

# Cervical length and maternal factors in expectantly managed prolonged pregnancy: prediction of onset of labor and mode of delivery

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**KEYWORDS:** cervical length; Cesarean section; induction of labor; prolonged pregnancy

## ABSTRACT

**Objective** To examine the value of combining cervical length and maternal characteristics in a prolonged-pregnancy clinic in the prediction of the probability of firstly, spontaneous onset of labor within the subsequent 10 days and secondly, the need for Cesarean section.

**Methods** This was a prospective study of women with singleton pregnancies attending an ultrasound-based prolonged-pregnancy clinic at 40 + 4 to 41 + 6 weeks of gestation. The policy was to delay induction of labor by 7–10 days unless there was evidence of a specific medical or obstetric indication or the mother wanted earlier delivery. The measurement of cervical length was not given to the obstetrician, midwife or patient. Regression analysis was used to determine which of the following factors had a significant contribution in predicting induction of labor: maternal age, body mass index (BMI), ethnic origin, parity and cervical length. Regression analysis was also used to determine which of the factors amongst the maternal characteristics, onset of labor and cervical length provided significant prediction of Cesarean section.

**Results** We examined 2316 pregnancies but we excluded from further analysis 452 (19.5%) cases because iatrogenic delivery was carried out within the subsequent 6 days, including 427 cases of induction of labor (340 at the request of the mother and 87 for medical indications) and 25 cases of Cesarean section. In the remaining 1864 cases there was spontaneous onset of labor and delivery within 10 days in 1536 (82.4%) and induction of labor in 7–10 days in 328 (17.6%). The rate of Cesarean section was 15.2% (233 of 1536) in those with spontaneous onset of labor and 36.0% (118 of 328)

in those whose labor was induced. Regression analysis demonstrated that in the prediction of induction of labor there were significant contributions from cervical length, BMI, parity and gestational age, and in the prediction of Cesarean section there were significant contributions from onset of labor, cervical length, BMI, parity and ethnicity.

**Conclusion** Ultrasonographic measurement of cervical length at 41 weeks together with maternal factors can define the patient-specific probability of spontaneous onset of labor in the subsequent week and the risk of Cesarean section. Copyright © 2008 ISUOG. Published by John Wiley & Sons, Ltd.

## INTRODUCTION

The probability of vaginal delivery or the need for Cesarean section in prolonged pregnancies undergoing induction of labor can be predicted by the pre-induction sonographic measurement of cervical length<sup>1</sup>. Similarly, cervical length at 37 weeks' gestation in expectantly-managed pregnancies can predict the gestation at subsequent spontaneous onset of labor and vaginal delivery. Ramanathan *et al.* measured cervical length at 37 weeks in 1571 singleton low-risk pregnancies and reported that 81% had spontaneous onset of labor and delivery before 41 + 3 weeks, and that both parity and cervical length provided significant contributions to predicting the rate of such delivery<sup>2</sup>. The incidence of delivery after 41 + 3 weeks and the rate of Cesarean section increased with cervical length and were higher in nulliparous than parous women.

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In this study we examined the value of combining cervical length and maternal characteristics in a prolonged-pregnancy clinic at 40 + 4 to 41 + 6 weeks of gestation in the prediction of the probability of firstly, spontaneous onset of labor within the subsequent 10 days and secondly, Cesarean section.

## METHODS

This was a prospective study of women attending an ultrasound-based prolonged-pregnancy clinic. At King's College Hospital, Lewisham General Hospital, and Queen Elizabeth Hospital, London, UK and Verona University Hospital, Verona, Italy all women attending for routine obstetric care were referred to a prolonged-pregnancy clinic at 40 + 4 to 41 + 6 weeks of gestation. Gestational age was determined from the menstrual history and confirmed by an ultrasound scan and measurement of the crown-rump length in the first trimester or the head circumference in the second trimester. Assessment in this clinic included transvaginal sonographic measurement of cervical length<sup>3</sup> and transabdominal ultrasonography for fetal biometry, measurement of the vertical distance of the deepest pool of amniotic fluid, determination of placental position and fetal presentation, and examination by Doppler ultrasound of whether the end-diastolic flow in the umbilical artery was positive or not. The maternal weight and height were measured and the body mass index (BMI) was calculated. Maternal characteristics – including age, ethnic origin, BMI, parity and gestational age and the ultrasound findings – were recorded in a database at the time of assessment. Data on pregnancy outcome were obtained from the labor ward and also recorded in the database.

