

This item was downloaded from IRIS Università di Bologna (<https://cris.unibo.it/>).
When citing, please refer to the published version.

(Article begins on next page)

Fetal head progression and regression on maternal pushing at term and labor outcome

A. Youssef¹, E. Brunelli¹, C. Azzarone¹, G. Di Donna¹, P. Casadio¹, G. Pilu¹

¹Department of Obstetrics and Gynecology, Sant'Orsola Malpighi University Hospital, University of Bologna, Bologna, Italy

Corresponding author:

Dr. Aly Youssef

Department of Obstetrics and Gynecology,

Sant'Orsola-Malpighi University Hospital

University of Bologna,

Via Massarenti 13, 40138 Bologna, Italy

e-mail: aly.youssef78@gmail.com

Running head: fetal head descent with pushing at term

Keywords: labor, angle of progression, transperineal ultrasound, translabial ultrasound

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/uog.22159

Contribution

What are the novel findings of this work?

- The increase in the angle of progression at maternal pushing at term before the onset of labor is associated with a shorter active second stage of labor.
- In about 15% of women the fetal head regresses in the birth canal with Valsalva maneuver. This finding however is not associated with adverse labor outcomes.

What are the clinical implications of this work?

- The present data increase our understanding of the role of maternal pushing efficiency, which seem to be detectable before the onset of labor, in the mechanism of birth.

Abstract

Objectives: The aim of our study, was two-fold; first to evaluate the association between the change in the angle of progression (AoP) with maternal pushing and labor outcome. Second, to assess the incidence and clinical significance of the reduction of AoP under maternal pushing.

Methods: We recruited a group of nulliparous women with singleton pregnancy at term. We measured AoP at rest and at maximum Valsalva maneuver before the onset of labor. The difference between AoP at Valsalva and that at rest (Δ AoP) was calculated for each woman. Following delivery and data collection, we assessed the association between Δ AoP and various labor outcome, including cesarean section (CS), various labor duration, APGAR score, and admission to Neonatal Intensive Care Unit (NICU). Lastly, the prevalence of women with reduction of AoP at Valsalva maneuver (AoP regression group) was calculated and its association with the mode of delivery and labor durations was assessed.

Results: Overall, 469 women were included in the analysis. Among these, 273 (58.2%) had spontaneous vaginal birth, 65 (13.9%) had instrumental delivery and 131 (27.9%) underwent CS. Women in the CS group were older, had narrower AoP at rest and at Valsalva, had a higher incidence of epidural administration and lower APGAR score at 1 and 5 minutes in comparison with the vaginal delivery group. Δ AoP was comparable between the two groups. On Pearson correlation, AoP at rest and at Valsalva had a significant negative correlation with the duration of the first stage of labor. Δ AoP showed a significant negative correlation with the active second stage of labor (Pearson's r -0.125, P value=0.02). Survival outcomes based on Cox-regression model showed that Δ AoP was an independently associated with

the duration of the active second stage (hazard ratio 1.014; 95% C.I. 1.003 to 1.025; P = 0.012) after adjusting for maternal age and BMI. Lastly, AoP reduction with Valsalva (regression) was found in 73 (14.7%) of women. In comparison with women who showed no or positive increase in AoP under Valsalva, the regression group did not demonstrate significant difference as regards maternal characteristics, mode of delivery, epidural analgesia, labor durations, APGAR scores or NICU admissions.

Conclusions: In nulliparous women at term before the onset of labor, narrower AoP at rest and at Valsalva, reflecting fetal head engagement, are associated with a higher risk of Cesarean delivery. Greater change of AoP from rest to Valsalva, reflecting more efficient maternal pushing, is associated with a shorter active second stage of labor. Fetal head regression with maternal pushing is present in about 15% of women and does not seem to have a clinical significance.

Introduction

Fetal head descent assessment in labor by digital examination is a fundamental skill in obstetrics, and remains the standard of care for the monitoring of labor progression^{1, 2}. However, many studies have questioned its reliability^{3, 4}. Digital examination has an error rate for fetal occiput position determination that ranges from 20 to 70% when considering ultrasound as the gold standard⁵. On the other hand, clinical examination for fetal head station assessment is subjective and poorly reproducible^{3, 4}. The use ultrasound in labor has been suggested as an accurate and reproducible complementary tool to digital examination⁶⁻⁸.

Many transperineal ultrasound (TPU) parameters have been suggested to assess the degree of fetal head engagement in the birth canal⁹⁻¹⁹. Among these, the angle of progression (AoP, also called the angle of fetal head descent) is one of the most studied^{9, 17, 18, 20-22}. Intrapartum measurements of AoP strongly correlate with labor outcome, such as cesarean section and failed instrumental delivery^{20, 23-26}.

