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RESEARCH ARTICLE

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What trans-vaginal ultrasound parameters are better correlated with a shorter labor induction to vaginal delivery interval? A prospective observational cohort study

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ABSTRACT

Objective: During the induction of labor (IOL) planning, it is important to provide patients with information regarding how long the induction process might take. This study aimed to determine which ultrasonographic cervical parameters are independently associated with a shorter IOL-to-vaginal delivery (VD) interval.

Methods: This was a prospective observational cohort study. For enrollment purposes, women with single pregnancy, fetus in cephalic presentation, age between 18 and 45 years and good Italian proficiency were included. Women with a history of uterine surgery, in active labor, and cases of fetal growth abnormalities were excluded. The enrolled women underwent a transvaginal ultrasound within 7 days from the scheduled labor induction in order to measure the following parameters: the cervical length (CL), the utero-cervical angle (UCA), the cervical sliding sign (CSS) and the cervical consistency index (CCI). Before starting the labor induction process, patients were also digitally evaluated, acquiring the Bishop score (BS). The method of IOL was determined based on the BS. Ultrasound assessments and Bishop score evaluations were performed independently and in a blinded manner to reduce bias. Statistical analyses were performed using STATA 18.0.

Results: Between June 2023 and November 2024, 400 women were nonconsecutively enrolled in the study. Of these, 83 experienced spontaneous labor before the scheduled labor induction, resulting in 317 women who underwent IOL. The median IOL-to-VD interval was 1264 min (IQR 694–1940). Univariable regression analysis demonstrated significant associations between the IOL-to-VD interval and CL ($\beta=29.15$; 95% CI 16.16, 42.23; $p<0.001$), CCI ($\beta=12.60$; 95% CI 3.93, 21.24; $p=0.004$), and BS ($\beta=-211.15$; 95% CI −271.59, −150.71; $p<0.001$). Multivariable analysis confirmed independent associations with CL ($\beta=13.89$; 95% CI 0.35,27.44; $p=0.044$) and BS ($\beta=-183.96$; −249.66, −118.27; $p<0.001$). When stratified by parity, univariable regression in parous women showed significant associations between the IOL-to-VD interval and CL ($\beta=37.44$; 95% CI 20.17, 54.72; $p<0.001$), CSS ($\beta=-582$; 95% CI −1014.05, 151.20; $p=0.009$), CCI ($\beta=15.43$; 95% CI 1.75, 29.11; $p=0.027$), and BS ($\beta=-227.96$; −315.57, −140.35; $p<0.001$).

Conclusions: In summary, among the evaluated parameters, CL consistently showed the strongest and most independent association with a shorter IOL-to-VD interval across analyses, supporting its role as the most reliable predictor. Future research should explore multivariable prediction models incorporating various ultrasonographic cervical parameters to enhance the predictive accuracy of transvaginal ultrasound.

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KEYWORDS
Labor induction; cervical length; utero-cervical angle; cervical sliding sign; cervical consistence index; Bishop score

Introduction

The induction of labor (IOL) is one of the most common procedures in modern obstetrics [1], and it is increasing worldwide. While the decision to induce labor may seem straightforward, it is inherently complex, requiring a careful balance of health outcomes for both the pregnant and the perinate, whose best interests may not always align. Additionally, the health

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outcomes vary significantly in type and severity, and different individuals may prioritize these outcomes differently [2]. In this context, various guidelines emphasize that the decision to induce labor should involve a shared decision-making process that carefully takes the woman's preferences into account [3–6], including experiences with IOL reported by other women.

Notably, inductions are often described as longer than what was expected [7]. In everyday experience, when counseling patients about induction, obstetricians often observe that the main concern of expectant mothers is related to the duration of the procedure. This concern may even outweigh the fear that induction could result in a cesarean section. From this perspective, during the IOL planning, it is becoming increasingly important to provide patients with information regarding how long the induction process might take and the likelihood of achieving a vaginal delivery (VD) within 24 h of induction. The expected outcomes and management of IOL have traditionally relied on a vaginal digital examination to determine the Bishop Score (BS) [8]. However, the BS has been found to be subjective and has demonstrated relatively low predictive accuracy [9,10]. As a result, recent studies have shifted focus toward using ultrasound as a more objective method for assessing the individual components of the BS. While some studies have indicated that these ultrasound measurements outperform digital assessments, their predictive accuracy remains controversial for routine clinical application [11,12]. Therefore, this study aimed to identify the transvaginal ultrasonographic parameters that most accurately represent cervical effacement, position, and consistency, and to determine their association with a shorter interval from labor induction to vaginal delivery.

