Successful induction of labor: prediction by pre-induction cervical length, angle of progression and cervical elastography

Susana Pereira, Alexander P. Frick, Leona C. Poon, Akaterina Zamprakou, Kypros H. Nicolaides

Harris Birthright Research Centre of Fetal Medicine, King's College Hospital, London, UK.

Key words: Induction of labor, Cervical length, Elastography, Angle of progression

Acknowledgement: This study was supported by a grant from the Fetal Medicine Foundation (UK Charity No: 1037116). The ultrasound machine with ElastoScan^{TM} elastography software was provided by Samsung-Medison, Seoul, Korea.

Correspondence:

Professor K.H. Nicolaides

Harris Birthright Research Centre for Fetal Medicine

King's College Hospital

Denmark Hill, London SE5 9RS

Telephone 00 44 20 3299 8256

Fax 00 44 20 7733 9543

Mail: kypros@fetalmedicine.com

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.13411

Abstract

Objective: To examine the potential value of pre-induction cervical length, cervical elastography and angle of progression (AOP) in the prediction of successful vaginal delivery and the induction-to-delivery interval.

Methods: This was a prospective study in 99 women with singleton pregnancy attending for pre-induction ultrasound assessment at 35-42 weeks' gestation. Cervical length, elastographic score at the internal os and AOP were measured. Regression analysis was used to determine the relationship between AOP and elastographic score with cervical length. Logistic regression analysis was used to determine which maternal factors, cervical length, AOP, and elastographic score were significant predictors of vaginal delivery and induction-to-delivery interval.

Results: There was vaginal delivery in 66 (66.7%) and Cesarean delivery in 33 (33.3%) cases. There were significant correlations between the cervical length with AOP (r=0.319) and elastographic score (r=0.374). Significant independent prediction of vaginal delivery and induction-to-delivery interval was provided by nulliparity and cervical length, with no additional significant contribution from electrographic score or AOP.

Conclusions: In women undergoing induction of labor, the AOP and elastographic score at the internal os are unlikely to be useful in the prediction of vaginal delivery and induction-to-delivery interval.

Introduction

In pregnant women undergoing induction of labor prediction of successful vaginal delivery and the induction-to-delivery interval is obtained by a combination of maternal characteristics and obstetric history with the pre-induction sonographic measurement of cervical length.[1-7] However, a systematic review and meta-analysis of 31 studies showed that cervical length at or near term has only a moderate capacity to predict the outcome of delivery after induction of labor.[8]

Recent studies have investigated the potential value of two additional sonographic measurements for their value in predicting labor outcome: cervical elastography and angle of progression (AOP). Elastography is an ultrasound-based technique that measures tissue stiffness; soft tissue deforms more easily than hard tissue. Differences in deformability are captured by ultrasound signals and are represented by use of a color map. Specific software can then convert the color signals into a numerical average stiffness. Four studies used cervical elastography before induction of labor and reported that cervical stiffness was less in those with than without successful induction.[9-12] However, the definition of successful induction was different in each study making it impossible to define the value of elastography in predicting vaginal / Cesarean delivery or the induction-to-delivery interval. The AOP provides a sonographic measure of head station and several studies in women during labor reported that if the angle is wide there is a high chance of successful vaginal delivery.[13-20] One study measured AOP in 100 nulliparous and 71 parous non-laboring women at 39-42 weeks and concluded that parous women have a narrower AOP than nulliparous women and in nulliparous a narrow AOP (<95º) is associated with a high rate of Cesarean section.[21]

The objective of this study is to examine the potential value of pre-induction cervical length, elastography and AOP in the prediction of successful vaginal delivery and the induction-to-delivery interval.

Methods

This was a prospective study of 101 women with singleton pregnancy attending an ultrasound-based research clinic prior to induction of labor at King's College Hospital, London between April and October 2013. The entry criteria for the study were live fetus in cephalic presentation and intact membranes undergoing induction of labor between 35^{+0} and 42^{+6} weeks' gestation. Written informed consent was obtained from the women agreeing to participate in the study, which was approved by the National Research Ethics Service Committee London of Surrey Borders South Thames.