The policy in the participating hospitals was to delay induction of labor for 7–10 days after attendance to the prolonged pregnancy. However, the obstetrician or midwife in charge of pregnancy care in consultation with the mother could decide on earlier delivery based on the wishes of the mother, the presence of pregnancy complications such as pre-eclampsia and the ultrasound findings of oligohydramnios (deepest pool of amniotic fluid less than 1.5 mm), fetal growth restriction, placenta previa or breech presentation. The measurement of cervical length was not given to the obstetrician, midwife or patient.

All the women gave their written informed consent to participate in the study, which was approved by the ethics committee of each hospital. The entry criteria for this study were singleton pregnancy, live fetus, cephalic presentation and a decision to manage the patients expectantly for between 7 and 10 days after attendance at the prolonged-pregnancy clinic.

### Statistical analysis

The Mann-Whitney or the Chi-square test where appropriate was performed to examine the significance of differences in maternal characteristics and ultrasound

findings in the different outcome groups. Regression analysis was used to determine which of the following factors had a significant contribution to predicting induction of labor: maternal age in years, BMI in kg/m<sup>2</sup>, ethnic origin (white, black, Indian or Pakistani, Chinese or Japanese and mixed), parity (parous or nulliparous if no delivery beyond 23 weeks), gestational age in days and cervical length in mm. Similarly, regression analysis was used to determine which of the factors amongst the maternal characteristics, onset of labor (spontaneous or induced) and cervical length had a significant contribution to predicting the need for Cesarean section.

The patient-specific risks (%) for induction of labor and for Cesarean section were calculated from the formula: risk = odds/(1 + odds), where odds = e<sup>Y</sup>. The values of Y were derived from the regression equations for the prediction of induction of labor and the prediction of the need for Cesarean section. The performance of screening was assessed by receiver-operating characteristics (ROC) curves. The statistical software package SPSS 15.0 (SPSS Inc., Chicago, IL, USA) was used for all data analysis.

## RESULTS

In total we examined 2316 singleton pregnancies with a live fetus attending the prolonged-pregnancy clinic at 40 + 4 to 41 + 6 weeks of gestation. We excluded from further analysis 452 (19.5%) cases because iatrogenic delivery was carried out within the subsequent 6 days, including 427 cases of induction of labor (340 at the request of the mother, 3 for antepartum hemorrhage, 5 for fetal growth restriction, 35 for oligohydramnios, 16 for prelabor amniorrhesis and 28 for pregnancy hypertension) and 25 cases of Cesarean section (20 for breech presentation, 1 for fetal growth restriction, 1 for fetal macrosomia, 2 for oligohydramnios and 1 for placenta previa). In all the pregnancies there was positive end-diastolic flow in the umbilical artery.

In the 1864 cases included in this study the mean gestational age at the visit to the prolonged-pregnancy unit was 41 + 0 (range, 40 + 4 to 41 + 6) weeks. There was spontaneous onset of labor and delivery within 10 days (at a mean gestational age of 41 + 5 (range, 40 + 4 to 43 + 0) weeks) in 1536 (82.4%) and induction of labor in 7–10 days (at a mean gestational age of 42 + 1 (range, 41 + 4 to 43 + 2) weeks) in 328 (17.6%). In the 1536 cases with spontaneous onset of labor, delivery was vaginal in 1303 (84.8%) and by Cesarean section in 233 (15.2%), including 125 for failure to progress and 108 for fetal distress. In the 328 cases with induction of labor delivery was vaginal in 210 (64.0%) and by Cesarean section in 118 (36.0%), including 72 for failure to progress and 46 for fetal distress. The maternal characteristics and ultrasound findings in the different outcome groups are compared in Table 1.

