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Prediction of Successful Outcome of Labor Induction at Term by Transvaginal Sonographic Assessment of Cervical Length

Narissara Sanpatichakit, M.D.,*
Prisana Panichkul, M.D.*

** Department of Obstetrics and Gynecology, Phramongkutklao Hospital, Bangkok, Thailand*

ABSTRACT

Objectives: To examine transvaginal sonography assessment of cervical length (TVSCL) as a predictor of active phase of labor, successful vaginal delivery after labor induction, and to estimate the most useful cut-off point for cervical length (CL).

Materials and Methods: A prospective cohort study was conducted in the Obstetrics and Gynecology Department of Phramongkutklao Hospital. Pre-induction cervical assessment was undertaken in 120 women with singleton pregnancy at 37-42 weeks of gestation who underwent induction of labor. All women were measured for CL using transvaginal sonography followed by pelvic examination for Bishop score (BS) assessment.

Results: Successful induction of labor to active phase within 24 hours occurred in 84.1% of the subjects. The best cut-off point of CL for the prediction of successful labor induction to active phase within 24 hours was found to be 3.14 cm or less with a sensitivity of 73.3 %, a specificity of 78.9 %, as well as negative and positive predictive values of 35.7% and 94.9%, respectively. In addition, a 3.14 cm or less cut-off point of CL can be used to predict successful vaginal delivery with a sensitivity of 73.6%, a specificity of 50%, as well as a negative and positive predictive value of 52.3% and 71.8%, respectively.

Conclusion: TVSCL was significantly associated with successful induction of labor to active phase within 24 hours and could be used as a predictor for successful induction to vaginal delivery with a 3.14 cm or less cut-off point of CL.

Keywords: bishop score, transvaginal sonography cervical length, induction of labor, sensitivity, specificity.

Correspondence to: *Narissara Sanpatichakit, M.D., Department of Obstetrics and Gynecology, Phramongkutklao Hospital, Bangkok 10400, Thailand, Email: zigzagsnake@gmail.com*

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การทำนายผลสำเร็จของการชักนำการคลอดในผู้ป่วยตั้งครรภ์ครบกำหนดโดยการวัดความยาวปากมดลูกด้วยอัลตราซาวนด์ทางช่องคลอด

นริศรา สัณห์พานิชกิจ, ปริศนา พานิชกุล

บทคัดย่อ

วัตถุประสงค์: *ประเมินการวัดความยาวปากมดลูกด้วยอัลตราซาวนด์ทางช่องคลอดเพื่อทำนายการเข้าสู่ระยะเร่งของปากมดลูก ความสำเร็จในการคลอดทางช่องคลอดหลังการชักนำการคลอด และหาค่าคงที่ของความยาวปากมดลูกที่สามารถทำนายผลสำเร็จของการชักนำการคลอด*

วัสดุและวิธีการ: *เป็นการศึกษาแบบไปข้างหน้าที่มีหญิงตั้งครรภ์เดี่ยว อายุครรภ์ระหว่าง 37-42 สัปดาห์ และมีข้อบ่งชี้ในการนอนโรงพยาบาลพระมงกุฎเกล้าเพื่อชักนำการคลอดเข้าร่วมงานวิจัย 120 คน ผู้เข้าร่วมวิจัยทุกคนจะได้รับการวัดความยาวปากมดลูกทางช่องคลอดตามด้วยการตรวจภายในเพื่อประเมินคะแนนบิชอพ ก่อนการชักนำการคลอด*

ผลการศึกษา: *มีหญิงตั้งครรภ์ประสบความสำเร็จในการชักนำการคลอดโดยปากมดลูกสามารถเข้าสู่ระยะเร่งใน 24 ชั่วโมงคิดเป็นร้อยละ 84.1 ของหญิงตั้งครรภ์ที่เข้าร่วมงานวิจัยทั้งหมด และพบว่าเมื่อค่าความยาวของปากมดลูกที่วัดโดยอัลตร้าซาวด์ทางช่องคลอดมีค่าน้อยกว่าหรือเท่ากับ 3.14 เซนติเมตร สามารถทำนายความสำเร็จของการชักนำการคลอดจนเข้าสู่ระยะเร่งมีค่าความไวคิดเป็นร้อยละ 73.3 ค่าความจำเพาะคิดเป็นร้อยละ 78.9 ค่าทำนายผลลบคิดเป็นร้อยละ 35.7 ค่าทำนายผลบวกคิดเป็นร้อยละ 94.9 ในส่วนการใช้ความยาวปากมดลูกเพื่อทำนายความสำเร็จในการคลอดทางช่องคลอดมีค่าความไวคิดเป็นร้อยละ 73.6 ค่าความจำเพาะคิดเป็นร้อยละ 50 ค่าทำนายผลลบคิดเป็นร้อยละ 52.3 ค่าทำนายผลบวกคิดเป็นร้อยละ 71.8*