Pre-induction ultrasound assessment

Integrated transvaginal (5-9 MHz 2D probe) and transperineal (2-6 MHz 3D abdominal probe) ultrasound scan was carried out by two operators (S.P., A.F.) using an ultrasound machine with ElastoScan™ elastography software (Accuvix XG, Samsung-Medison, Seoul, Korea). Cervical length was measured by transvaginal ultrasound according to the Fetal Medicine Foundation criteria (www.fetalmedicine.com). A sagittal view of the cervix with no compression was obtained. The image was zoomed until the cervix occupied at least two-thirds of the image, the gain was adjusted to obtain a clear view of the cervical canal and the cervical length was measured by placing the calipers on the internal and external cervical os. Elastographic images of the cervix were generated after taking care to avoid any movements in the ultrasound probe. A paired image with a 2D gray scale view of the cervix side by side with an electrographic color map was produced and stored for subsequent analysis. Off-line analysis of the stiffness of an area of 816 pixels around the internal os (Figure 1) was undertaken with the software 'stiff me tool' (Samsung-Medison, Seoul, Korea); this system attributes a score from 0 (maximum softness) to 1 (minimum softness).

Transperineal ultrasound was then performed to measure the AOP as previously described.[13] A covered transabdominal probe was placed between the labia majora, below the symphysis pubis and an image was acquired to include the symphysis pubis and the fetal head. The urethra was used to help align the image in the mid-sagittal plane. The AOP was measured between the longitudinal axis of the pubic bone to the lowest convexity of the fetal skull (Figure 2).

Maternal weight and height were measured at the time of assessment. Maternal characteristics, including age, racial origin, parity and gestational age, and the ultrasound findings were recorded in a secured database (Viewpoint, GE Healthcare Gmbh, Solingen, Germany). Gestational age was determined from the first date of the last menstrual period and confirmed by the measurement of the crown–rump length in the first trimester or the head circumference in the second trimester.

Induction of labor

Induction of labor was performed according to a standard protocol. The Bishop score was assessed by an experienced obstetrician or midwife. Patients with an unfavorable cervix (Bishop score less than 5) received 10 mg Dinoprostone slow-release vaginal pessary (Propess®, Pharmacia & Upjohn, Milton Keynes, UK), those with a Bishop score of 5 or 6 received 3 mg Dinoprostone vaginal tablet (Prostin®, Pharmacia & Upjohn, Milton Keynes, UK), and those with a score of 7 or more had artificial rupture of the membranes (ARM). 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 ARM was carried out. Those who had received Prostin® were reassessed 6 hours later; if there was no change in Bishop score a further 3 mg of Prostin® was given and if the cervix was favorable ARM was carried out. Oxytocin augmentation was started in cases with no onset of labor following ARM and in those with unsatisfactory progress of labor.

Cesarean section was performed in cases of suspected fetal distress, or failure to progress, defined as no progress in cervical dilatation in two consecutive examinations four hours apart in the presence of regular strong contractions maximized by the use of oxytocin. The management of labor was conducted by the on call labor ward team, who were blinded to the findings of the pre-induction ultrasound assessment. Data on pregnancy outcomes were acquired from the labor ward birth register and were also recorded in the database.

Intra- and inter-observer repeatability of elastographic score

The reproducibility of measurement of the elastography score using the software 'stiff me tool' (Samsung-Medison, Seoul, Korea) by a single examiner and between two different examiners was investigated from the study of 30 images, which were selected at random from the database. One operator (S.P.) made the measurements twice and a second operator (A.F) made the measurements once. The operators were not aware of the measurements of each other and S.P when making the measurements on the second occasion was not aware of her measurements on the first occasion.