Multiple regression analysis demonstrated that in the prediction of induction of labor there were significant contributions from cervical length, BMI, parity and

Table 1 Maternal characteristics and cervical length in the four outcome groups

Maternal characteristic	Spontaneous onset of labor		Induction of labor	
	Vaginal delivery (n = 1303)	Cesarean section (n = 233)	Vaginal delivery (n = 210)	Cesarean section (n = 118)
Maternal age (years, median (range))	30 (16–45)	30 (16–43)	29 (16–43)	31 (16–43)
Body mass index (kg/m <sup>2</sup> , median (range))	23.5 (15.5–49)	24.6 (16.8–45)*	24.9 (16.3–53)*	25.2 (18.6–46.1)†
Cervical length (mm, median (range))	17 (0–48)	20 (0–40)†	25 (5–42)†	30 (8–45)†
Ethnicity (n (%))				
White	846 (64.9)	116 (49.8)†	147 (70.0)	69 (58.5)
Black	364 (27.9)	96 (41.2)†	46 (21.9)	41 (34.7)
Asian	60 (4.6)	12 (5.2)	13 (6.2)	6 (5.1)
Oriental	18 (1.4)	3 (1.3)	2 (1.0)	1 (0.8)
Mixed	15 (1.2)	6 (2.6)	2 (1.0)	1 (0.8)
Parity (n (%))				
Nulliparous	714 (54.8)	197 (84.5)†	132 (62.9)‡	104 (88.1)†
Parous	589 (45.2)	36 (15.5)†	78 (37.1)‡	14 (11.9)†

Each group was compared to the spontaneous onset of labor and vaginal delivery group. \* $P < 0.01$ ; † $P < 0.001$ ; ‡ $P < 0.05$ .

gestational age but not maternal age ( $P = 0.49$ ) or ethnicity ( $P = 0.55$ ):

$$\begin{aligned}
 Y &= 25.2 + (0.108 \times \text{cervical length in mm}) \\
 &+ (0.039 \times \text{BMI in kg/m}^2) \\
 &+ (0 \text{ if nulliparous, } -0.703 \text{ if parous}) \\
 &- (0.104 \times \text{gestational age in days}); \\
 r^2 &= 0.213, P < 0.001 \text{ (Figure 1)}.
 \end{aligned}$$

In the prediction of Cesarean section there were significant contributions from onset of labor, cervical length, BMI, parity and ethnicity but not maternal age ( $P = 0.14$ ) or gestational age ( $P = 0.277$ ):

$$\begin{aligned}
 Y &= -3.276 + (0 \text{ if spontaneous onset of labor,} \\
 &0.717 \text{ if induction of labor}) \\
 &+ (0.045 \times \text{cervical length in mm}) \\
 &+ (0.038 \times \text{BMI in kg/m}^2) \\
 &+ (0 \text{ if nulliparous, } -1.720 \text{ if parous}) \\
 &+ (0.710 \text{ if black, } 0 \text{ if other ethnic group}); \\
 r^2 &= 0.204, P < 0.001 \text{ (Figure 2)}.
 \end{aligned}$$

#### Patient-specific risk for induction of labor and Cesarean section

In a nulliparous black woman with BMI of 22 kg/m<sup>2</sup> and a cervical length of 10 mm at 41 weeks, the risk for induction of labor is:

$$\begin{aligned}
 Y &= 25.2 + (0.108 \times 10 \text{ for cervical length}) \\
 &+ (0.039 \times 22 \text{ for BMI}) + (0 \text{ for nulliparity}) \\
 &- (0.104 \times 287 \text{ for gestation}) = -2.71. \\
 \text{Odds} &= \exp(-2.71) = 0.067 \\
 \text{Risk} &= 0.067 / (1 + 0.067) \times 100 = 6.24\%
 \end{aligned}$$