Most studies measured TPU parameters in labor at rest, while the dynamic change of fetal head engagement has been rarely investigated^{13, 18, 25-28}. Efficient maternal pushing is normally associated with descent of the fetal head in the birth canal. Very recently, in a cohort of nulliparous women undergoing instrumental delivery, it was demonstrated that the fetal head regresses under maternal pushing efforts in some cases.²⁹ This phenomenon is not well-understood and has been rarely reported.

The aim of our study, was two-fold; first to evaluate the association between the change in the angle of progression with maternal pushing and labor outcome. Second to

assess the incidence and clinical significance of the fetal head regression under maternal pushing as measured by the angle of progression.

Accepted Article

Materials and Methods

This was a prospective cohort study. We recruited a non-consecutive series of nulliparous women with singleton pregnancy at term gestation (37-41 weeks). Women were recruited before the onset of labor during their routine visit at term at our University Hospital's outpatient clinics. We excluded women with any of the following criteria: non-cephalic presentations, previous uterine surgery, regular uterine contraction or ruptured fetal membranes. In addition to standard outpatient visit including vaginal examination and transabdominal scan to assess fetal biophysical profile, recruited women underwent a transperineal ultrasound before the onset of labor and immediately after the routine outpatient clinic assessment.

Transperineal ultrasound scan (TPU) (Figure 1)

Ultrasound was performed using a two-dimensional (2D) convex transducer covered by a sterile glove. The transducer was positioned on the midsagittal plane using a machine (Voluson P8 Ultrasound System or Voluson 730 Expert, GE Healthcare; Zipf, Austria), visualizing the pubic symphysis and the fetal skull. The angle of progression (AoP) was measured at rest and under maximum Valsalva maneuver, as previously described (videoclip 1) ⁹. The angle of progression is included between two lines, one passing through the long axis of the pubic symphysis and the other starting from the inferior edge of the pubic symphysis and passing tangential to the lowermost edge of the fetal skull. Images at maximum Valsalva were obtained following verbal instructions to the patient and education with the aid of visual feedback if needed ³⁰. The change in AoP from rest to Valsalva (ΔAoP) was calculated ($\Delta\text{AoP} = \text{AoP}_{\text{Valsalva}} - \text{AoP}_{\text{rest}}$). ΔAoP was used as an index of the efficiency of maternal pushing. We postulated that fetal head regression was present when the AoP

during maximum Valsalva was less than that in the resting state, thus having negative values of ΔAoP . This group was called “AoP regression group”. Women with no or any increase in AoP with Valsalva were called “AoP progression group”.

Following delivery, investigators consulted women’s medical records and collected the following data: mode of delivery, birthweight, gestational age at delivery, the use of epidural analgesia, duration of first, second and active second stages, APGAR score, and admission to Neonatal Intensive Care Unit (NICU). We then compared AoP values at rest, Valsalva and ΔAoP between women who delivered vaginally (spontaneous vaginal or instrumental delivery) and women who underwent a caesarean section (CS). We also assessed the correlation of AoP measurements and ΔAoP with various labor durations. Lastly, maternal characteristics and various labor outcomes were compared between the AoP regression and progression groups. In our hospital, vacuum is the only instrumental delivery performed.

Statistics

Mean, median, SD, range and frequencies were used as descriptive statistics. Differences between women who delivered vaginally and those who underwent CS were assessed by unpaired two-tailed Student’s t-test for continuous variables and Fisher Exact Test for categorical variables. Similar analyses were applied in the comparison between AoP progression versus AoP regression groups with Valsalva. The correlation between various AoP values, including ΔAoP , and labor durations were assessed by means of Pearson correlation. Lastly, multivariate Cox regression analysis was used to study the association between ΔAOP and labor durations. Cox regression analysis was adjusted for factors found to be associated with labor durations on Pearson’s correlation for continuous

variables and Student's t test for categorical variables. The statistical analyses were performed using 21.0 SPSS version (SPSS Inc., Chicago, IL, USA), and two-tailed P-values < 0.05 were considered statistically significant.

Ethics

The protocol of the present study was approved by the local Ethical Committee and a consent form was signed by each eligible patient in the outpatient clinic.