Statistical analysis

Comparisons of maternal demographic characteristics, pregnancy and neonatal outcomes between mode of delivery groups were by student's t-test or Mann-Whitney U-test for continuous variables and $\chi 2$-test or Fisher's exact test for categorical variables. Regression analysis was used to determine the relationship between AOP and elastographic score at the internal os with cervical length. The induction-to-delivery interval was square root transformed to achieve Gaussian distribution (Kolmogorov-Smirnov test: P=0.200). Logistic regression analysis was used to determine which of the factors amongst the maternal characteristics, parity, occiput position, Bishop score, indication of induction of labor, method of induction, cervical length, AOP and elastographic score were significant predictors of vaginal delivery. Regression analysis was used to determine which of the factors amongst the maternal characteristics, parity, occiput position, Bishop score, indication of induction of labor, method of induction, cervical length, AOP, elastographic score and mode of delivery were significant predictors of the square root transformed induction-to-delivery interval. Intra- and inter-observer repeatability of elastographic score was examined using 95% limits of agreement [22].

The statistical software package SPSS 20.0 (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp) was used for data analyses.

Results

Measurement of cervical length, elastography score and AOP were successfully obtained from all patients examined. Two of the 101 women were excluded for the final analysis because there was spontaneous onset of labor between the ultrasound assessment and induction of labor. In 66 (66.7%) of the 99 cases delivery was vaginal and 33 (33.3%) by cesarean section, including seven (21.2%) for fetal distress and 26 (78.8%) for failure to progress. The maternal characteristics of the mode of delivery groups and pregnancy outcome are summarized in Table 1. In the Cesarean section group, compared to the vaginal delivery group, there was a higher prevalence of nulliparous women and admission to the neonatal unit, and a lower bishop score, a longer cervical length and induction-to-delivery interval.

In the total population, there were significant associations between cervical length and both elastographic score and AOP (Table 2, Figure 3). Univariate regression analysis demonstrated that vaginal delivery was significantly associated with parity, Bishop score and cervical length but not maternal age, weight, height, racial origin, indication and method of induction of labor, occiput position, AOP and elastographic score (Table 3). Multivariate regression analysis demonstrated that significant independent prediction of vaginal delivery was provided by parity and cervical length (R2=0.227; Table 4). Univariate regression analysis demonstrated that the square root transformed induction-to-delivery interval was significantly associated with Afro-Caribbean racial origin, parity, Bishop score, cervical length, elastographic score, method of induction and mode of delivery but not maternal age, weight, height, indication of induction of labor and AOP (Table 5). Multivariate regression analysis demonstrated that significant independent prediction of square root transformed induction-to-delivery interval was provided by parity, cervical length (Figure 4) and method of induction (R2=0.461), but not Afro-Caribbean racial origin, elastographic score or mode of delivery (Table 4).

In the subgroup of 77 cases with bishop score <7, multivariate regression analysis demonstrated that significant independent prediction of vaginal delivery was provided by parity only (R2=0.173) and significant independent prediction of square root transformed induction-to-delivery interval was provided by parity and cervical length (R2=0.332; Table 5).

Intra- and inter-observer repeatability of elastographic score

Mean (95% confidence interval [CI]) difference between the two elastographic scores of operator S.P. was -0.003 (-0.083 to 0.076). The intra-class correlation coefficient was 0.990. Mean (95% CI) difference between the cervical elastographic scores of operators S.P. and A.F. was -0.005 (-0.094 to 0.084). The intra-class correlation coefficient was 0.988.

Discussion

Main findings of the study

The study has demonstrated that in women with singleton pregnancies undergoing induction of labor, firstly, the AOP and the elastographic score at the internal os are not significantly different between those who had a vaginal delivery and those who had an emergency Cesarean section, secondly, there are significant associations between cervical length, AOP and elastographic score, and thirdly, the AOP and elastographic score do not improve the prediction of vaginal delivery and the induction-to-delivery interval provided by parity and cervical length.

Limitations of the study

The study population was relatively small and included women of different racial origins and parities, wide gestational range and varied indications and methods of induction of labor. There were significant associations between cervical length, AOP and elastographic score and it is possible that studies in larger and more homogeneous populations may demonstrate significant contributions from AOP and elastographic score in the prediction of labor outcome.

The method of induction of labor differed according to the Bishop score and therefore indirectly the ultrasonographic measures of the cervical length, AOP and elastographic score that we evaluated for their ability to predict the outcome of induction. To reduce the effect of such potential bias both the Bishop score and method of induction were included in the multiple regression analysis.