สรุป: *การวัดความยาวของปากมดลูกด้วยวิธีอัลตราซาวนด์ทางช่องคลอดมีความสัมพันธ์กับความสำเร็จในการชักนำการคลอดโดยปากมดลูกสามารถเข้าสู่ระยะเร่งได้ภายใน 24 ชั่วโมง และประสบความสำเร็จในการคลอดทางช่องคลอดอย่างมีนัยสำคัญทางสถิติ โดยที่ความยาวปากมดลูกนั้นมีค่าน้อยกว่าหรือเท่ากับ 3.14 เซนติเมตร*

คำสำคัญ: *คะแนนบิชอพ, การวัดความยาวของปากมดลูกด้วยวิธีอัลตราซาวนด์ทางช่องคลอด, การชักนำการคลอด, ค่าความไว, ค่าความจำเพาะ*

Introduction

Induction of labor is a process in which uterine contractions are initiated by medical or surgical means prior to the spontaneous onset of labor that is frequently carried out in approximately 20% of pregnancies[1]. Induction of labor is warranted as a therapeutic option when the benefits of expeditious delivery outweigh the risks of continuing the pregnancy. Indications for induction are attributed to a number of factors including health problems and obstetrical complications in pregnancy. The commonest indication for induction is prolonged pregnancy, where several studies have shown that induction compared to expectant management is associated with a substantial reduction in perinatal mortality[2-4]. In instances where induction is indicated and the status of the cervix is unfavorable, agents for cervical ripening may be used. The status of the cervix can be determined by the Bishop score (BS) system[5], the sole standard method to predict the outcome of labor induction. The BS system comprises identification of cervical dilation, cervical effacement, cervical consistency, cervical position, and fetal station, where a maximum score of 13 can be obtained[6]. The American College of Obstetricians and Gynecologists 2009 defines an unfavorable cervix at BS ≤ 6, and furthermore reports no failures with a score of ≥ 9[5]. Be this as it may, this assessment is subjective, allowing for differences to arise in digital assessments of the cervix. These differences are alluded to in several bodies of research and studies, which have demonstrated a poor predictive value for the outcome of induction, especially in women with a low BS, and this contributes to limitations in assessing the change of the internal os when the external os is closed[7, 8].

Transvaginal sonography is a well-known objective technique for assessing the entire length of the cervix and the morphological characteristics of the internal os even when the external os is closed[9,10]. A recent systematic review of meta-analysis indicated that transvaginal sonography assessment of cervical length (TVSCL) at or near term has a moderate capacity to predict the outcome of delivery after induction[11]. To date, most studies on the possible role of TVSCL in labor induction have focused specifically on the mode of delivery or the total duration of labor as a primary outcome, e.g. research conducted by Kaoian et al found that TVSCL and BS were useful evaluations prior to labor induction to predict the risk of cesarean delivery[12]. However, the mode of delivery and the total duration of labor can be affected by multiple factors other than cervical status, such as parity, body mass index (BMI), fetal weight, and indications of cesarean delivery. To limit the scope of analysis the current analysis will adopt a definition of labor induction as the ability to initiate labor[5]. Given the aforementioned limitations and in attempts to provide further and less subjective forms of assessment TVSCL evaluations were performed to probe the degree to which TVSCL and active labor within 24 hours after initiation of labor induction are correlated, as well as to provide an estimate of cut-off points of cervical length (CL) and prediction of successful vaginal delivery after labor induction.

Materials and Methods

This prospective cohort study was conducted at the Obstetrics and Gynecology Department of Phramongkutklao Hospital between November 2017 and July 2018 upon receiving approval from the Institutional Review Board of the Royal Thai Army Medical Department. In total, pre-induction TVSCL assessment was carried out in 120 women who were attended for delivery. Inclusion criteria for the current analysis comprised singleton pregnant woman, who were at least 18 years old with gestational ages between 37 and 42 weeks, as well as a living fetus with cephalic presentation, absence of labor (defined as the presence of regular and painful uterine contractions), no uterine scar, and no contraindication for vaginal delivery. Women who presented with fetal distress upon initial admission and those who underwent cesarean sections within 24 hours before the onset of active labor were excluded. Eligible women were enrolled into the study after obtaining

