Three-dimensional ultrasound assessment of the cervix for predicting time to spontaneous onset of labor and time to delivery in prolonged pregnancy.

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Short title: 3D ultrasound and cervix.

Key words: cervix uteri, three-dimensional imaging, Doppler ultrasound, spontaneous delivery, prolonged pregnancy.

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ABSTRACT

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Rovas L., Sladkevicius P., Strobel E., De Smet F., De Moor B., Valentin L., ``Three-dimensional ultrasound assessment of the cervix for predicting time to spontaneous onset of labor and time to delivery in prolonged pregnancy.", *Ultrasound in Obstetrics and Gynecology*, vol. 28, no. 2, 2006, pp. 306-311., Lirias number: 12868.

Objectives The aim of this study was to determine if three-dimensional (3D) power Doppler ultrasound examination of the cervix are useful to predict time to spontaneous onset of labor and time to delivery in prolonged pregnancy.

Methods A prospective study was conducted in 60 women who went into spontaneous labor at 41 gestational weeks + 5 days or later. All 60 women underwent transvaginal 3D power Doppler ultrasound examination of the cervix immediately before a planned routine post-term check-up. The variables analysed were length, anterior-posterior diameter and width of the cervix and of any cervical funneling, cervical volume (cm^3), vascularisation index (VI), flow index (FI) and vascularisation flow index (VFI), parity and Bishop score. Logistic regression was used to determine which variables predicted onset of spontaneous labor >24h and >48h and vaginal delivery >48h and >60h.

Results Vaginal delivery occurred in 56 (93%) women. Sonographically measured cervical length was shorter (median 0.9 cm. vs. 2.0 cm.; p = 0.001), Bishop score was higher (mean 5.5 vs. 4.1; p = 0.01), and VI and VFI tended to by higher **(but the difference was not statistically significant)** among women who were in labor ≤ 48 h after the ultrasound examination than in those who were not. Bishop score and VI were higher (mean 5.6 vs. 3.8; p = 0.005; median 7.1 vs. 3.5; p = 0.05), and sonographic cervical length was shorter among women who delivered ≤ 60 h than among those who delivered later.

Conclusion Bishop score, cervical length and results of 3D power Doppler ultrasound examination of the cervix are related to the time to spontaneous onset of labor and to the time to delivery in women with prolonged pregnancy.

Introduction

Efforts have been made to understand the cervical ripening and opening process, but we still have insufficient knowledge about why some women deliver pre-term and others post-term. The traditional method to investigate cervical readiness for labor is digital examination, where the results of the examination are summarised as a Bishop score[1]. Although the Bishop score is recognised as a useful method, there are problems with its accuracy, because half of the cervix is not palpable at vaginal examination if the cervical canal is closed[2]. Transvaginal ultrasound allows visualisation of the entire **cervix irrespective of whether the internal cervical os is closed or open at palpation.** There are several studies showing transvaginal ultrasound examination of the cervix to be a good predictor of preterm, term or post-term delivery, and outcome of labor induction[3-6]. However, one research team found no relationship between sonographically measured cervical length and time to spontaneous onset of labor[7]. A few studies have suggested three-dimensional (3D) ultrasound examination of the cervix to allow a more complete assessment of the cervix than_two-dimensional (2D) ultrasound examination [8,9].

There is evidence that angiogenic factors may play a role in cervical ripening and the birth process [10]. Therefore, we speculate that there might be changes in cervical vascularization during the cervical ripening process potentially detectable by 3D power Doppler ultrasound examination, and that therefore 3D power Doppler ultrasound examination might be useful to predict time to spontaneous onset of labor.

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The aim of this study was to determine if 3D ultrasound examination of the cervix including 3D power Doppler ultrasound examination can **provide useful information to** predict the time to spontaneous onset of labor or to vaginal delivery in prolonged pregnancy.

Material and methods

The Ethics Committee of the Medical faculty of Lund University, Sweden approved the study protocol. Informed written consent was obtained from all women, after the nature of the procedures had been fully explained to them.