Comparison with other studies

We found that parity and cervical length provided significant but rather poor prediction of vaginal delivery ($R2=0.227$) and induction-to-delivery interval ($R2=0.401$). These findings are in general agreement with previous studies that evaluated the role of cervical length in the prediction of labor induction outcome. A meta-analysis of 31 studies on a total of 5,029 women reported a wide range of results in the rate of Cesarean section (11-60%) and performance of screening with cervical length for Cesarean delivery; the detection rate (DR) ranged from 14-92% and the false-positive rate (FPR) ranged from 0-65%.[8] Summary estimates of DR and FPR for Cesarean delivery at the cervical length cut-offs of 20, 30 and 40 mm were 82% and 66%, 64% and 36% and 13% and 5%, respectively.

Elastographic assessment of the cervix was not useful in the prediction of outcome following induction of labor and this finding could be the consequence of the inherent limitations of the technique. Elastography is a measurement of stiffness and has been successfully applied in the assessment of tumors in different organs, such as breast and thyroid, because malignant tumors are stiffer than the adjacent normal tissue.[23,24] However, in the case of the cervix there is no reference tissue for comparison and the elastographic map color achieved varies with the amount of compression applied. Some of these limitations have been addressed by trying to minimize the degree of compression during the examination, avoiding movement of the probe and relying on the patient's breathing and arterial pulsation to obtain elastographic images.[9,10] Recently, an attempt was made to compensate for the lack of reference tissue in the uterine cervix by the application of a cap made of a material with a well-defined stiffness to the end of the transvaginal ultrasound transducer.[12]

There are four previous studies examining cervical elastography before induction of labor with major differences, between them and with our study, in the method of elastographic assessment, method of induction of labor and definitions of outcome measures. Swiatkowska-Freund and Preis, assessed the tissue around the internal os by a visual cervical elastographic score in 29 patients before induction at 33-42 weeks' gestation using oxytocin infusion; the tissue was softer in those with progress in labor within nine hours than in those with failed induction.[9] Hwang *et al*, measured the elastographic score of the entire cervix in 145 patients before induction at 37-42 weeks using oxytocin infusion; prediction of successful induction, defined as active labor within nine hours or delivery within 24 hours from the onset of induction, was better by a combination of cervical length and elastographic score, rather than each parameter alone.[10] Fruscalzo *et al.,* assessed tissue stiffness in the anterior lip of the cervix in 77 patients before induction at 38-42 weeks using vaginal Dinoprostone; there was no significant difference in elastographic score between those who had a vaginal delivery and those who had Cesarean section and the score was not predictive of the induction-to-delivery interval.[11] Hee *et al.,* assessed tissue stiffness in the anterior lip of the cervix in 49 patients at 37-43 weeks before induction using oral Misoprostol; the elastrographic score was better than the Bisop score and cervical length in predicting the cervical dilation time from 4 cm to 10 cm during active labor.[12]

We found that the AOP was significantly associated with the pre-induction cervical length, but the AOP was not different between those with and without successful induction of labor. This is contrary to the expectation that in women with a lower head station, reflected in a wider AOP, induction of labor would be more successful than in those with a narrow AOP. Most previous studies examining the value of the AOP in predicting the outcome of labor have examined women during labor and reported that if the angle is wide there is a high chance of successful vaginal delivery.[13-20] The only one study that examined non-laboring women at term reported that the median AOP within one week prior to onset of labor was significantly narrower in those delivering by Cesarean section than in those delivered vaginally only if the women were nulliparous.[21]

Implications for clinical practice

In women undergoing induction of labor the AOP and elastographic score at the internal os are unlikely to provide useful prediction of vaginal delivery and induction-to-delivery interval.

References

1. Boozarjomehri F, Timor-Tritsch I, Chao CR, Fox HE. Transvaginal ultrasonographic evaluation of the cervix before labor: presence of cervical wedging is associated with shorter duration of induced labor. Am J Obstet Gynecol 1994; 171: 1081-1087.

2. Ware V, Raynor D. Transvaginal ultrasonographic cervical measurement as a predictor of successful labor induction. Am J Obstet Gynecol 2000; 182: 1030-1032.