written informed consent to participate in the study and baseline characteristics such as age, gestational age (GA), and indication of induction were recorded. TVSCLs in centimeters (cm) were obtained by one of two fellows of maternal fetal medicine who have been extensively trained in transvaginal ultrasonography using a HS60 (Samsung Medison Co. Ltd., Seoul, Korea) machine equipped with a 6 MHz transvaginal probe. Upon obtaining the TVSCL, a BS score was calculated by obstetrics and gynecology residents who were unaware of the result of the sonographic findings, and this was followed by induction of labor as determined by the derived BS score. Clinically, it is difficult to identify the precise time of onset of true labor. Instead, active labor is often recognized by cervical dilatation of 4 cm or greater in the presence of uterine contractions[13].

Preinduction TVSCL was performed according to the Fetal Medicine Foundation protocol[14]. After emptying the bladder, subjects were placed in a lithotomy position and a probe was gently placed in the anterior vaginal fornix to ensure a sagittal view of the cervix, identification of the internal os, external os, cervical canal, endocervical mucosa and lessen falsely elongated measurement due to undue pressure. Calipers were used to measure the distance between the internal os and external os. In each evaluation, three measurements were performed, and the shortest distance was taken as the CL.

Induction of labor was performed according to the standard labor induction guidelines of Phramongkutklao Hospital which is based on Royal College of Obstetricians and Gynecologists[1] issued in July 2008. If the BS was equal to or less than 6, the induction of labor was started within one hour after the cervical assessment. A 3-milligram (mg) dinoprostone (PGE2) vaginal tablet was inserted, and the time of the application was recorded. The adopted regimens of PGE2 were one dose of vaginal PGE2 followed by a second dose after 6 hours, in the event that labor was not established (up to a maximum of two doses in 24 hours)[1]. Oxytocin was administered via intravenous infusion for augmentation of labor following cervical ripening, BS > 6, in the event that irregular uterine contractions were present, or following amniotomy. Oxytocin was administered as per standard protocols 6 hours after the last PGE2 dose, and if cervical progression did not ensue after 8 hours of oxytocin infusion, the protocol was repeated the following day. Electronic fetal heart rate monitoring was carried out for all women and induction active phase interval, number of doses of PGE2 and mode of delivery were recorded. The primary outcome investigated in this analysis was successful induction, which was defined as the ability to achieve the active phase of labor corresponding to a painful uterine contractions (interval, 2–3 minutes) developed and cervical dilatation of 4 cm or more within 24 hours of initiating induction of labor. Secondary outcomes included producing estimates of the most useful cut-off points of CL and predicting successful vaginal delivery after labor induction.

Sample size justification

Sample size calculations are based on Yang et al's study[15] which reported the sensitivity and specificity of transvaginal ultrasound for cervical assessment before induction of labor to predicting successful induction of labor to active phase to be 75% and 83%, respectively. To probe for statistical significance, a type-1 error-value (α) of 0.05 was adopted as well as a power-value of 0.8, acceptable error (d) 0.1, and $Z_{0.025} = 1.96$. At least one hundred women were required for the sample sized in this study.

Statistical analysis

Data were analyzed using STATA/MP12. Numerical variables were presented in mean ± standard deviation (SD) and in median (min-max) while categorical variables were presented as number of cases and percentages. A chi-squared test (χ^2) and Fisher's exact test were used for comparison between the groups to analyze categorical variables, while Mann–Whitney U-test (un-normal distribution) and student's t test (normal distribution) were used for continuous variable analysis, where two-sided p

values were reported throughout. The performance of TVSCL and BS as tests to predict successful induction was evaluated using receiver operating characteristic curves (ROC). The area under the curve (AUC) was then calculated, and the confidence intervals (CIs) for this area were established. Sensitivity, specificity, positive predictive value and negative predictive value at different cut-off points were calculated for both CL and BS. Following this, a Pearson correlation calculation was conducted to analyze the relationship between BS, CL and successful induction time intervals. Statistical significance was defined by p values < 0.05.