Pregnant women are routinely seen in our antenatal out-patient department for a routine post-term check-up of the mother-to-be and fetus at 42 gestational weeks (gws) and 0 days (42 + 0 gws). If a pregnant woman reaches 42 + 0 gws during a weekend, the assessment is done on the preceding weekday. As a result of this, some women are examined at gws 41 + 5 or 41 + 6. Based on the results of the examinations of the fetus and mother, the managing obstetrician chooses either to induce labor or to await spontaneous start of labor. Post-term check–ups are scheduled to take place at 7.30 a.m. All pregnant women coming to our antenatal out-patient department for their first post-term check-up were asked to participate in our study, i.e., to undergo a transvaginal 3D power Doppler ultrasound examination of the cervix immediately before their routine post-term check-up.

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Inclusion criteria for this study were: singleton pregnancy at ≥ 41 + 5 gws, gestational age determined by early ultrasound fetometry at 14 – 20 gws, live fetus, vertex presentation, intact membranes and spontaneous onset of labor, **no previous cone biopsy, not in labor at ultrasound examination, no digital examination of the cervix ≤ 24 h before the ultrasound examination.**

Of 121 women asked to participate, six women declined participation. Thus, a transvaginal ultrasound examination of the cervix was performed in 115 women. Sixty of these women fulfilled our inclusion criteria and constitute our study population.

Transvaginal sonography was carried out by the first author as described below. The equipment used was a GE Voluson 730 ultrasound system (General Electrics, Zipf, Austria) equipped with a 2.8 – 10 MHz transvaginal transducer. The field of view was 146°. Identical pre-installed ultrasound settings were used in all women. The power Doppler settings used were: frequency 3 - 9 MHz, pulse repetition frequency 0.6 kHz, gain -5.0, wall motion filter 'low 1'. The women were examined in the lithotomy position with an empty bladder. The ultrasound probe was slowly introduced into the vagina and care was taken to avoid exerting undue pressure, which may artificially lengthen the cervix[13]. After a satisfactory image had been obtained, the probe was withdrawn until the image became blurred. Then the probe was gradually advanced with only enough pressure to restore a satisfactory image. A sagittal plane through the cervix was selected where the internal os, the cervical canal and the external os were all visible simultaneously. Neither fundal nor suprapubic pressure was applied. After obtaining a good 2D gray scale ultrasound image of the cervix, the system was switched into the 3D mode, and then into the power Doppler mode. A longitudinal section of the cervix was centralized within the 3D sector appearing on the ultrasound screen. An ultrasound volume, containing the cervix, was acquired by holding the transducer stationary while its crystals were mechanically rotated across the sector with a sweep angle of 90°. The duration of the volume acquisition was 15 – 20 seconds depending on the dimensions of the 3D sector. The acquired volumes were stored on the hard disk of the ultrasound system for later analysis off-line. The following measurements were taken using 'any-plane' slicing of the volume acquired: length, anterior-posterior diameter and width of the cervix and of any cervical funneling (Figure 1). Funneling was defined as any visible opening of the internal cervical os. Cervical volume (cm^3) and power Doppler flow indices were calculated using the virtual organ computer aided analysis software

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(VOCAL^{TM}), which is integrated into the Voluson 730 ultrasound system. The following Doppler indices were calculated as described earlier[14,15] refer to our reproducibility study instead!: vascularization index (VI), flow index (FI) and vascularization flow index (VFI); see Figure 1. All ultrasound results were unavailable to the clinical staff.

After the ultrasound examination a digital examination of the cervix (Bishop score) was performed by the obstetrician in charge in the labor ward. Onset of labor was defined as the time when uterine contractions were regular with at least two contractions per 10 minutes. Clinical information about the patients was obtained from their medical records.