3. Pandis GK, Papageorghiou AT, Ramanathan VG, Thompson MO, Nicolaides KH. Preinduction sonographic measurement of cervical length in the prediction of successful induction of labor. Ultrasound Obstet Gynecol 2001; 18: 623-628.

4. Gabriel R, Darnaud T, Chalot F, Gonzalez N, Leymarie F, Quereux C. Transvaginal sonography of the uterine cervix prior to labor induction. Ultrasound Obstet Gynecol 2002; 19: 254-257.

5. Bueno B, San-Frutos L, Salazar F, Perez-Medina T, Engels V, Archilla B, Izquierdo F, Bajo J. Variables that predict the success of labor induction. Acta Obstet Gynecol Scand 2005; 84: 1096–1097.

6. Daskalakis G, Thomakos N, Hatziioannou L, Mesogitis S, Papantoniou N, Antsaklis A. Sonographic cervical length measurement before labor induction in term nulliparous women. Fetal Diagn Ther 2006; 21: 34–38.

7. Peregrine E, O'Brien P, Omar R, Jauniaux E. Clinical and ultrasound parameters to predict the risk of cesarean delivery after induction of labor. Obstet Gynecol 2006; 107: 227-233.

8. Verhoeven CJM, Opmeer BC, Oei SG, Latour V, Van Der Post JAM, Mol BWJ. Transvaginal sonographic assessment of cervical length and wedging for predicting outcome of labor induction at term: a systematic review and meta-analysis. Ultrasound Obstet Gynecol 2013; 42: 500-508.

9. Swiatkowska-Freund M, Preis K. Elastography of the uterine cervix: implications for success of induction of labor. Ultrasound Obstet Gynecol 2011; 38: 52-56.

10. Hwang HS, Sohn IS, Kwon HS. Imaging analysis of cervical elastography for prediction of successful induction of labor at term. J Ultrasound Med 2013; 32: 937-946.

11. Fruscalzo A, Londero AP, Frohlich C, Meyer-Wittkopf M, Schmitz R. Quantitative Elastography of the Cervix for Predicting Labor Induction Success. Ultraschall Med 2014 (epub ahead of print).

12. Hee L, Rasmussen CK, Schlutter JM, Sandager P, Uldbjerg N. Quantitative sonoelastography of the uterine cervix prior to induction of labor as a predictor of cervical dilation time. Acta Obstet Gynecol Scand 2014 (epub ahead of print).

13. 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.

14. Dückelmann 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.

15. 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.

16. Ghi T, Contro E, Farina A, Nobile M, Pilu G. Three-dimensional ultrasound in monitoring progression of labor: a reproducibility study. Ultrasound Obstet Gynecol 2010; 36: 500-506.

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

18. 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; 4: 430-435.

19. Molina FS, Terra R, Carrillo MP, Puertas A, Nicolaides KH. What is the most reliable ultrasound parameter to assess fetal head descent? Ultrasound Obstet Gynecol 2010; 36: 493-499.

20. Kalache KD, Dückelmann 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. 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.

22. Bland JM, Altman DG. Statistical method for assessing agreement between two methods of clinical measurement. Lancet 1986; 1: 307–310.

23. Gong X, Xu Q, Xu Z, Xiong P, Yan W, Chen Y. Real-time elastography for the differentiation of benign and malignant breast lesions: a meta-analysis. Breast Cancer Res Treat 2011;130: 11-18.

24. Ding J, Cheng H, Ning C, Huang J, Zhang Y. Quantitative measurement for thyroid cancer characterization based on elastography. J Ultrasound Med 2011; 30: 1259-1266.

Table 1. Maternal characteristics in the study population.