Results

Overall, 469 women were recruited for the purpose of the study. Population characteristics of the study population and the characteristics subdivided according to the mode of delivery (CS vs. vaginal delivery) are reported in the Table 1. Among the study population, 273 women (58.2%) had spontaneous vaginal birth, 65 (13.9%) had instrumental delivery and 131 (27.9%) delivered by CS. Indications for CS were abnormal findings in fetal heart monitoring (CTG) in 77 (58.8%) and dystocia in 54 (41.2%) women. Indications for instrumental delivery were CTG abnormalities in 42 (64.6%), dystocia in 13 (20.0%) and maternal exhaustion in 10 (15.4%) women. Regarding maternal characteristics, women in the CS group were older, had narrower AoP at rest and at Valsalva, had a higher incidence of epidural administration and lower APGAR scores at 1 and 5 minutes. No significant difference in Δ AoP was found between the two groups. No significant difference was observed between the two groups in the other population characteristics including rate of induction of labor, ethnicity, maternal BMI, birthweight, gestational age at ultrasound and delivery, or admission to NICU.

Results of the Pearson's correlation analyses are displayed in table 2. Both AoP at rest and at Valsalva had a significant negative correlation with the duration of the first stage of labor. The change of AoP from rest to Valsalva (Δ AoP) showed a significant negative correlation with the active second stage of labor (Pearson's r -0.125, P value=0.02). Survival outcomes based on Cox-regression model showed that Δ AoP was independently associated with the duration of the active second stage (hazard ratio 1.014; 95% C.I. 1.003 to 1.025; P = 0.012) after adjusting for maternal age and BMI. The more the increase of AoP

from rest to Valsalva the shorter the active second stage of labor. The 25th, 50th and 75th centile of Δ AoP were 2.2°, 8.2°, and 14.0°, respectively.

Table 3 demonstrates the data on AoP reduction with Valsalva (fetal head regression). AoP regression was found in 73 (14.7%) of women. In comparison with women who showed no or positive increase in AoP under Valsalva (the progression group), the regression group did not demonstrate any significant difference as regards maternal characteristics, mode of delivery, epidural analgesia, labor durations, APGAR scores or NICU admissions. Lastly, we analyzed the effect of epidural analgesia on the mode of delivery within the AoP regression group (Supplementary table 1). In the regression group, women who were administered epidural analgesia were more likely to deliver by cesarean section (18/47 versus 3/26, $P=0.017$), whereas no significant difference was found regarding spontaneous vaginal or instrumental delivery.

Discussion

Our study provides original data on the evaluation of the dynamic changes of angle of progression (AoP) before the onset of labor. This is the largest cohort of nulliparous undergoing transperineal ultrasound for the assessment of AoP before labor. Due to the large recruited population, we were able to analyze the significance of AoP values both at rest and at Valsalva, in addition to AoP change from rest to Valsalva. We demonstrated that narrower AoP values at term before the onset of labor (reflecting a higher pre-labor fetal head) both at rest and at Valsalva's maneuver were associated with a higher risk of cesarean delivery and with a longer first stage of labor. Interestingly, only the change of AoP from rest to Valsalva, reflecting maternal pushing efficiency, correlated with the duration of the active second stage of labor. This is the first study that analyzes together the values of AoP and the change in AoP before labor for the prediction of labor outcomes. According to our results, fetal head station and the change of station with maternal pushing seem two different and independent mechanisms needed for childbirth. Fetal head engagement, as assessed by single AoP values, reflects the interaction between fetal head dimensions and the maternal pelvis. On the other hand, the maternal ability to improve fetal head descent by pushing seems essential for the duration active second stage of labor.

The role of the angle of progression as an index of fetal head engagement has been investigated by many authors^{23, 26, 31-33}. Intrapartum measurements of AoP was found to be associated with the mode of delivery and labor duration^{9, 18, 20, 23, 26, 31}. When performed before the onset of labor, ultrasound findings have been found to correlate with labor outcome^{10, 34-37}. In fact, narrower AoP before the onset of labor were found to be associated with a higher risk of Cesarean section^{38, 39}. However, static AoP alone before the onset of

labor do not seem to be accurate enough to be applied in clinical practice. Providing a reliable predictive model of adverse obstetrical outcome before the onset of labor may be useful in counseling women about their future delivery. The change in AoP from rest to Valsalva added to the prediction of the active second stage duration but not to the mode of delivery.