Statistical calculations were made using the Statistical Package for the Social Sciences (SPSS Inc., Chicago, Illinois, USA, version 12.02). Our outcome variables, start of labor >24h and >48h, and delivery >48h, and >60h after the ultrasound examiantion were chosen à priori. The statistical significance of a possible relationship between the outcome and the background variables was determined using logistic regression with likelihood ratios, the background variables examined being parity (multiparous vs. nulliparous), gestational age (<42 +0 gws vs. ≥ 42+0 gws), Bishop score, cervical length, anterior-posterior diameter and width, flow indices, funneling (yes vs. no), and funnel size. Logistic regression with stepwise selection of variables was used to determine which variables were independently associated with the outcome. The multivariable logistic regression analyses were made including parity (nulliparous coded as 0 vs. multiparous coded as 1), gestational age (<42 +0 gws coded as 0 vs. ≥ 42+0 gws coded as 1), and results of 3D ultrasound examination with and without Bishop score as predicting variable (all measurements in mm, funneling expressed as the mean of length, anterior-posterior diameter and width with 0 indicating absence of funneling). The

likelihood ratio test was used to determine which variables to include in the logistic regression model, a P-value < 0.05 being the threshold for inclusion. The objective of the model building process was to obtain a 'good fit' for the data with the least number of independent variables. The application of the regression equation to data from each woman gave the probability for that woman to go into spontaneous labor >24h or > 48h, and to deliver >48h or >60h, the estimated probability ranging from 0 to 1. Receiver operating characteristic (ROC) curves [ROC REF RICHARDSSON] were drawn for each diagnostic test (i.e., Bishop score, cervical length, and logistic regression models) to evaluate its diagnostic ability. The area under the ROC curve and the 95% confidence interval (CI) of this area were calculated. If the lower limit of the CI for the area under the ROC curve was > 0.5, the diagnostic test was considered to have a discriminatory potential. The statistical significance of a difference in the area under the ROC curve between the different diagnostic tests was determined as described by Hanley and MacNeil (23, 24 ref I EE´s artikel) using a customized computer program written in MATLAB (Version 6.0.0.88 release 12) designed by one of the co-authors (FDS). The ROC curves were also used to determine the best cut-off value for each diagnostic test, the best cut-off value being defined as the one corresponding to the point on the ROC curve situated most far away from the reference line [(ref till ROC-kurva] RICHARDSSON). The sensitivity, false positive-rate, and positive and negative likelihood ratio of the optimal cut-off values with regard to predicting start of labor >24h, >48h, delivery >48h and >60h were also calculated. Exact confidence intervals were calculated using the exact binomial distribution. Two tailed p-values ≤ 0.05 are considered statistically significant.

Results

Mean age was 31 years ± 4.9 (SD; standard deviation) and mean body mass index 28.7 kg/m^2 ± 3.09. Twenty-nine (48%) women were multipara. Nineteen women were examined at 41 + 5 – 6 gws, 37 women at 42 + 0 gws, and four women at 42 + 1 - 4 gws. Vaginal delivery occurred in 56 (93%) women, whereas Caesarean section was performed in four women, the indication being fetal distress (n = 2), placental abruption (n = 1), and mother's own request (n = 1). In 14 patients information about Bishop score was unavailable.

Results of univariate analyses are shown in Tables 1, 2, 3, and 4. Bishop score was lower, the cervix as measured by ultrasound was longer and cervical volume was larger in women who went into spontaneous labor >24h and >48h than in those who went into labor earlier, and Bishop score was lower and the cervix was longer in women who delivered >48h and >60h than in those who went delivered earlier. VI and VFI were lower in women who went into labor >48h and in those who delivered vaginally >60h than in those who went into spontaneous labor/delivered earlier, but the differences reached only marginal statistical significance (p-values 0.050 – 0.116). The proportion of nullipara tended to be higher among women who delivered >48h and >60h, but the differences were not statistically significant (p = 0.056 and 0.075).