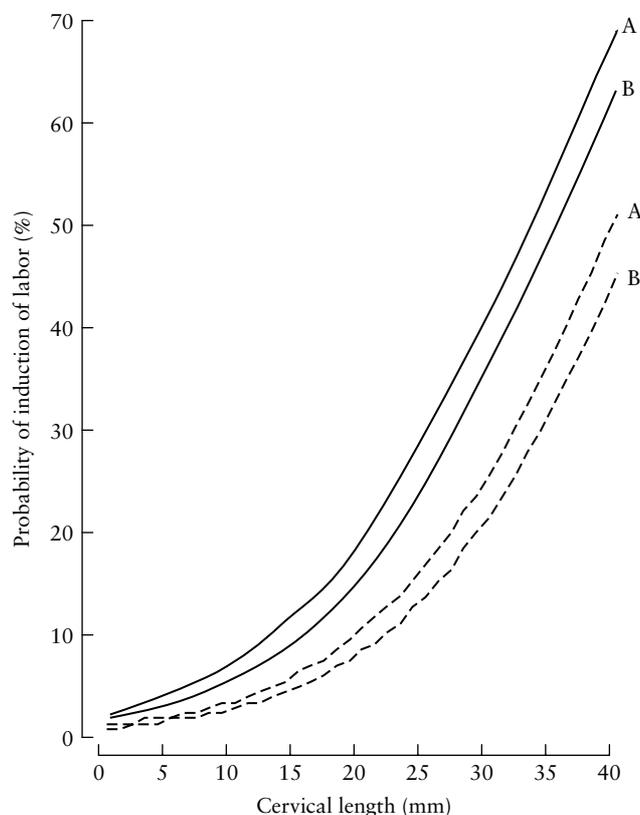
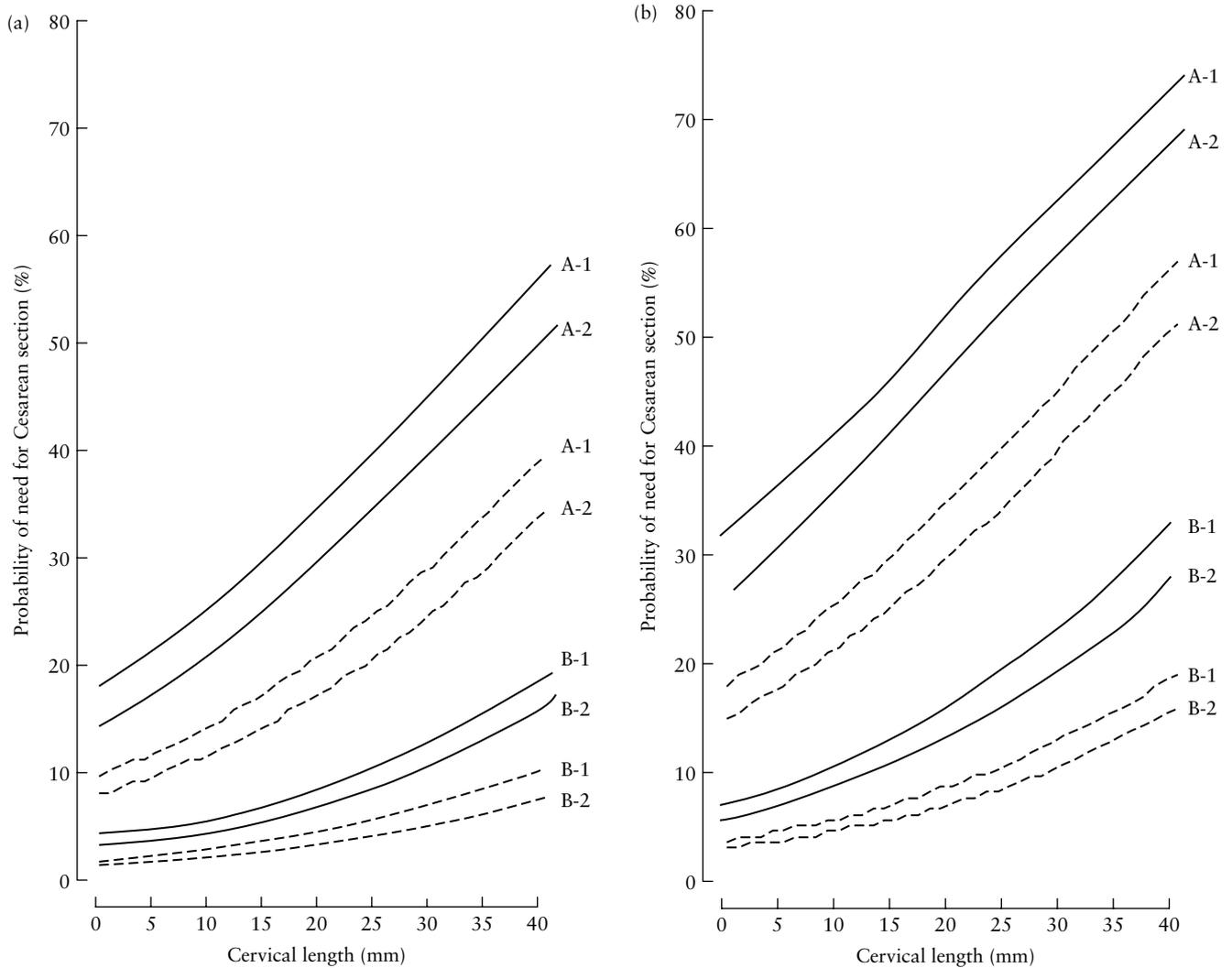


Figure 1 Relationship between cervical length at 41 + 0 weeks of gestation and probability that the woman will not have spontaneous onset of labor and will require induction of labor in 7–10 days. - - - -, parous women; —, nulliparous women; A, body mass index (BMI) > 25 kg/m<sup>2</sup>; B, BMI ≤ 25 kg/m<sup>2</sup>.