Maternal characteristics	Vaginal delivery (n=66)	Caesarean section (n=33)	P-value
Age in years, median (IQR)	32.0 (29.0-35.3)	33.0 (30.0-35.5)	0.324
Weight in Kg, median (IQR)	85.7 (76.5-94.5)	83.2 (76.0-93.2)	0.064
Height in cm, median (IQR)	167.0 (161.0-170.4)	163 (160.0-168.5)	0.713
Gestation at scan in wks, median (IQR)	41.4 (39.3-41.6)	41.0 (38.7-41.6)	0.522
Racial origin			
Caucasian, n (%)	39 (59.1)	22 (66.7)	0.517
Afro-Caribbean, n (%)	22 (33.3)	9 (27.3)	0.648
South Asian, n (%)	5 (7.6)	2 (6.1)	>0.999
Nulliparous, n (%)	41 (62.1)	31 (93.9)	0.001*
Indication for induction of labor			
Postdate, n (%)	39 (59.1)	17 (51.5)	0.523
Hypertension, n (%)	9 (13.6)	8 (24.2)	0.258
Diabetes, n (%)	11 (16.7)	5 (15.2)	>0.999
Others, n (%)	7 (10.6)	3 (9.1)	>0.999
Method of induction of labor			
Propess, n (%)	43 (65.2)	28 (84.8)	0.058
Prostin, n (%)	9 (13.6)	3 (9.1)	0.746
Artificial rupture of membranes, n (%)	14 (21.2)	2 (6.1)	0.081
Bishop score, median (IQR)	5 (3-7)	4 (2-5)	0.037*
Cervical length in mm, median (IQR)	19.6 (11.7-26.7)	23.0 (15.0-32.2)	0.049*
Angle of progression in degree, median (IQR)	89.1 (77.6-98.0)	88.1 (77.4-92.7)	0.387
Elastographic score, median (IQR)	0.266 (0.152-0.452)	0.391 (0.184-0.511)	0.187
Epidural analgesia, n (%)	32 (48.5)	22 (66.7)	0.133
Occiput position			
Anterior, n (%)	24 (36.4)	12 (36.4)	>0.999
Transverse, n (%)	22 (33.3)	14 (42.4)	0.386
Posterior, n (%)	20 (30.3)	7 (21.2)	0.473
Induction-to-delivery interval in min, median (IQR)	1,355 (772-2,490)	2,764 (1,643-3,486)	0.001*
Neonatal birth weight, median (IQR)	3,475 (3,115-3,875)	3,632 (2,883-3,980)	0.959
Apgar score <7 at 5 min, n (%)	1 (1.5)	3 (9.1)	0.107
Admission to the neonatal unit, n (%)	2 (3.0)	5 (15.2)	0.039*

IQR = interquartile range. Comparison between mode of delivery groups by student's t-test or Mann Whitney-U test for continuous varibles and by χ2 or Fisher exact test for categorical variables. Statistical significance P<0.05*.

Table 2. Pearson correlations between cervical length, angle of progression and elastographic score.

	Cervical length	**Angle of progression**	**Elastographic score**
Cervical length	-	r=-0.319; p=0.001	r=0.368; p<0.0001
Angle of progression	r=-0.319; p=0.001	-	r=-0.027; p=0.790
Elastographic score	r=0.368; p<0.0001	r=-0.027; p=0.790	-

Independent variable	Univariate		Multivariate	
	Odds ratio (95% CI)	**P-value**	**Odds ratio (95% CI)**	**P-value**
Maternal age in years	0.952 (0.869 to 1.043)	0.289	-	-
Maternal weight in Kg	1.000 (0.971 to 1.031)	0.986	-	-
Maternal height in cm	1.017 (0.969 to 1.067)	0.499	-	-
Racial origin				
Caucasian	1		-	-
Afro-Caribbean	1.379 (0.541 to 3.513)	0.501	-	-
South Asian	1.410 (0.252 to 7.884)	0.695	-	-
Nulliparous	0.106 (0.023 to 0.481)	0.004*	0.100 (0.022 to 0.462)	0.003*
Indication for induction				
Postdate	1		-	-
Hypertension	0.490 (0.162 to 1.488)	0.208	-	-
Diabetes	0.959 (0.289 to 3.187)	0.945	-	-
Others	1.017 (0.234 to 4.413)	0.982	-	-
Method of induction				
Propess	1		-	-
Prostin	1.953 (0.486 to 7.848)	0.345	-	-
Artificial rupture of membranes	4.558 (0.962 to 21.608)	0.056	-	-
Cervical length	0.955 (0.913 to 1.000)	0.048*	0.951 (0.906 to 0.999)	0.044*
Bishop score	1.274 (1.020 to 1.592)	0.033*	1.118 (0.835 to 1.495)	0.454
Occiput position				
Anterior	1		-	-
Transverse	0.786 (0.300 to 2.060)	0.624	-	-
Posterior	1.429 (0.473 to 4.313)	0.527	-	-
Angle of progression	1.010 (0.976 to 1.045)	0.566	-	-
Elastographic score	0.236 (0.024 to 2.341)	0.217	-	-

Table 3. Regression model for the prediction of vaginal delivery in the total population.