Results of multivariable logistic regression analyses are shown in Table 5. Areas under ROC curves for Bishop score, cervical length, and logistic regression models, and optimal cutoff values with regard to predicting start of labor >24h, >48h, and delivery >48h and >60h, and the sensitivity, false-positive rate (1 minus specificity), and positive and negative likelihood ratios for the optimal cutoff of each predicting variable are shown in Table 6. Bishop score and vascular indices

did not enter any model to predict start of labor, only cervical length and width and parity did, the likelihood of start of labor >24h increasing with increasing cervical length and width and the likelihood of start of labor >48h being lower in parous women and increasing with increasing cervical length. When Bishop score was included in the logistic regression model building process it was the only variable independently related to vaginal delivery >48h, the likelihood of delivery >48h increasing with decreasing Bishop score. If Bishop score was not included in the model building, then cervical length, VI and FI independently predicted delivery >48h, the likelihood of delivery >48h increasing with increasing cervical length, decreasing VI and increasing FI. Cervical length and Bishop score were both independent predictors of delivery >60h. The areas under the ROC curves did not differ significantly (?) To be calculated.

Discussion

Our results show that both the Bishop score and ultrasonographic cervical length can predict the time to spontaneous onset of labor and the time to vaginal delivery in prolonged pregnancy. This is in agreement with results of other studies examining which factors are associated with the time to spontaneous onset of labor and/or time to spontaneous delivery[4,5,7]. Moreover, VI, which reflects the vascularization of the cervix, seems to be related to the time to vaginal delivery in prolonged pregnancy, VI being higher in women giving birth within 60 h than in those giving birth later ($p = 0.05$).

Multivariable logistic regression showed that ultrasound variables (cervical length and width) were independent predictors of time to start of labor (>24h and >48h), but that Bishop score did not contribute any additional predictive information. On the other hand, Bishop score was the only variable to independently predict vaginal delivery >48h, and both Bishop score and cervical length independently predicted vaginal delivery >60h. If Bishop score was not included in the model building process, then cervical length, VI and FI were independent predictors of delivery >48h, but cervical length was the only variable to independently predict delivery >60h. A possible interpretation of the finding that increasing VI and decreasing FI increased the likelihood of delivery $\leq$ 48h is that with progression of cervical ripening the density of small vessels in the cervix increases (FI should be low in small vessels, because small vessels contain few blood corpuscles, and therefore the back scattered energy should be low). Our findings support the theory that the cervix becomes increasingly vascularised during the cervical ripening process. To the best of our knowledge there are no other studies examining cervical vascularization in pregnancy using Doppler ultrasound techniques.

None of the variables tested with regard to their ability to predict the time to spontaneous onset of labor or to vaginal delivery were particularly good predictors. Most predictors were associated with only a small or moderate change in the likelihood of the outcome, the positive likelihood ratio of the selected cut-offs never exceeding 5.8 and the lowest negative likelihood ratio being 0.09 (Jaeschke). We must check and comment on the difference in areas under ROC curves.

Is the improved prediction of start of labor > 24h by using 3D ultrasound (length and width) instead of Bishop score worth the effort? Was the difference in the area under the ROC curve for 1st model statistically significantly different from the area under the ROC curve for Bishop score or cx length? Adding parity to cervical length measurement in a model improved the prediction marginally: worth the effort to feed the data into a computer? Or measure cervical length only? Feed one variable (cervical length or Bishop score) into a model or just use one selected cutoff? The model including cervical length, VI and FI was not superior to Bishop score for predicting delivery > 48h but it was superior to cervical length measurement alone (statistically significant difference in area under the ROC curve of model and of cervix length?). Even though our results show that vascularization of the cervix may have something to do with cervical ripening, 3D power Doppler ultrasound examination of the cervix to predict time to vaginal delivery in prolonged pregnancy is probably not clinically very useful, because we can obtain similar information by the Bishop score, and Bishop score does not require any technical equipment. Whether the improvement in prediction of vaginal delivery > 60h by adding ultrasound examination to Bishop score is substantial enough to justify the added use of ultrasound exmination may be questioned (statistically significant difference in area under the ROC curveOF 5^{TH} REGRESSION MODEL AND bishop score?).