Methods

This was a prospective observational cohort study carried out at the Clinic of Obstetrics and Gynecology of the University Hospital of Udine, Italy. This study has been conducted in strict adherence to the ethical principles outlined in the Declaration of Helsinki [13]. All participants were fully informed about the study, and informed consent was obtained prior to participation. The study protocol was reviewed and approved by an independent ethics committee to ensure scientific validity and participant safety (reference codes CEUR-2023-Os-42 n.0017139/P/GEN/ARCS). The study was conducted and reported in accordance with STROBE guidelines.

As part of routine clinical care, all women presenting at term (≥37 weeks' gestation) for a scheduled consultation were invited to learn about our prospective observational cohort study at the time of labor-induction planning. Eligible participants were those with a singleton, cephalic-presentation pregnancy, maternal age 18–45 years, and adequate Italian proficiency. The primary indications for induction included post-term pregnancy, maternal diabetes, near term rupture of membranes, hypertensive disorders, suspected intra-amniotic infection, and abnormal amniotic fluid volume (oligohydramnios or polyhydramnios). Women were excluded if they had a history of uterine surgery, were already in active labor, or if the fetus had structural malformations or growth abnormalities (fetal growth and estimated fetal weight <10th percentile for fetal growth restriction or >90th percentile for accelerated fetal growth) [14].

The cervical transvaginal ultrasound evaluation was carried out when women were attending the outpatient Cardiotocography Clinic or the High-Risk Pregnancy Clinic, within 7 days from the scheduled IOL (Philips Affiniti 70 Ultrasound and Voluson E8 Ultrasound). Patients were asked to empty their bladder, and a mid-sagittal scan was obtained. This scan, following visualization of the external and internal uterine orifices and the cervical canal, allowed the measurement of the following parameters: the cervical length (CL) [15], the utero-cervical angle (UCA) [16], the cervical sliding sign (CSS)[17] and the cervical consistency index (CCI) [18]. These parameters were chosen because representative of three cervical characteristics included in the BS: the effacement (reflected by the CL), the position (reflected by the UCA); the consistency (reflected by the CSS and the CCI). Dilatation and engagement were intentionally excluded from consideration, as they suggest a mature cervix and a favorable condition for the onset of labor.

The CL was obtained tracing a line along the cervix from one orifice to the other according to the technique described by Kagan et al. in 2015 [15]. The UCA was generated by the intersection of two lines, one passing from the internal to the external orifice and the other parallel to the anterior uterine wall, following the technical procedure described by Eser et al. in 2018 [16]. The CSS was deemed present when, on the mid-sagittal scan, a gentle compression applied to the cervix allowed the anterior cervical lip to slide over the posterior lip, as detailed by Volpe et al. in 2022 [17]. Finally, the CCI was measured according the technique described by Parra-Saavedra et al. in 2011, which includes the following steps: (a) identifying the midpoint of the line connecting the external and internal orifices; (b) measuring the anteroposterior diameter of the cervix perpendicular to the cervical line at its midpoint; (c) measuring the anteroposterior diameter both before and after applying pressure on the cervix with the transvaginal probe; (d) calculating the CCI as follows: (AP′/AP) × 100 [18]. For graphic illustration refer to Figure 1. The ultrasound assessment was conducted by both attending obstetricians and residents, all of whom were properly trained healthcare providers.

Anthropometric and anamnesis data of the patients were recorded. To minimize potential bias, clinicians performing the transvaginal ultrasound examinations were blinded to the Bishop score assessments, and healthcare providers managing labor were blinded to the antepartum ultrasound findings. Before starting the labor induction process, patients were also digitally evaluated, acquiring the Bishop score.

The method of IOL was determined based on the BS. According to the standard local protocol, when the BS was ≥6, the cervix was considered ripe or favorable, and IOL proceeded with Oxytocin infusion and/or amniotomy. When the BS was <6, a course of low dosage Misoprostol in tablets was usually used. Vaginal Dinoprostone pessary could be occasionally used. Alternatively, combined methods were used, such as cervical ripening balloon plus Misoprostol or plus Oxytocin. The cycles of stimulation with Prostaglandins could be repeated if necessary. Failure to enter the active phase was defined as the inability of the cervix to efface and dilate to 5–6 cm within 18 h after amniotomy and Oxytocin infusion. After delivery, the following data were collected: reason for labor induction and gestational age at delivery, characteristics of labor stages [19], such as duration in minutes of the latent phase (defined by the interval between induction and labor onset), the active phase of the first stage of labor (at approximately 5–6 cm of cervical dilatation), the second stage of labor (from full dilation to delivery), use of epidural analgesia, interval between epidural analgesia and delivery; delivery mode: vaginal delivery (VD), operative vaginal delivery (OVD), cesarean delivery (CD); vaginal and perineal lacerations (Grades I/II/III/IV (OASI), episiotomy); neonatal outcomes (neonatal sex, birth weight, blood gas pH and BD, Apgar score at 1 and minutes), placental weight and histological examination of the placenta.