Another original finding of our study is the analysis of the fetal head regression with Valsalva. In order to achieve efficient pushing, women should be able to increase their intraabdominal pressure and relax the pelvic floor. Recent studies have shed the light on the correlation between the pelvic floor function and childbirth. Various studies have found a correlation between smaller levator hiatal dimensions at rest and Valsalva with longer second stage of labor.⁴⁰⁻⁴³ Recently, in a multicenter study on women before instrumental delivery, the authors found that some women showed a higher fetal station with pushing in comparison with that at rest.^{29, 44} The authors speculated that this phenomenon of fetal head regression with Valsalva may be due the phenomenon of pelvic floor contraction rather than relaxation with Valsalva, known also as levator ani muscle coactivation.^{45, 46} Levator ani coactivation was previously found to be associated with less engaged fetal head at term and with longer second stage of labor.^{42, 43, 47} However, fetal head regression with maternal pushing before the onset of labor has not been previously studied. In our study, fetal head regression was present in about 15% of women and it was not associated with the mode of delivery nor the various durations of labor. The lack of association of fetal regression with labor durations, contrary to what was previously found with levator ani coactivation, suggests that these two phenomena are different entities.

In the regression group, we observed a higher incidence of cesarean delivery in women who administered epidural analgesia. Epidural analgesia may lead to partial relaxation of the pelvic floor muscles which may theoretically counteract a pelvic floor hypertone if present. However, our data suggest that women who do not push efficiently are unlikely to be helped by epidural analgesia. When interpreting these findings it is important to consider two points. Firstly, although it is hypothesized that fetal head regression with pushing is associated with levator ani muscle coactivation, there are no solid data to prove this association. Secondly, many women especially in our hospital, require or are offered epidural analgesia when they already have a slowly progressing labor which may lead to selection bias.

Our study has some limitations. Labor is a complex process, and fetal head engagement before labor, although is associated with labor outcome, is unlikely to be clinically useful when used alone. This also applies to the association between the change in AoP with Valsalva and the duration of the active second stage of labor. This association was statistically significant although it is unlikely to be strong enough to reach clinical significance. Further studies integrating transperineal ultrasound with other predictors of labor outcome may be needed in order to obtain a clinically useful predictive model. Secondly, although we found an association between the change in AoP and the active second stage duration, we could not comment whether it is a modifiable factor. Previous studies have shown that visual feedback may improve pelvic floor relaxation and maternal pushing efficiency^{30, 43, 48, 49}. Further studies assessing the efficacy of interventions aiming at improving fetal head descent with maternal pushing (e.g. by using visual feedback) on labor outcome are needed. In the present study women with no change in AoP with Valsalva

were allocated to the AoP progression group (n=10). This choice may be debatable. However, we repeated the analysis by assigning these women to the AoP regression group with no change in the results. Lastly, it may be argued that women with cesarean or instrumental delivery due to fetal heart monitoring abnormalities should be excluded as it is unlikely that ultrasound indices of fetal head engagement can predict these events. In our study, we analyzed the data following the exclusion of operative deliveries due to CTG anomalies and we found no difference in the results. Consequently, we reported the results of the whole population as this would increase the external validity of our results.

To sum up, we found that narrower AoP at rest and at Valsalva, reflecting fetal head engagement, are associated with a higher risk of Cesarean delivery. On the other hand, higher change of AoP from rest to Valsalva, reflecting efficient maternal pushing, is associated with a shorter active second stage of labor. In our population, fetal head regression with maternal pushing occurred in about 15% of women and did not seem to have a clinical significance.

Declaration of interests

The authors report no declaration of interest.