Acknowledgments

This study was supported by the Swedish Medical Research Council (grants nos. K2001-72X-11605-06A and K2002-72X-11605-07B), two governmental grants (Landstingsfinansierad regional forskning, Region Skåne, and ALF-medel), and Funds administered by Malmö University Hospital.

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16. hanley and MacNeil?

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Figure 1. ROC curves for methods of predicting start of labor ≤ 48h (n = 44). Bishop score, cervical length as measured by 2D ultrasound, cervical length as measured by 3D ultrasound, regression model 1, regression model2, and regression model 3. The regression models are described in the footnote of Table 4.

Figure 2. ROC curves for methods of predicting delivery ≤ 48h (n = 44). Bishop score, cervical length as measured by 2D ultrasound, cervical length as measured by 3D ultrasound, regression model 4. The regression model is described in the footnote of Table 4.

Figure 3. ROC curves for methods of predicting delivery ≤60h (n = 44). Bishop score, cervical length as measured by 2D ultrasound, cervical length as measured by 3D ultrasound, regression model 5. The regression model is described in the footnote of Table 4.

Table 1. Gestational age, parity, ultrasound results, and Bishop score for women with spontaneous start of labor ≤ 24 h vs. > 24 h after ultrasound examination

Results	Delivery ≤ 24 h	Delivery > 24 h	P-value
	n =21	n = 39	
Multipara; n (%)	9 (43%)	20 (51%)	0.533
< 42+0 gws at examination	8 (38%)	11 (28%)	0.435
3D ultrasound			
Cervix			
Length, mm; median (range)	7 (2 - 37)	15 (2 - 40)	0.002
AP diameter, mm; mean ± SD	38 ± 10.1	37 ± 8.5	0.874
Width, mm; mean ± SD	41 ± 5.2	44 ± 5.8	0.047
Volume, cm^3; mean ± SD	24.2 ± 10.09	33.7 ± 13.52	0.005
Flow indices			
VI; median (range)	7.5 (0.3 - 23.7)	4.5 (0.9 - 17.0)	0.268
FI; mean ± SD	29.2 ± 3.47	29.3 ± 3.98	0.891
VFI; median (range)	2.0 (0.1 - 8.3)	1.3 (0.2 - 5.6)	0.324
Funnel; n (%)	12 (57%)	24 (62%)	0.741
Length, mm; median (range)	6 (1 - 20)	8 (2 -16)	0.920
AP diameter, mm; median (range)	9 (5 - 16)	9 (5 - 19)	0.905
Width, mm; mean ± SD	14 ± 5.0	15 ± 4.7	0.606
	n = 18	n = 28	
Bishop score; mean ± SD	5.8 ± 1.98	4.3 ± 1.76	0.006

VI, vascularisation index; FI, flow index; VFI, vascularisation flow index; SD, standard deviation; AP, anterior-posterior; gws, gestational weeks.

Table 2. Gestational age, parity, ultrasound results, and Bishop score for women with spontaneous onset of labor ≤ 48 h vs. > 48 h after ultrasound examination