Results

The mean gestation age at induction was 39.2 ± 1.5 weeks and 82 (68.3%) of the 120 women were nulliparous. The indications for labor induction were GA beyond 40 weeks of gestation in 46 women (38.3%), hypertension in 31 women (25.8%), gestational diabetes mellitus (GDM) in 30 women (25%), oligohydramnios with intrauterine growth restriction (IUGR) in 12 women (10%), and premature rupture of membranes (PROM) in 1 woman (0.8%). Further demographic characteristics of the population are shown in Table 1. Of the total subjects, 101 women (84.1%) had successful induction of labor to active phase within 24 hours, while failure was observed in 19 cases (15.8%). Be this as it may, both groups were similar with regards to mean age, GA, fetal weight and indication of induction. When compared to the women with successful induction of labor to active phase within 24 hours, those for whom labor could not be induced within 24 hours had significantly higher BMIs (27.4 ±4.7 vs. 22.7±4.2 kg/m^2, respectively) and a higher proportion of them were among the nulliparous group (18 (22%) vs 1 (2.6%), respectively) (Table 2).

Table 1. Demographic characteristics of the study population (n=120).

Characteristics	n	%
Age (years)		
Mean (mean ± SD)	29.5 ± 6.0	
Body mass index (kg/m^2)		
Mean (mean ± SD)	23.4 ± 4.5	
< 30	111	92.5
30$^+$	9	7.5
Parity		
Nulliparous	82	68.3
Multiparous	38	31.6
Gestational age (weeks)		
Mean (mean ± SD)	39.2 ± 1.4	
Indication of induction		
GDM	30	25.0
HT	31	25.8
Gestational age beyond 40 weeks	46	38.3
Oligohydramnios with IUGR	12	10.0
PROM	1	0.8

SD: standard deviation, GDM: gestational diabetes mellitus, HT: hypertension, IUGR: intrauterine growth restriction, PROM: prelabor rupture of membranes.

Table 2. Comparison of demographic characteristics with time of induction to active phase.

Characteristics	Induction to active phase interval		p value
	< 24 hours (101)	≥ 24 hours (19)	
Maternal age (years) (mean ± SD)	29.3 ± 5.9	30.2 ± 6.7	0.588
GA (weeks) (mean ± SD)	39.3 ± 1.4	38.8 ± 1.2	0.187
Body mass index (kg/m^2) (mean ± SD)	22.7 ± 4.1	27.4 ± 4.7	< 0.001
Fetal weight (kg) (mean ± SD)	3.1 ± 0.5	3.1 ± 0.4	0.762
Indication (n (%))			
GA beyond 40 weeks	43 (42.6%)	3 (15.8%)	0.038 *
GDM	23 (22.7%)	7 (36.8%)	0.248*
HT	23 (22.8%)	8 (42.1%)	0.091*
Oligohydramnios with IUGR	11 (10.9%)	1 (5.3%)	0.688*
PROM	1 (1%)	0 (0%)	1*
Parity (n (%))			
nulliparous	64 (63.3%)	18 (94.7%)	0.006*
multiparous	37(36.6%)	1(5.3%)	0.006*

independent t-test, Fisher's exact test*, significant p<0.05.
SD: standard deviation, GA: gestation age, GDM: gestational diabetes mellitus, HT: hypertension, IUGR: intrauterine growth restriction, PROM: prelabor rupture of membranes.

The number of parities was found to exert an effect on the duration of the active phase with multiparous women showing shorter duration of labor induction to active phase than for nulliparous women (11.6 ± 5.1 vs. 17.5 ± 10.7 hours, respectively ($p < 0.001$)). Mean CL values in nulliparous and multiparous woman were 2.8 ± 0.9 and 2.8 ± 0.9 cm, respectively ($p = 0.840$) and mean BS in nulliparous and multiparous woman were 4 ± 1.4 and 4.1 ± 1.3 cm, respectively ($p = 0.618$). From this, it can be observed that the number of parities had no noticeable effect on the mean CL and BS. Conversely, BMI and parity provided significant and independent contributions to the prediction of active phase within 24 hours of induction. The mean TVSCL before induction of labor was 2.8 ± 0.9 cm and the mean induction to active phase interval was 15.6 ± 9.7 hours. The association between CL and the induction to active phase interval is shown in Fig. 1. These results indicate that a shorter CL was significantly related to a shorter induction to active phase interval ($p < 0.001$). Furthermore, both cervical assessment methods were significantly correlated, such that a higher BS scores correlated with lower CL as shown in Fig. 2. ($r = -0.481$, $p < 0.001$). Fig. 3 shows the ROC plots for BS and CL with respect to active phase interval within 24 hours. The values obtained for both BS and CL were consistently above the reference line, which indicated that there was a significant relationship between these variables and prediction of induction of labor. Here, the AUC for CL was 0.846 (95%CI 0.0390-0.770) and the AUC for BS was 0.765 (95%CI 0.671-0.858), however, a p value of 0.115 was found. Both methods (TVSCL and BS) provided a useful prediction of successful induction of labor to active phase within 24 hours. An optimized cut-off point of CL, as determined by the ROC, was found to be 3.14 cm or less with a sensitivity of 73.3%, a specificity of 78.9%, a positive predictive value of 94.9%, and a negative predictive value of 35.7%. This cut off point value could be used in both nulliparous and multiparous groups as the number of parities was not observed to exert an significant influence on the CL.