Accepted Article

References

1. Cunningham FG, Hauth JC, Leveno KJ, III GLC, Bloom SL, Wenstrom KD. Williams Obstetrics. Maternal anatomy. 22nd ed: McGraw-Hill:New York; 2005. p. 13-38.
2. American College of O, Gynecology. Operative vaginal delivery. Clinical management guidelines for obstetrician-gynecologists. American College of Obstetrics and Gynecology. International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics 2001;**74**:69-76.
3. Dupuis O, Silveira R, Zentner A, Dittmar A, Gaucherand P, Cucherat M, Redarce T, Rudigoz RC. Birth simulator: reliability of transvaginal assessment of fetal head station as defined by the American College of Obstetricians and Gynecologists classification. Am J Obstet Gynecol 2005;**192**:868-874.
4. Buchmann E, Libhaber E. Interobserver agreement in intrapartum estimation of fetal head station. Int J Gynaecol Obstet 2008;**101**:285-289.
5. Dupuis O, Ruimark S, Corinne D, Simone T, Andre D, Rene-Charles R. Fetal head position during the second stage of labor: comparison of digital vaginal examination and transabdominal ultrasonographic examination. Eur J Obstet Gynecol Reprod Biol 2005;**123**:193-197.
6. Ghi T, Eggebo T, Lees C, Kalache K, Rozenberg P, Youssef A, Salomon LJ, Tutschek B. ISUOG Practice Guidelines: intrapartum ultrasound. Ultrasound Obstet Gynecol 2018;**52**:128-139.
7. Ramphul M, Ooi PV, Burke G, Kennelly MM, Said SA, Montgomery AA, Murphy DJ. Instrumental delivery and ultrasound : a multicentre randomised controlled trial of ultrasound assessment of the fetal head position versus standard care as an approach to prevent morbidity at instrumental delivery. BJOG 2014;**121**:1029-1038.
8. Youssef A, Ghi T, Pilu G. How to perform ultrasound in labor: assessment of fetal occiput position. Ultrasound Obstet Gynecol 2013;**41**:476-478.
9. Barbera AF, Pombar X, Perugino G, Lezotte DC, Hobbins JC. A new method to assess fetal head descent in labor with transperineal ultrasound. Ultrasound Obstet Gynecol 2009;**33**:313-319.
10. Gray's Anatomy. The Anatomical Basis of Clinical Practice edited by Susan Standring, 40esima edizione, [S.I.], Elsevier Limited, 2008 (Elsevier Masson, 2009).
11. Dietz HP, Lanzarone V, Simpson JM. Predicting operative delivery. Ultrasound Obstet Gynecol 2006;**27**:409-415.
12. Eggebo TM, Gjessing LK, Heien C, Smedvig E, Okland I, Romundstad P, Salvesen KA. Prediction of labor and delivery by transperineal ultrasound in pregnancies with prelabor rupture of membranes at term. Ultrasound Obstet Gynecol 2006;**27**:387-391.
13. Henrich W, Dudenhausen J, Fuchs I, Kamena A, Tutschek B. Intrapartum translabial ultrasound (ITU): sonographic landmarks and correlation with successful vacuum extraction. Ultrasound Obstet Gynecol 2006;**28**:753-760.
14. Ghi T, Farina A, Pedrazzi A, Rizzo N, Pelusi G, Pilu G. Diagnosis of station and rotation of the fetal head in the second stage of labor with intrapartum translabial ultrasound. Ultrasound Obstet Gynecol 2009;**33**:331-336.
15. Youssef A, Bellussi F, Montaguti E, Maroni E, Salsi G, Morselli-Labate AM, Paccapelo A, Rizzo N, Pilu G, Ghi T. Agreement between two- and three-dimensional transperineal ultrasound methods for assessment of fetal head-symphysis distance in active labor. Ultrasound Obstet Gynecol 2014;**43**:183-188.
16. Youssef A, Bellussi F, Maroni E, Pilu G, Rizzo N, Ghi T. Ultrasound in labor: is it time for a more simplified approach? Ultrasound Obstet Gynecol 2013;**41**:710-711.
17. Duckelmann AM, Bamberg C, Michaelis SA, Lange J, Nonnenmacher A, Dudenhausen JW, Kalache KD. Measurement of fetal head descent using the 'angle of progression' on transperineal

ultrasound imaging is reliable regardless of fetal head station or ultrasound expertise. *Ultrasound Obstet Gynecol* 2010;**35**:216-222.

18. Tutschek B, Braun T, Chantraine F, Henrich W. A study of progress of labour using intrapartum translabial ultrasound, assessing head station, direction, and angle of descent. *BJOG* 2011;**118**:62-69.

19. Youssef A, Maroni E, Cariello L, Bellussi F, Montaguti E, Salsi G, Morselli-Labate AM, Paccapelo A, Rizzo N, Pilu G, Ghi T. Fetal head-symphysis distance and mode of delivery in the second stage of labor. *Acta Obstet Gynecol Scand* 2014;**93**:1011-1017.

20. Kalache KD, Duckelmann AM, Michaelis SA, Lange J, Cichon G, Dudenhausen JW. Transperineal ultrasound imaging in prolonged second stage of labor with occipitoanterior presenting fetuses: how well does the 'angle of progression' predict the mode of delivery? *Ultrasound Obstet Gynecol* 2009;**33**:326-330.

21. Molina FS, Terra R, Carrillo MP, Puertas A, Nicolaidis KH. What is the most reliable ultrasound parameter for assessment of fetal head descent? *Ultrasound Obstet Gynecol* 2010;**36**:493-499.

22. Youssef A, Kamel R. Ultrasound in labor: impact of a theoretical and practical course on caregiver's perspective and accuracy. *J Matern Fetal Neonatal Med* 2019:1-7.

23. Eggebo TM, Hassan WA, Salvesen KA, Lindtjorn E, Lees CC. Sonographic prediction of vaginal delivery in prolonged labor: a two-center study. *Ultrasound Obstet Gynecol* 2014;**43**:195-201.