	Onset of labour		
	≤ 48 h	> 48 h	P-value
	n =35	n = 25	
Multipara; n (%)	20 (57%)	9 (36%)	0.104
< 42+0 gws at examination; n (%)	13 (37%)	6 (24%)	0.276
3D ultrasound			
Cervix			
Length, mm; median (range)	9 (2 - 4)	20 (5 - 39)	0.005
AP diameter, mm; mean ± SD	39 ± 8.3	35 ± 9.7	0.138
Width, mm; mean ± SD	44 ± 5.6	42 ± 5.8	0.335
Volume, cm^3; mean ± SD	27.4 ± 12.50	34.5 ± 13.19	0.037
Flow indices			
VI; median (range)	6.9 (0.3 - 23.7)	4.6 (0.9 - 16.4)	0.096
FI; mean ± SD	29.5 ± 3.36	29.0 ± 4.35	0.635
VFI; median (range)	1.8 (0.1 - 8.3)	1.0 (0.2 - 5.6)	0.116
Funnel; n (%)	20 (57%)	16 (64%)	0.220
Length, mm; median (range)	5 (1 - 20)	8 (2 - 16)	0.333
AP diameter, mm; median (range)	7 (5 - 18)	9 (5 - 19)	0.685
Width, mm; mean ± SD	15 ± 4.7	14 ± 4.9	0.716
	n = 25	n = 21	
Bishop score; mean ± SD	5.6 ± 1.96	4.1 ± 1.73	0.009

VI, vascularisation index; FI, flow index; VFI, vascularisation flow index; SD, standard deviation; AP, anterior-posterior; gws, gestational weeks.

Table 3. Gestational age, parity, ultrasound results, and Bishop score for women who delivered vaginally ≤ 48 h vs. > 48 h after ultrasound examination

	Delivery ≤ 48 h	Delivery > 48 h	P-value
	n =29	n = 27	
Multipara; n (%)	17 (59%)	9 (33%)	0.056
< 42+0 gws at examination	9 (31%)	7 (26%)	0.672
3D ultrasound			
Cervix			
Length, mm; median (range)	8 (2 - 40)	19 (2 - 39)	0.015
AP diameter, mm; mean ± SD	39 (23 - 59)	37 (20 - 56)	0.330
Width, mm; mean ± SD	43 ± 5.9	43 ± 5.9	0.902
Volume, cm^3; mean ± SD	27.0 ± 12.74	33.2 ± 12.95	0.078
Flow indices			
VI; median (range)	6.9 (0.3 - 23.7)	4.3 (0.9 - 16.4)	0.118
FI; mean ± SD	28.9 ± 3.18	29.8 ± 4.43	0.334
VFI; median (range)	1.8 (0.1 - 8.3)	1.1 (0.2 - 5.6)	0.210
Funnel; n (%)	16 (55%)	18 (67%)	0.378
Length, mm; median (range)	6 (1 - 2)	7 (2 -16)	0.646
AP diameter, mm; median (range)	9 (5-18)	9 (5-19)	0.495
Width, mm; mean ± SD	15 ± 4.9	14 ± 4.4	0.314
	n = 22	n = 20	
Bishop score; mean ± SD	5.9 ± 1.79	3.8 ± 1.71	0.003

VI, vascularisation index; FI, flow index; VFI, vascularisation flow index; SD, standard deviation; AP, anterior-posterior; gws, gestational weeks.

Table 4 Gestational age, parity, ultrasound results, and Bishop score for women who delivered vaginally ≤ 60 h vs. > 60 h after ultrasound examination

Results	Delivery ≤ 60 h	Delivery > 60 h	P-value
	n =34	n = 22	
Multipara; n (%)	19 (56%)	7 (32%)	0.075
< 42+0 gws at examination	12 (35%)	4 (19%)	0.158
3D ultrasound			
Cervix			
Length, mm; median (range)	9 (2 - 40)	19 (2 - 39)	0.015
AP diameter, mm; mean ± SD	39 (23 - 59)	34 (20 - 56)	0.220
Width, mm; mean ± SD	44 ± 6.0	42 ± 6.0	0.330
Volume, cm^3; mean ± SD	27.6 ± 12.65	33.7 ± 13.15	0.083
Flow indices			
VI; median (range)	7.1 (0.3 - 23.7)	3.5 (0.9 - 16.4)	0.050
FI; mean ± SD	29.3 ± 3.37	29.2 ± 4.52	0.877
VFI; median (range)	1.9 (0.1 - 8.3)	1.0 (0.2 - 5.6)	0.076
Funnel, n (%)	20 (59%)	14 (64%)	0.718
Length, mm; median (range)	5 (1 - 20)	8 (2 - 16)	0.466
AP diameter, mm; median (range)	7 (5 - 18)	9 (5 - 19)	0.900
Width, mm; mean ± SD	15 ± 4.7	14 ± 4.5	0.366
	n = 24	n = 18	
Bishop score; mean ± SD	5.6 ± 1.97	3.8 ± 1.74	0.004

VI, vascularisation index; FI, flow index; VFI, vascularisation flow index; SD, standard deviation; AP, anterior-posterior; gws, gestational weeks.