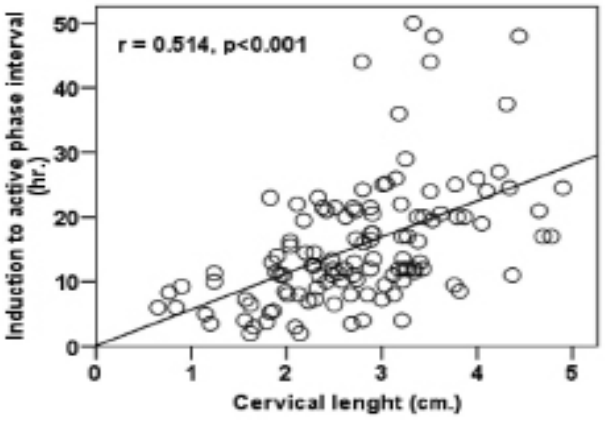

Fig. 1. Correlation between cervical length and Induction to active phase interval (hours).
Pearson's correlation; $p < 0.05$ statistical significance.

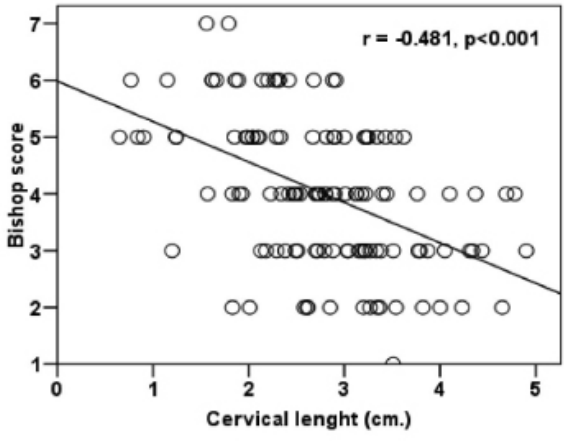

Fig. 2. Correlation between transvaginal sonographic assessment of cervical length and Bishop score.
Pearson's correlation; $p < 0.05$ = statistical significance

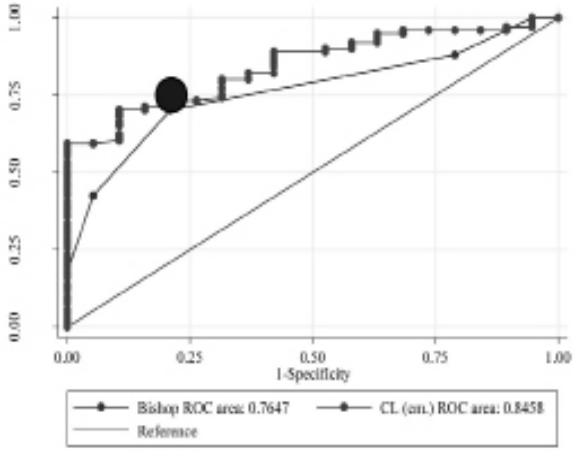

Fig. 3. Receiver-operating characteristic curves for the two methods of assessment.
Receiver operating characteristic (ROC) curves, Independent T-test, significant $p < 0.05$

Table 3 contains information concerning the relationship between CL and the success rate of induction of labor to active phase within 24 hours. Here, it can be seen that shorter than median CL achieved significantly higher success rates than those with longer CL values (2.6 cm (0.7-4.8) vs 3.5 cm (2.8-4.9), respectively, $p < 0.001$). It was found that 73.3% of successful inductions of labor to active phase within 24 hours were predicted adopting a cut-off point of 3.14 cm or less, while only 26.7% of successful inductions presented a CL > 3.14 cm, i.e. CL values below the cut-off point (3.14 cm) were good indicators of successful induction of labor to active phase within 24 hours.

Table 3. Predictability of CL for successful induction to active phase.