24. Bultez T, Quibel T, Bouhanna P, Popowski T, Resche-Rigon M, Rozenberg P. Angle of fetal head progression measured using transperineal ultrasound as a predictive factor of vacuum extraction failure. *Ultrasound Obstet Gynecol* 2016;**48**:86-91.

25. Cuerva MJ, Bamberg C, Tobias P, Gil MM, De La Calle M, Bartha JL. Use of intrapartum ultrasound in the prediction of complicated operative forceps delivery of fetuses in non-occiput posterior position. *Ultrasound Obstet Gynecol* 2014;**43**:687-692.

26. Ghi T, Youssef A, Maroni E, Arcangeli T, De Musso F, Bellussi F, Nanni M, Giorgetta F, Morselli-Labate AM, Iammarino MT, Paccapelo A, Cariello L, Rizzo N, Pilu G. Intrapartum transperineal ultrasound assessment of fetal head progression in active second stage of labor and mode of delivery. *Ultrasound Obstet Gynecol* 2013;**41**:430-435.

27. Ghi T, Maroni E, Youssef A, Morselli-Labate AM, Paccapelo A, Montaguti E, Rizzo N, Pilu G. Sonographic pattern of fetal head descent: relationship with duration of active second stage of labor and occiput position at delivery. *Ultrasound Obstet Gynecol* 2014;**44**:82-89.

28. Sainz JA, Borrero C, Aquise A, Serrano R, Gutierrez L, Fernandez-Palacin A. Utility of intrapartum transperineal ultrasound to predict cases of failure in vacuum extraction attempt and need of cesarean section to complete delivery. *J Matern Fetal Neonatal Med* 2016;**29**:1348-1352.

29. Kahrs BH, Usman S, Ghi T, Youssef A, Torkildsen EA, Lindtjorn E, Ostborg TB, Benediktsdottir S, Brooks L, Harmsen L, Salvesen KA, Lees CC, Eggebo TM. Descent of the fetal head during active pushing: a secondary analysis of a prospective cohort study investigating ultrasound examinations before an operative vaginal delivery. *Ultrasound Obstet Gynecol* 2019 (epub ahead of print).

30. Youssef A, Dodaro MG, Montaguti E, Consolini S, Ciarlariello S, Farina A, Bellussi F, Rizzo N, Pilu G. Dynamic changes of fetal head descent at term before the onset of labor correlate with labor outcome and can be improved by ultrasound visual feedback. *J Matern Fetal Neonatal Med* 2019:1-8.

31. Torkildsen EA, Salvesen KA, Eggebo TM. Prediction of delivery mode with transperineal ultrasound in women with prolonged first stage of labor. *Ultrasound Obstet Gynecol* 2011;**37**:702-708.