The risk for Cesarean section if she goes into labor spontaneously is:

$$\begin{aligned}
 Y &= -3.276 + (0 \text{ for spontaneous onset of labor}) \\
 &+ (0.045 \times 10 \text{ for cervical length}) \\
 &+ (0.038 \times 22 \text{ for BMI}) + (0 \text{ for nulliparity})
 \end{aligned}$$



**Figure 2** Relationship between cervical length at 40 + 4 to 41 + 6 weeks of gestation and probability of the need for Cesarean section for white (a) and black (b) women. - - - -, spontaneous onset of labor; —, induction of labor; A, nulliparous; B, parous; 1, body mass index (BMI) > 25 kg/m<sup>2</sup>; 2, BMI ≤ 25 kg/m<sup>2</sup>.

$$+ (0.710 \text{ for black ethnicity}) = -1.280$$

$$\text{Odds} = \exp(-1.280) = 0.278$$

$$\text{Risk} = 0.278 / (1 + 0.278) \times 100 = 21.8\%$$

The risk for Cesarean section if she needs induction of labor is:

$$\begin{aligned} Y = & -3.276 + (0.717 \text{ for induction of labor}) \\ & + (0.045 \times 10 \text{ for cervical length}) \\ & + (0.038 \times 22 \text{ for BMI}) + (0 \text{ for nulliparity}) \\ & + (0.710 \text{ for black ethnicity}) = -0.563 \end{aligned}$$

$$\text{Odds} = \exp(-0.563) = 0.569$$

$$\text{Risk} = 0.569 / (1 + 0.569) \times 100 = 36.3\%$$

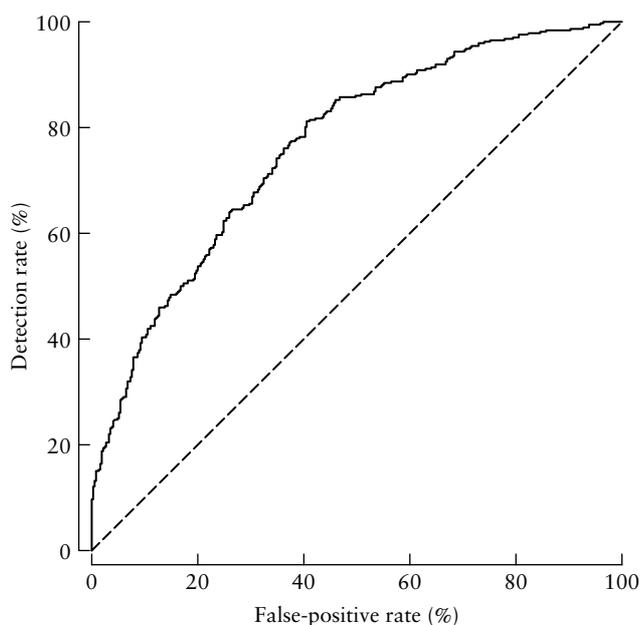
**Performance of screening for induction of labor and Cesarean section**

The areas under the ROC curves for the prediction of induction of labor and Cesarean section were 0.762

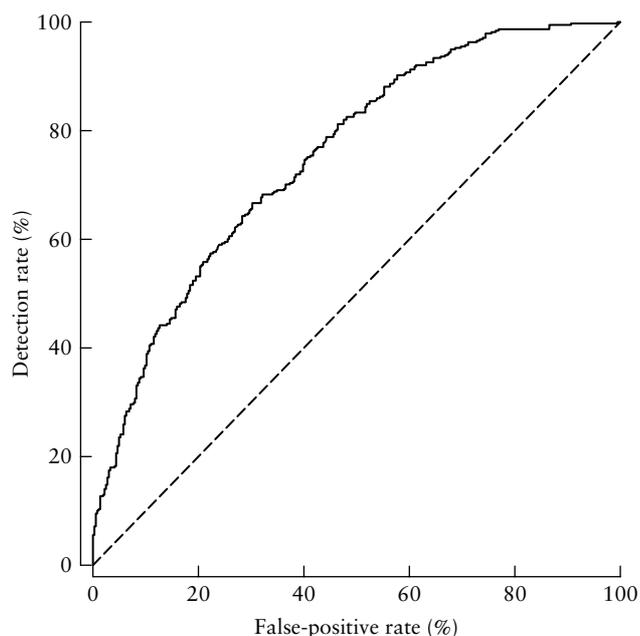
(95% CI, 0.734–0.789; *P* < 0.001) and 0.752 (95% CI, 0.725–0.779; *P* < 0.001), respectively (Figures 3 and 4).