	Induction to active phase interval		p value
	< 24 hours (101)	≥ 24 hours (19)	
CL median (min-max) cm	2.61 (0.65-4.78)	3.51 (2.79-4.9)	< 0.001
CL ≤ 3.14 cm	74 (73.3%)	4 (21.1%)	< 0.001
CL > 3.14 cm	27 (26.7%)	15 (78.9%)	

Mann-Whitney U test, significant $p < 0.05$
CL: Cervical length

Investigation into the route of delivery found that 76 women (63.3%) delivered vaginally and 44 women (36.7%) delivered by cesarean section. The indications for cesarean section were fetal distress (n = 5), cephalopelvic disproportion (n = 26), failed induction (n = 12) and preeclampsia with severe feature (n = 1). The TVSCL was observed to be significantly shorter in women who delivered vaginally when compared with women who delivered by cesarean section (2.6 ± 0.8 vs. 3.0 ± 1.0 cm, respectively, $p = 0.049$). Table 4 contains data concerning routes of delivery across CL. This table indicates that of all vaginal deliveries, 73.7% of women had a TVSCL of 3.14 cm or less, while the same length of CL was observed in only 50% of the women who underwent a cesarean section ($p = 0.009$). Furthermore, a CL cut off point of 3.14 cm or less was found to be a predictor of successful vaginal delivery with a sensitivity of 73.6%, a specificity of 50%, as well as negative and positive predictive values of 52.3% and 71.79%, respectively. Thus, TVSCL was a useful predictor of successful labor induction for vaginal delivery.

Table 4. Correlations of cervical length with route of delivery.

	Cesarean section (n = 44) n (%)	Vaginal delivery (n = 76) n (%)	p value
CL (cm)			
≤ 3.14	22 (50%)	56 (73.7%)	0.009*
> 3.14	22 (50%)	20 (26.3%)	

Chi-squared test, significant $p < 0.05$
CL: Cervical length

Discussion

This present demonstrated that successful induction of labor to active phase within 24 hours occurred in 84.1% of women. In addition, the above results indicated that the pre-induction CL was significantly associated with the induction-to-active

phase interval as well as the success of vaginal delivery. This finding, when considered against previous studies, is both corroborated and contested. Khandelwal et al [16] examined 66 women before induction to predict induction of labor to active phase within 6 hours and BS showed more promising statistically significant results than CL. Furthermore, the sensitivity and specificity of BS were found to be higher than TVSCL with sensitivity of 69% and specificity of 79% versus sensitivity of 51% and specificity of 70%, respectively. Park et al[17], conducted a randomized trial which did not demonstrate superiority of one method over the other to predict success in achieving the active phase of labor within 12 hours. However, the present study's findings are corroborated by those of Yang et al[15], who examined 105 women for TVSCL prior to labor induction. Yang et al's results demonstrated that TVSCL was a useful and independent predictor of successful labor induction as well as a predictor of the duration of induction to active phase. Similar to the present, Yang et al's results also indicated that the TVSCL was a better predictor of successful labor induction than the Bishop score. A possible explanation of this could take root in the differences of induction agents used and the ranges of assessment times to achieve active phase after labor induction. Khandelwal et al[16] used misoprostol and mechanical devices while Park et al[17] used 10-mg dinoprostone vaginal inserts (continuous release) as well as assessment of successful induction within 6 and 12 hours after induction of labor. This differs from the present study which, as stated, made use of 3-mg PGE2 vaginal inserts and assessment at 24 hours after induction of labor.

Perhaps most notable of the results of the present were that 56 women (73.7%) with TVSCL ≤ 3.14 cm had successful vaginal delivery while only 22 women (50%) underwent cesarean sections, thus resulting in a significant correlation ($p = 0.009$) (Table 4). Furthermore, a 3.14 cm or less cut-off point of CL was found to predict successful vaginal delivery with a sensitivity of 73.6%, a specificity of 50%, as well as negative and positive predictive values of 52.3% and 71.79%, respectively. This correlation was clear indication that TVSCL was a good predictor of successful vaginal delivery. These findings were in agreement with those put forth by Pandis et al[18], which similarly demonstrated that CL appears to be a better predictor of successful vaginal delivery within 24 hours than BS with a sensitivity of 87% and a specificity of 71% compared to 58% and 77%, respectively. Furthermore, a systematic review and meta-analysis proposed by Verhoeven et al[11] indicated that CL and cervical wedging, as measured sonographically at or near term, had moderate capacity to predict the outcome of vaginal delivery after induction of labor. Daskalakis et al[19] consistently showed that transvaginal sonographic measurement of CL was a good predictor of a successful labor induction (vaginal delivery) at term in nulliparous women, while BS was not predictive of the mode of delivery. Although, the outcome of the current study differs from those of Hatfield et al[20] which revealed CL did not predict any specific outcome with regards to mode of delivery in their recently published systematic review with meta-analysis, Kaoian et al[12] found that TVSCL was more sensitive in predicting risk of cesarean delivery, a finding which was corroborated by the current analysis. Gonen et al[21] reported that only the BS and parity were significantly correlated with successful induction and the duration of labor. A possible explanation of these different outcomes may take root in differences in population characteristics, methods of induction of labor, indications of cesarean section and cut-off values. When comparing, the different cut-off points of the CL with previous studies, the present adopted a cut-off point of CL 3.14 cm with sensitivity at 73.3%, and specificity 78.9%. Kaoian et al[12] adopted a CL value of 2 cm with sensitivity of 85%, and specificity of 38%. Pandis et al[18] used a CL value of 28 mm, sensitivity of 87% and a specificity of 71% while Khandelwal et al[16] adopted a CL value less than 25 mm with sensitivity of 51% and specificity of 70%. These differences in CL values support the notion that findings may vary based on populations and corresponding adopted cut-off values.