Table 4. Regression model for the prediction of square root transformed induction-to delivery interval in the total population.

Independent variable	Univariate		Multivariate	
	Regression coefficient (95% CI)	**P-value**	**Regression coefficient (95% CI)**	**P-value**
Maternal age in years	0.119 (-0.669 to 0.906)	0.764	-	-
Maternal weight in Kg	0.117 (-0.150 to 0.385)	0.385	-	-
Maternal height in cm	0.134 (-0.252 to 0.520)	0.491	-	-
Racial origin				
Caucasian	0		0	
Afro-Caribbean	-8.997 (-16.673 to -1.321)	0.022*	2.262 (-3.148 to 7.671)	0.408
South Asian	-12.736 (-26.410 to 0.938)	0.067	-	-
Nulliparous	12.521 (5.524 to 19.518)	0.001*	11.360 (5.747 to 16.973)	<0.0001*
Indication for induction				
Postdate	0			
Hypertension	-1.289 (-12.467 to 9.889)	0.818	-	-
Diabetes	4.135 (-6.185 to 14.454)	0.426	-	-
Others	7.114 (-5.294 to 19.522)	0.256	-	-
Method of induction				
Propess	0		0	
Prostin	-18.681 (-26.930 to -10.431)	<0.0001*	-8.607 (-16.880 to -0.334)	0.042*
Artificial rupture of membranes	-19.578 (-26.892 to -12.264)	<0.0001*	-11.339 (-18.683 to -3.996)	0.003*
Cervical length	0.640 (0.259 to 1.021)	0.001*	0.574 (0.286 to 0.863)	<0.0001*
Bishop score	-3.966 (-5.340 to -2.592)	<0.0001*	-0.490 (-2.459 to 1.479)	0.622
Occiput position				
Anterior	0		-	-
Transverse	0.249 (-7.204 to 7.703)	0.947	-	-
Posterior	1.829 (-6.221 to 9.880)	0.653	-	-
Angle of progression	-0.136 (-0.433 to 0.161)	0.363	-	-
Elastographic score	26.762 (10.283 to 43.242)	0.002*	11.148 (-2.696 to 24.992)	0.113
Vaginal delivery	-11.636 (-17.928 to -5.345)	<0.0001	-3.683 (-9.156 to 1.791)	0.185

Table 5. Regression model for the prediction of vaginal delivery and prediction of square root transformed induction-to-delivery interval in the subgroup with Bishop score less than seven.

Vaginal delivery		
Independent variable	**Odds ratio (95% CI)**	**P-value**
Nulliparous	0.121 (0.026 to 0.572)	0.008
Square root transformed induction-to-delivery interval		
Independent variable	**Regression coefficient (95% CI)**	**P-value**
Nulliparous	13.614 (7.097 to 20.130)	<0.0001
Cervical length	0.694 (0.372 to 1.016)	<0.0001

Figure legends

Figure 1. Gray scale and elastographic images of a long cervix (top) and short cervix (bottom). The arrows indicate the internal and external cervical os and the circle the area around the internal os for assessment of elastographic stiffness (soft tissue is red and stiff tissue is purple/blue).

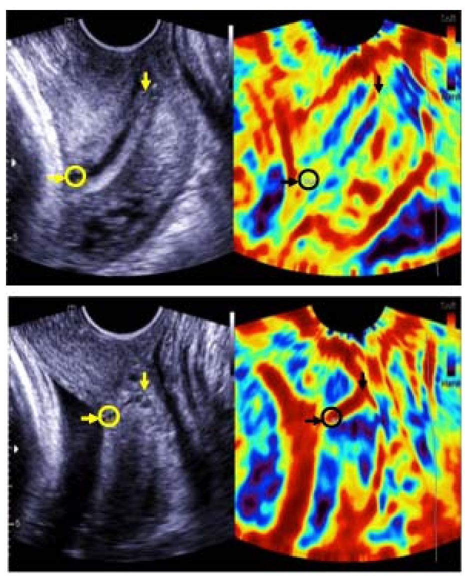

Figure 1

Figure 2. Measurement of the angle of progression between the longitudinal axis of the pubic bone to the lowest convexity of the fetal skull.