**DISCUSSION**

The traditional approach to the management of prolonged pregnancy is to undertake delivery during the 41<sup>st</sup> week of gestation. In this study we report the results of a new approach whereby an ultrasound-based assessment was undertaken at the end of the 40<sup>th</sup> week or during the 41<sup>st</sup> week of gestation, and unless there was evidence of a specific medical or obstetric indication induction of labor was delayed by 7–10 days. In about 20% of cases iatrogenic delivery was carried out within a few days of attendance at the prolonged-pregnancy clinic and in 75% of such cases it was at the request of the mother. However, in 25% of the cases there was a specific indication that was diagnosed at the clinic, including a large number of breech presentations that had not been previously identified during routine clinical examination.



**Figure 3** Receiver–operating characteristics curve of the combination of cervical length and maternal characteristics in the prediction of the need for induction of labor.



**Figure 4** Receiver–operating characteristics curve of the combination of cervical length and maternal characteristics in the prediction of the need for Cesarean section.

The study demonstrated that in women attending the prolonged-pregnancy clinic a policy of delaying induction of labor by 7–10 days resulted in spontaneous onset of labor and delivery in more than 80% of cases. In addition, the rate of Cesarean section for failure to progress or fetal distress was about 19% in the total population, including 15% in those with spontaneous onset of labor and 36% in those requiring induction of labor.

Multiple regression analysis was used to establish the methodology for the calculation of patient-specific

chances for spontaneous or induced onset of labor and vaginal or Cesarean delivery that can be used in counseling women attending a prolonged-pregnancy clinic. The chance of spontaneous onset of labor is higher in parous than nulliparous women and is inversely related to maternal BMI and cervical length. The chance of vaginal delivery is higher in those with spontaneous than induced onset of labor, in parous than nulliparous women, and in white than black women and is inversely related to maternal BMI and cervical length. These findings are compatible with the results of previous studies which reported that firstly, in women undergoing induction of labor there is a contribution from both cervical length and parity in the prediction of the risk for Cesarean section<sup>1,4,5</sup>; secondly, the median intrapartum uterine activity needed to achieve vaginal delivery in both spontaneous and induced labor is lower in parous than nulliparous women<sup>6,7</sup>; thirdly, the need for induction of labor and risk of Cesarean section increase with maternal BMI<sup>8</sup>; and fourthly, the risk of Cesarean section is higher in black than in white women after correction for other confounders<sup>9</sup>.

Previous studies involving cervical assessment at 39–41 weeks' gestation in expectantly managed pregnancies have reported contradictory evidence on the value of cervical length and maternal characteristics for the prediction of spontaneous onset of labor and vaginal delivery or Cesarean section<sup>10–13</sup>. The most likely explanations for the contradictory results are firstly, the small number of cases examined and secondly, differences in methodology between the studies. Rozenberg *et al.*<sup>10</sup> measured cervical length at 39 + 4 to 40 + 3 weeks in 128 singleton pregnancies and reported an association of cervical length with spontaneous onset of labor within 7 days but not with the risk of Cesarean section. Vimercati *et al.*<sup>11</sup> examined 120 singleton pregnancies in nulliparous women and reported that the cervical length at 39 and 40 weeks was significantly decreased in those with spontaneous onset of labor within the subsequent 7 days. Strobel *et al.*<sup>12</sup> examined 97 singleton pregnancies at 41 + 4 to 42 + 2 weeks and reported that cervical length provided a significant prediction of spontaneous onset of labor and delivery within the subsequent 1–2 days but not within 4 days in either nulliparous or parous women. Vankayalapati *et al.*<sup>13</sup> measured cervical length in 179 singleton pregnancies at 41 + 3 weeks and, to those who had not delivered by 42 + 0 weeks, they offered induction of labor. In 112 (62.6%) cases there was spontaneous onset of labor and delivery at 41 + 3 to 43 + 4 weeks, and in 67 cases there was induction of labor and delivery at 42 + 0 to 42 + 6 weeks. Significant contribution to the prediction of the need for induction of labor was provided by cervical length but not parity, whereas in the prediction of the need for Cesarean section there were contributions from both cervical length and parity.