Parity, BMI, and pre-induction TVSCL provided a significant and independent contribution in the prediction of the outcome of induction of labor. This relationship can be observed given that in multiparous

subjects, the incidence of successful vaginal delivery was approximately 10% higher than in nulliparous subjects. Furthermore, the induction-to-active phase interval in multiparous participants was lower than that found in the nulliparous group, obtaining a p value of less than 0.006. This is important, as it indicates that parity affects the induction-to-active phase interval and successfulness of vaginal delivery, a finding which is corroborated in Pandis et al[18] and Gonen et al[21]. In addition, when compared to women who had successfully induced labor to the active phase within 24 hours, those for whom labor could not be induced within 24 hours had significantly higher BMIs (27.4 ± 4.7 vs 22.7 ± 4.2 kg/m^2, respectively), obtaining a p value of less than 0.001, a finding which is corroborated by the findings of Soghra et al[22] and Park et al[23]

Ultrasound technology is available in most obstetrics centers, and it is a safe, accurate, and inexpensive form of technology with robust applications in medicine. TVSCL was successfully obtained in all cases with minimal discomfort to the women[12] and CL-values appeared to be a more objective and more reproducible than BS values. Furthermore, it has also been shown to have reduced intra- and interobserver variability[10]. While CL provides a useful prediction of successful induction of labor to active phase within 24 hours practitioners should receive appropriate training as the technique, when performed at term, is more difficult compared to mid-trimester cervical assessment, especially when the head is engaged and the alignment of the cervix is distorted.

There were several limitations of this study including this present analysis did not exclude other factors that could affect the success of labor induction such as maternal BMI and parity factors in induction of labor as no subgroup analysis of primiparous and multiparous women were conducted. However, the effects of parity on mean CL were considered and it was found that the number of parities did not affect the mean CL. Furthermore, differences of induction protocol may influence the outcome of induction.

Strengths of this current study were various and multifaceted in nature. First, this study was performed in a tertiary care hospital with a maternofetal medicine fellowship program, where CL was measured by well-trained operators thus decreasing error in measurement. Second, the obstetricians making management decisions were blinded to the CL measurement, thereby decreasing bias in decisions concerning methods of intervention. Third, the definition of successful induction of labor was labor that achieved active phase within 24 hours after induction which differed from other studies that defined successful labor induction as successful delivery. With the broad definition adopted in other studies, several other factors may influence results at various stages of the delivery. Finally, the population of this study included only at-term pregnant women. The population of this study comprised 101 women (84.2%) who achieved the active phase of labor within 24 hours, of which 76 (63.3%) delivered vaginally after induction. From the above, it is important to note that the mode of delivery can be affected by multiple factors other than cervical status, such as parity, BMI, fetal weight, method of induction and indications of cesarean delivery that included cephalopelvic disproportion (82.1%), fetal distress (14.3%), and preeclampsia (3.5%). Of significant importance is the adoption of a unique cut-off point as indicated in the aforementioned statistical analysis, which may differ in other bodies of research.

Conclusion

TVSCL was significantly associated with successful induction of labor to active phase within 24 hours and could be used as a predictor for successful induction to vaginal delivery with a cut-off point of 3.14 cm or less.

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Potential conflicts of interest

The authors declare no conflict of interest.