32. Yonetani N YR, Murata M, Nakajima E, Taguchi T, Ishii K, Mitsuda N. Prediction of delivery time in the second stage of labor using transperineal ultrasound. *Ultrasound in obstetrics & gynecology : the official journal of the International Society of Ultrasound in Obstetrics and Gynecology* 2016.
33. Youssef A, Salsi G, Montaguti E, Bellussi F, Pacella G, Azzarone C, Farina A, Rizzo N, Pilu G. Automated Measurement of the Angle of Progression in Labor: A Feasibility and Reliability Study. *Fetal Diagn Ther* 2017;**41**:293-299.
34. Eggebo TM, Heien C, Okland I, Gjessing LK, Romundstad P, Salvesen KA. Ultrasound assessment of fetal head-perineum distance before induction of labor. *Ultrasound Obstet Gynecol* 2008;**32**:199-204.
35. Kamel R, Youssef A. How reliable is fetal occiput and spine position assessment prior to induction of labor? *Ultrasound Obstet Gynecol* 2019;**53**:535-540.
36. Pereira S, Frick AP, Poon LC, Zamprakou A, Nicolaides KH. Successful induction of labor: prediction by preinduction cervical length, angle of progression and cervical elastography. *Ultrasound Obstet Gynecol* 2014;**44**:468-475.
37. Youssef A, Ghi T, Martelli F, Montaguti E, Salsi G, Bellussi F, Pilu G, Rizzo N. Subpubic Arch Angle and Mode of Delivery in Low-Risk Nulliparous Women. *Fetal Diagn Ther* 2016;**40**:150-155.
38. Levy R, Zaks S, Ben-Arie A, Perlman S, Hagay Z, Vaisbuch E. Can angle of progression in pregnant women before onset of labor predict mode of delivery? *Ultrasound Obstet Gynecol* 2012;**40**:332-337.
39. Gillor M, Vaisbuch E, Zaks S, Barak O, Hagay Z, Levy R. Transperineal sonographic assessment of angle of progression as a predictor of successful vaginal delivery following induction of labor. *Ultrasound Obstet Gynecol* 2017;**49**:240-245.
40. Siafarikas F, Staer-Jensen J, Hilde G, Bo K, Ellstrom Engh M. Levator hiatus dimensions in late pregnancy and the process of labor: a 3- and 4-dimensional transperineal ultrasound study. *Am J Obstet Gynecol* 2014;**210**:484 e481-487.
41. Lanzarone V, Dietz HP. Three-dimensional ultrasound imaging of the levator hiatus in late pregnancy and associations with delivery outcomes. *Aust N Z J Obstet Gynaecol* 2007;**47**:176-180.
42. Kamel R, Montaguti E, Nicolaides KH, Soliman M, Dodaro MG, Negm S, Pilu G, Momtaz M, Youssef A. Contraction of the levator ani muscle during Valsalva maneuver (coactivation) is associated with a longer active second stage of labor in nulliparous women undergoing induction of labor. *Am J Obstet Gynecol* 2019;**220**:189 e181-189 e188.
43. Youssef A, Montaguti E, Dodaro MG, Kamel R, Rizzo N, Pilu G. Levator ani muscle coactivation at term is associated with longer second stage of labor in nulliparous women. *Ultrasound Obstet Gynecol* 2019;**53**:686-692.
44. Kahrs BH, Usman S, Ghi T, Youssef A, Torkildsen EA, Lindtjorn E, Ostborg TB, Benediktsdottir S, Brooks L, Harmsen L, Salvesen KA, Lees CC, Eggebo TM. Fetal rotation during vacuum extractions for prolonged labor: a prospective cohort study. *Acta Obstet Gynecol Scand* 2018.
45. Raimondo D, Youssef A, Mabrouk M, Del Forno S, Martelli V, Pilu G, Rizzo N, Zannoni L, Paradisi R, Seracchioli R. Pelvic floor muscle dysfunction on 3D/4D transperineal ultrasound in patients with deep infiltrating endometriosis: a pilot study. *Ultrasound Obstet Gynecol* 2017;**50**:527-532.
46. Orno AK, Dietz HP. Levator co-activation is a significant confounder of pelvic organ descent on Valsalva maneuver. *Ultrasound Obstet Gynecol* 2007;**30**:346-350.
47. Youssef A, Brunelli E, Montaguti E, Di Donna G, Dodaro MG, Bianchini L, Pilu G. Transperineal ultrasound assessment of maternal pelvic floor at term and fetal head engagement. *Ultrasound Obstet Gynecol* 2020. (epub ahead of print)

48. Del Forno S, Arena A, Alessandrini M, Pellizzone V, Lenzi J, Raimondo D, Casadio P, Youssef A, Paradisi R, Seracchioli R. Transperineal Ultrasound Visual Feedback Assisted Pelvic Floor Muscle Physiotherapy in Women With Deep Infiltrating Endometriosis and Dyspareunia: A Pilot Study. *J Sex Marital Ther* 2020:1-9.
49. Ghi T, Youssef A, Pilu G, Malvasi A, Ragusa A. Intrapartum sonographic imaging of fetal head asynclitism. *Ultrasound Obstet Gynecol* 2012;**39**:238-240.

Figure legend

Figure 1. Technique for the measurement of the angle of progression positioning the ultrasound transducer in the midsagittal plane transperineally (A) identifying pubic symphysis and the fetal skull (B). The angle of progression is measured as the angle between two lines: the first one running along the long axis of the pubic symphysis and the second one extending from the most inferior portion of the pubic symphysis tangentially to the fetal skull contour (C and D).

Supplementary table 1 Comparison between the mode of delivery in women with and without epidural analgesia in the regression group (women with reduction of the angle of progression at Valsalva). Data are given as mean (\pm SD) or n (%).

Video clip 1 Transperineal ultrasound before the onset of labor from rest to maximum Valsalva maneuver.

Table 1. Characteristics of the study population. Data are given as median (interquartile range), mean (\pm SD) or n (%). Data on the first stage and second of labor were available for 370 and 345 women, respectively. (AoP= angle of progression; BMI: body mass index.