An ultrasound-based prolonged-pregnancy clinic can identify previously undiagnosed problems, such as breech presentation, that may benefit from elective Cesarean section<sup>14</sup>, or oligohydramnios and fetal growth restriction

for which early delivery with close intrapartum monitoring would be needed. In those with no specific medical indications for delivery during the 41<sup>st</sup> week a policy of delaying induction of labor by 7–10 days would reduce substantially the rate of induction for prolonged pregnancy. The extent to which such a policy could reduce the overall rate of Cesarean section without an increase in perinatal death can only be answered by a randomized study.

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## REFERENCES

1. Rane S, Guirgis R, Higgins B, Nicolaides KH. Pre-induction sonographic measurement of cervical length in prolonged pregnancy: the effect of parity in the prediction of the need for Cesarean section. *Ultrasound Obstet Gynecol* 2003; **22**: 45–48.
2. Ramanathan G, Yu C, Osei E, Nicolaides K. Ultrasound examination at 37 weeks' gestation in the prediction of pregnancy outcome: the value of cervical assessment. *Ultrasound Obstet Gynecol* 2003; **22**: 598–603.
3. Sonek J, Shellhaas C. Cervical sonography: a review. *Ultrasound Obstet Gynecol* 1998; **11**: 71–78.
4. Ware V, Raynor D. Transvaginal ultrasonographic cervical measurement as a predictor of successful labor induction. *Am J Obstet Gynecol* 2000; **182**: 1030–1032.
5. 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.
6. Arulkumaran S, Gibb DM, Lun KC, Heng SH, Ratnam SS. The effect of parity on uterine activity in labour. *Br J Obstet Gynaecol* 1984; **91**: 843–848.
7. Arulkumaran S, Gibb DM, Ratnam SS, Lun KC, Heng SH. Total uterine activity in induced labour – an index of cervical and pelvic tissue resistance. *Br J Obstet Gynaecol* 1985; **92**: 693–697.
8. Sebire NJ, Jolly M, Harris JP, Wadsworth J, Joffe M, Beard RW, Regan L, Robinson S. Maternal obesity and pregnancy outcome: a study of 287,213 pregnancies in London. *Int J Obes Relat Metab Disord* 2001; **25**: 1175–1182.
9. Braveman P, Egerter S, Edmonston F, Verdon M. Racial/ethnic differences in the likelihood of cesarean delivery, California. *Am J Public Health* 1995; **85**: 625–630.
10. Rozenberg P, Goffinet F, Hessabi M. Comparison of the Bishop score, ultrasonographically measured cervical length, and fetal fibronectin assay in predicting time until delivery and type of delivery at term. *Am J Obstet Gynecol* 2000; **182**: 108–113.
11. Vimercati A, Greco P, Lopalco P, Loizzi V, Scioscia M, Mei L, Rossi A, Selvaggi L. The value of ultrasonographic examination of the uterine cervix in predicting post-term pregnancy. *J Perinat Med* 2001; **29**: 317–321.
12. Strobel E, Sladkevicius P, Rovas L, De Smet F, Karlsson ED, Valentin L. Bishop score and ultrasound assessment of the cervix for prediction of time to onset of labor and time to delivery in prolonged pregnancy. *Ultrasound Obstet Gynecol* 2006; **28**: 298–305.
13. Vankayalapati P, Sethna F, Roberts N, Ngeh N, Thilaganathan B, Bhide A. Ultrasound assessment of cervical length in prolonged pregnancy: prediction of spontaneous onset of labor and successful vaginal delivery. *Ultrasound Obstet Gynecol* 2008; **31**: 328–331.
14. Hannah ME, Hannah WJ, Hewson SA, Hodnett ED, Saigal S, Willan AR. Planned caesarean section versus planned vaginal birth for breech presentation at term: a randomised multicentre trial. Term Breech Trial Collaborative Group. *Lancet* 2000; **356**: 1375–1383.