References

1. The Royal College of Obstetricians and Gynaecologists (RCOG). Induction of labor. NICE clinical guideline 70. London: National Institute for Health and Clinical Excellence 2008.
2. Cole RA, Howie PW, Magnaughton MC. Elective induction of labour. A randomized prospective trial. Lancet 1975;1:767-70.
3. Sande HA, Tuveng J, Fonstelien T. A prospective randomized study of induction of labor. Int J Gynaecol Obstet 1983;21:333-6.
4. Sue-A-Quan AK, Hannah ME, Cohen MM, Foster GA, Liston RM. Effect of labour induction on rates of stillbirth and cesarean section in post-term pregnancies. CMAJ 1999;160:1145-9.
5. ACOG Committee on Practice Bulletins - Obstetrics. ACOG Practice Bulletin No. 107. Induction of labor. Obstet Gynecol 2009;114:386-97.
6. Bishop EH. Pelvic scoring for elective induction. Obstet Gynecol 1964;24:266-8.
7. Hendrix NW, Chauhan SP, Morrison JC, Magann EF, Martin JN Jr., Devoe LD. BS: a poor diagnostic test to predict failed induction versus vaginal delivery. South Med J 1998;91:248-52.
8. Roman H, Verspyck E, Vercoustre L, Degre S, Col JY, Firmin JM, et al. Does ultrasound examination when the cervix is unfavorable improve the prediction of failed labor induction. Ultrasound Obstet Gynecol 2004;23: 357-62.
9. Lams JD, Paraskos J, Landon MB, Teteris JN, Johnson FF. Cervical sonography in preterm labor. Obstet Gynecol 1994;84:40-6.
10. Jackson GM, Ludmir J, Bader TJ. The accuracy of digital examination and ultrasound in the evaluation of cervical length. Obstet Gynecol 1992;79:214-8.
11. Verhoeven CJ, Opmeer BC, Oei SG, Latour V, van der Post JA, Mol BW. Transvaginal sonographic assessment of CL and wedging for predicting outcome of labor induction at term: a systematic review and meta-analysis. Ultrasound Obstet Gynecol 2013;42:500-8.
12. Kaoian V, Luangdansakul W, Wacharasint P. Transvaginal sonographic CL versus BS in labor induction to predict the risk of cesarean delivery: a comparison study. J Med Assoc Thai 2018;101:157-61.
13. Cunningham FG, Leveno KJ, Bloom SL, Hauth JC, Gilstrap III LC, Wenstrom KD, et al. Williams Obstetrics. 25nd ed. New York: McGraw-Hill 2018:421-40.
14. Fetalmedicine.org [Internet]. London: Cervical assessment; 2016 [cited 2016 November 05]. Available from: https://fetalmedicine.org/training-n-certification/certificates-of- competence/cervical-assessment-1.
15. Yang SH, Roh CR, Kim JH. Transvaginal ultrasonography for cervical assessment before induction of labor. J Ultrasound Med 2004;23:375-82.
16. Khandelwal R, Patel P, Pitre D, Sheth T, Maitra N. Comparison of CL measured by transvaginal ultrasonography and BS in predicting response to labor induction. J Obstet Gynaecol India 2018;68:51-7.
17. Park KH, Kim SN, Lee SY, Jeong EH, Jung HJ, Oh KJ. Comparison between sonographic CL and BS in preinduction cervical assessment: a randomized trial. Ultrasound Obstet Gynecol 2011;38:198-204.
18. Pandis GK, Papageorghiou AT, Ramanathan VG, Thompson MO, Nicolaides KH. Preinduction sonographic measurement of CL in the prediction of successful induction of labor. Ultrasound Obstet Gynecol 2001;18:623-8.
19. Daskalakis G, Thomakos N, Hatziioannou L, Mesogitis S, Papantoniou N, Antsaklis A. Sonographic CL measurement before labor induction in term nulliparous women. Fetal Diagn Ther 2006;21:34-8.
20. Hatfield AS, Sanchez-Ramos L, Kaynitz AM. Sonographic cervical assessment to predict the success of labor induction: a systematic review with meta-analysis: Am J Obstet Gynecol 2007;197:186-92.
21. Gonen R, Degani S, Ron A. Prediction of successful induction of labor: comparison of transvaginal ultrasonography and the BS. Eur J Ultrasound 1998;7: 183-7.
22. Khazardoost S, Ghotbizadeh F, Latif S, Tahani M, Rezaei MA, Shafaat M. The Predictive Value of Trans-Vaginal Ultrasound Measurements Compared with Bishop Score in Determining Successful Induction of Labor. J Obstet Gynecol Cancer Res 2016;1:e8259.
23. Park KH, Hong JS, Kang WS, Shin DM, Kim SN. Body mass index, Bishop score, and sonographic measurement of the cervical length as predictors of successful labor induction in twin gestations. J Perinat Med 2009;37: 519-23.