Δ AoP= AoP_{Valsalva} – AoP_{rest}, NICU=neonatal intensive care unit)

	Total (n=469)	Vaginal Delivery (n= 338)	Cesarean section (n=131)	P- value*
Maternal age (years)	33.0 \pm 5.0	32.4 \pm 5.0	34.6 \pm 4.7	<0.001
BMI (Kg/m ²)	26.7 \pm 4.0	26.5 \pm 4.0	27.2 \pm 4.3	0.093
Induction of labor	128 (27.3%)	88 (26.0%)	40 (30.5%)	0.356
Ethnicity				
Caucasian	442 (94.2%)	319 (94.4%)	123 (93.9%)	0.827
African	10 (2.1%)	8 (2.4%)	2 (1.5%)	0.733
Eastern Asian	7 (1.5%)	6 (1.8%)	1 (0.8%)	0.417
Southern Asian	10 (2.1%)	5 (1.5%)	5 (3.8%)	0.151
AoP at Rest (°)	95.5 \pm 14.8	96.8 \pm 13.9	92.1 \pm 16.3	0.004
AoP on Valsalva (°)	104.3 \pm 16.5	105.9 \pm 15.9	100.3 \pm 17.2	0.001
Δ AoP (°)	8.6 \pm 9.9	8.8 \pm 10.1	8.1 \pm 9.5	0.481
Gestational age at ultrasound (weeks)	40.0 \pm 1.3	40.0 \pm 1.3	40.0 \pm 1.3	0.34
Gestational age at delivery (weeks)	40.4 \pm 1.1	40.3 \pm 1.0	40.4 \pm 1.1	0.629
First stage (minutes)	278 \pm 200	262 \pm 188	425 \pm 251	0.001
Second stage (minutes)	72 \pm 62	70 \pm 60	133 \pm 76	0.028
Active second stage (minutes)	49 \pm 38	47 \pm 36	104 \pm 69	0.053
Birthweight (grams)	3321 \pm 422	3316 \pm 398	3334 \pm 482	0.683
Apgar at 1 minute	9 (9-10)	9 (8-10)	9 (7-10)	<0.001
Apgar at 5 minutes	10 (10-10)	10 (10-10)	10 (9-10)	0.002

Epidural analgesia	288 (60.9%)	185 (54.7%)	103 (78.6%)	<0.001
Admission to NICU	20 (4.2%)	11 (3.2%)	9 (6.9%)	0.077

* Student t-test was used to compare continuous variables, whereas Fischer's exact test was used for categorical data.

Table 2 Correlation between angle of progression (AoP) at rest and Valsalva and change from rest to Valsalva maneuver (Δ AoP) with the duration of the first, second and active second stage of labor. Data on the first stage and second of labor were available for 370 and 345 women, respectively.

		First stage (minutes)	Second stage (minutes)	Active second stage (minutes)
AoP rest	Pearson's r	-.107	-0.016	-0.015
	P value	0.041	0.768	0.78
AoP Valsalva	Pearson's r	-.123	-0.055	-0.093
	P value	0.018	0.307	0.085
Δ AoP	Pearson r	-0.036	-0.058	-.125
	P value	0.488	0.285	0.02

Table 3 Comparison between women with reduction angle of progression (AoP) at Valsalva (regression group) versus women with no or positive increase AoP at Valsalva (progression group). Data are given as median (interquartile range), mean (\pm SD) or n (%). Data on the first stage and second of labor were available for 370 and 345 women, respectively. (BMI=body mass index, NICU=neonatal intensive care unit)

	Regression group (n=73)	Progression group (n=396)	P-value*
Maternal age (years)	33.0 \pm 4.9	33.0 \pm 5.0	0.967
BMI	26.2 \pm 3.2	26.75 \pm 4.194	0.22
Gestational age at delivery	40.2 \pm 1.3	40.4 \pm 1.0	0.39
Spontaneous vaginal delivery	41 (56.2%)	232 (58.6%)	0.7
Cesarean delivery	21 (28.8%)	110 (27.8%)	0.86
Vacuum Delivery	11 (15.0%)	54 (13.6%)	0.75
First stage (minutes)	289 \pm 185	278 \pm 204	0.70
Second stage (minutes)	81 \pm 67	70 \pm 61	0.26
Active second stage (minutes)	58 \pm 52	47 \pm 35	0.13
Birthweight	3332 \pm 429	3321 \pm 422	0.85
Apgar 1	9 (8-10)	9 (7-10)	0.003
Apgar 5	10 (10-10)	10 (9-10)	0.02
Epidural	47 (64.4%)	239 (60.4%)	0.52
Admission to NICU	1 (1.4%)	19 (4.8%)	0.18

*Student t-test was used to compare continuous variables, and Fischer's exact test was used for categorical data.