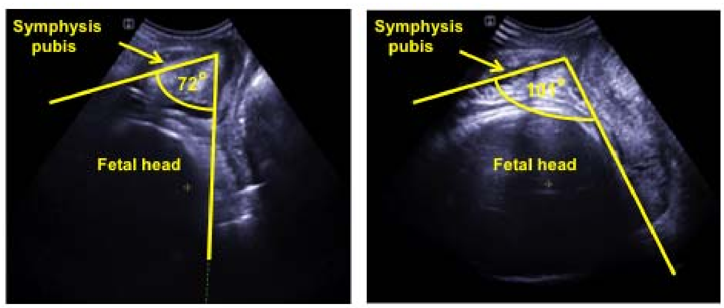

Figure 2

Figure 3. Relationship between cervical length with angle of progression (left) and elastographic score at the internal os (right).

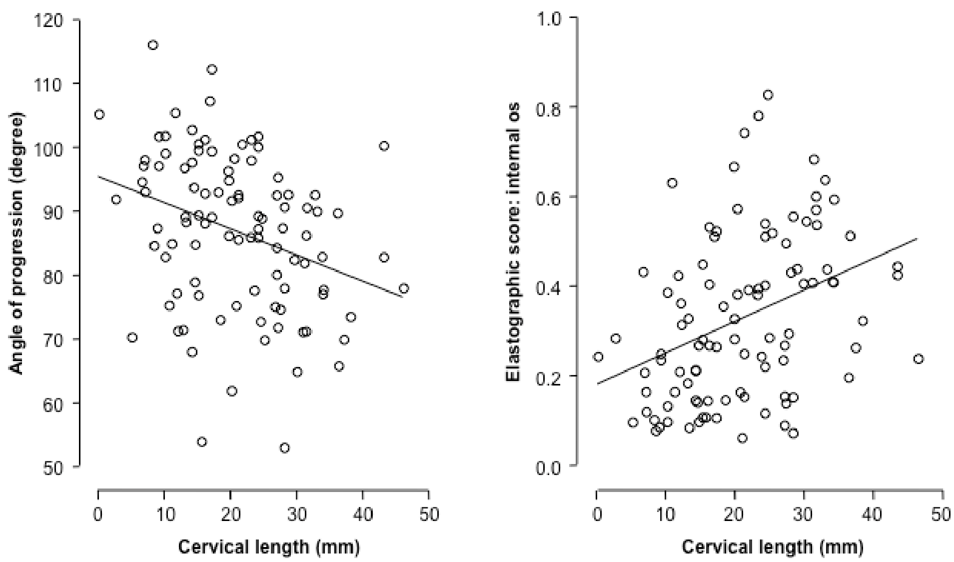

Figure 3

Figure 4. Relationship between induction-to-delivery interval with cervical length.

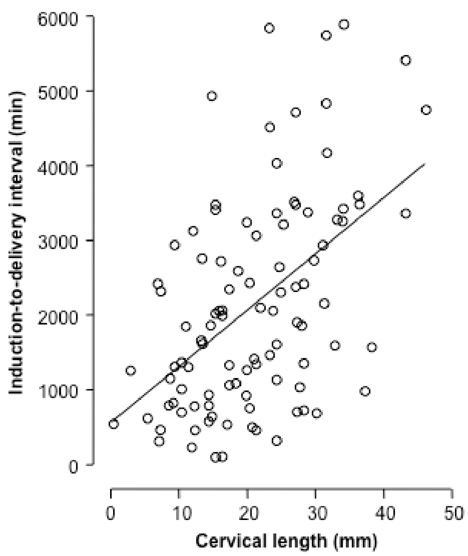

Figure 4