Table 5. Logistic regression models to predict time to start of labor and delivery

		Maximum Likelihood Estimates		Odds Ratio Estimates		
		Standard Estimate	P-value	Effect	Point Estimate	95% Confidence Limits
Start of labor > 24h						
Model building with Bishop score (n = 46)						
Intercept		-1.414	0.040			
Cervical length	Labor 24h3	0.149	0.008	Cervical length	1.160	1.040 – 1.295
Model building without Bishop score (n = 60)	Labor 24h1					
Intercept		-7.409	0.012			
Cervical length		0.129	0.004	Cervical length	1.138	1.042 – 1.243
Cervical width		0.147	0.020	Cervical width	1.158	1.024 – 1.310
Start of labor > 48h						
Model building with Bishop score (n = 46)						
Intercept	Labor 7	0.344	0.749			
Cervical length		0.107	0.008	Cervical length	1.113	1.028 – 1.204
Parity		-1.447	0.047	Parity	0.235	0.057 – 0.979
Model building without Bishop score (n = 60)						
Intercept		-1.529	0.004			
Cervical length	Labor 5	0.076	0.009	Cervical length	1.079	1.020 – 1.142

Cont.

Table 4. Continued

	Maximum Likelihood Estimates		Odds Ratio Estimates		
	Standard Estimate	P-value	Effect	Point Estimate	95% Confidence Limits
Delivery > 48h					
Model building with Bishop score (n = 42)					
Intercept	3.424	0.006			
Bishop score Delivery 48h7	-0.722	0.003	Bishop score	0.486	0.303 – 0.780
Model building without Bishop score (n = 56)					
Intercept delivery 48h6		-6.019	0.036		
Cervical length	0.066	0.037	Cervical length	1.068	1.004 – 1.136
VI	-0.154	0.045	VI	0.857	0.737 – 0.996
FI	0.203	0.047	FI	1.225	1.003 – 1.495

Cont.

Table 4. Continued

	Maximum Likelihood Estimates		Odds Ratio Estimates		
	Standard Estimate	P-value	Effect	Point Estimate	95% Confidence Limits
Delivery > 60h					
Model building with Bishop score (n = 42)					
Intercept delivery60h7	0.621	0.608			
Bishop score	-0.442	0.033	Bishop score	0.643	0.428 – 0.966
Cervical length	0.082	0.048	Cervical length	1.086	1.001 – 1.178
Model building without Bishop score (n =56)					
Intercept	-1.638	0.004			
Cervical length	0.076	0.011	Cervical length	1.079	1.017 – 1.144

VI, vascularity index; FI, flow index

Table 6. Areas under receiver operator characteristic (ROC) curves for Bishop score, cervical length and logistic regression models, and optimal cutoff values with regard to predicting start of labor >24 h and > 48h and delivery > 48h and >60h, and the sensitivity, false-positive rate (1 minus specificity), and positive and negative likelihood ratios for the optimal cutoff

	Area under ROC curve		Optimal cutoff	Sensitivity	False-positive rate	LR+	LR–
	Estimate	95% CI					
Start of labor > 24h							
For women with Bishop score (n = 46)							
1st regression model[1]	0.839	0.721 – 0.958	0.56*	0.82	0.17	4.8	0.21
Cervical length	0.789	0.656 – 0.921	8.5 mm*	0.82	0.33	2.5	0.27
			12.5 mm*	0.64	0.11	5.8	0.40
Bishop score	0.724	0.569 – 0.880	5**	0.57	0.22	2.6	0.55
For all women (n =60)							
1st regression model[1]	0.836	0.724 – 0.948	0.56*	0.85	0.19	4.5	0.19
Cervical length	0.758	0.628 – 0.889	8.5 mm*	0.85	0.38	2.2	0.25
			12.5 mm*	0.64	0.14	4.5	0.42

Cont.

Table 5. Continued

	Area under ROC curve		Optimal cutoff	Sensitivity	False-positive rate	LR+	LR–
	Estimate	95% CI					
Start of labor > 48h							
For women with Bishop score (n = 46)							
2nd regression model [2]	0.788	0.659 – 0.917	0.44*	0.71	0.24	3.0	0.38
Cervical length, mm	0.783	0.646 – 0.920	8.5 mm*	0.91	0.40	2.3	0.16
			12.5 mm*	0.71	0.20	3.6	0.36
Bishop score	0.717	0.568 – 0.867	5**	0.76	0.36	2.1	0.37
For all women, n =60							
2nd regression model[2]	0.753	0.631 – 0.875	0.44	0.72	0.29	2.5	0.39
Cervical length	0.745	0.619 – 0.871	8.5 mm**	0.92	0.51	1.9	0.16

Cont.

Table 5. Continued

	Area under ROC curve		Optimal cutoff	Sensitivity	False-positive rate	LR+	LR–
	Estimate	95% CI					
Delivery > 48h							
For women with Bishop score (n = 42)							
Bishop score, mm	0.816	0.682 – 0.950	5**	0.85	0.27	3.1	0.21
3rd regression model [3]	0.805	0.659 – 0.950	0.39*	0.85	0.23	3.7	0.19
Cervical length, mm	0.749	0.590 – 0.908	8.5 mm*	0.90	0.41	2.2	0.17
			12.5 mm*	0.70	0.18	3.8	0.37
For all women, n = 56							
3rd regression model [3]	0.784	0.654 – 0.914	0.56*	0.70	0.14	5.1	0.34
Cervical length	0.736	0.596 – 0.876	8.5 mm*	0.93	0.48	1.9	0.14
			12.5 mm*	0.74	0.21	3.6	0.33

Cont.

Table 5. Continued

	Area under ROC curve		Optimal cutoff	Sensitivity	False-positive rate	LR+	LR–
	Estimate	95% CI					
Delivery > 60h							
For women with Bishop score (n = 42)							
4th regression model [4]	0.806	0.668 – 0.943	0.38	0.83	0.25	3.3	0.22
Cervical length	0.786	0.643-0.929	8.5 mm*	0.94	0.42	2.3	0.10
Bishop score	0.752	0.602 – 0.903	5**	0.83	0.33	2.5	0.25
For all women (n =56)							
Cervical length	0.748	0.618 – 0.878	8.5 mm*	0.96	0.53	1.8	0.09

ROC, receiver operating characteristics; CI, confidence interval; LR+ , positive likelihood ratio; LR–, negative likelihood ratio

*Larger values of the test result indicate stronger evidence for the outcome

** Smaller values of the test result indicate stronger evidence for the outcome

[1] Probability of start of labor >24 h = $[e^z/(1+e^z)]$ where z = -7.409 + 0.129 x cervical length + 0.147 x cervical width

[2] Probability of start of labor > 48 h = $[e^z/(1+e^z)]$ where z = 0.344 + 0.107 x cervical length -1.447 x parity

[3] Probability of delivery > 48 h = $[e^z/(1+e^z)]$ where $z = -6.019 + 0.066 \times \text{cervical length} - 0.154 \times \text{VI} + 0.203 \times \text{FI}$

[4] Probability of delivery > 60 h = $[e^z/(1+e^z)]$ where $z = 0.621 - 0.442 \times \text{Bishop score} + 0.082 \times \text{cervical length}$