The primary outcome of this study was to identify what transvaginal ultrasonographic parameters better correlate with a shorter labor induction to VD interval.

Secondary outcomes included: (i) to identify what transvaginal ultrasonographic parameters better correlate with a shorter labor induction to VD interval among nulliparous and parous women; (ii) to identify the success rate of IOL (defined as the proportion of women undergoing induction who achieved a vaginal delivery within 24 h from the beginning of IOL, [17]) in our cohort and (iii) to compare the measurements of each transvaginal ultrasonographic parameter and

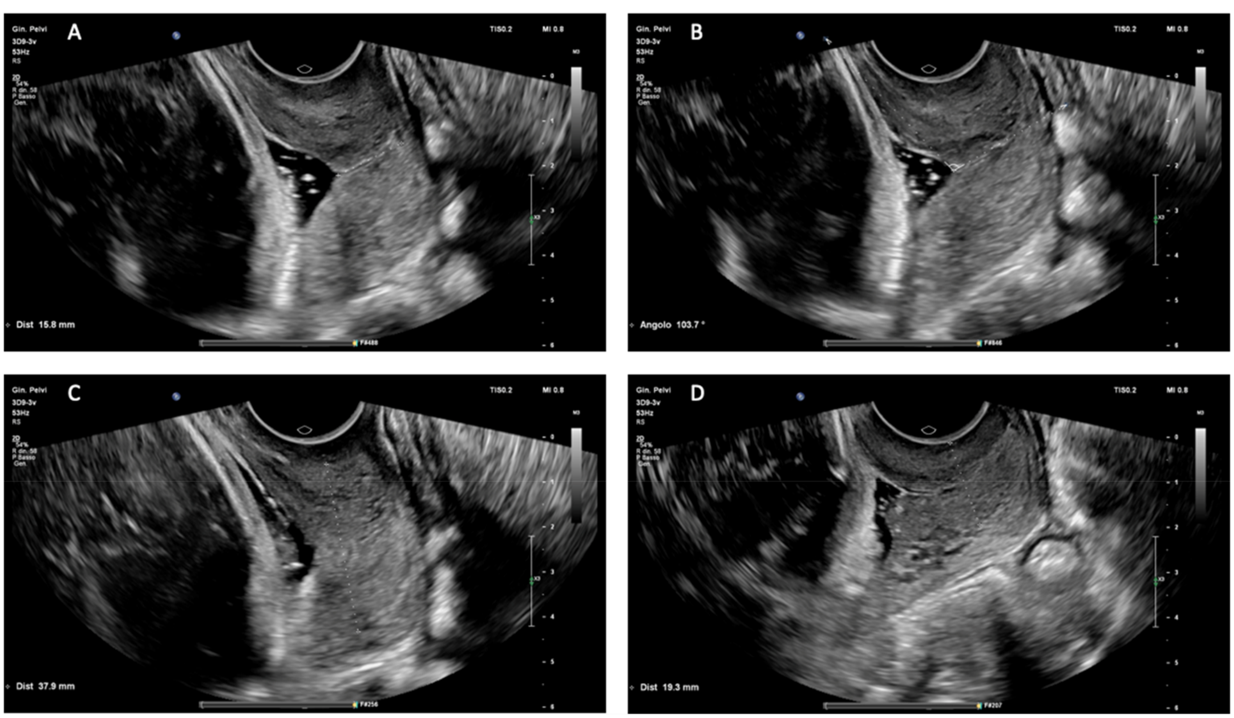

Figure 1. Transvaginal ultrasound showing the sagittal plane of the uterine cervix, 2D: a cervical length (CL), B utero-cervical angle (UCA), C and D cervical consistence index (CCI). The cervical sliding sign (CSS) is not shown in this figure, since it is acquired dynamically and therefore cannot be adequately represented with an image.

of BS between the 2 groups, differently defined by the presence or absence of a successful IOL.

Patient demographic and clinical characteristics were presented with absolute values and percentages for categorical variables and means or medians (standard deviation [SD] or interquartile ranges [IQRs]) for continuous variables. The Shapiro-Wilk test was used to assess whether data were normally or non-normally distributed. Categorical variables were compared using the chi-squared test or Fisher's exact test, while quantitative variables were compared using the t test or Mann-Whitney U test, as appropriate. Univariable and multivariable linear regression were performed to estimate the association between the IOL-to-VD interval and ultrasonographic parameters or BS, by calculating the linear regression coefficient (β) and 95% confidence intervals (CIs). The multivariable analyses included all variables significant at $p < 0.05$ in the univariable analysis, taking into account potential collinearities between ultrasonographic parameters. A sensitivity analysis for the univariable and multivariable linear regression was assessed for considering the effect of parous women. Missing data imputation was not applied. Statistical analyses were performed using STATA 18.0.

The study was powered based on the observed frequency of VD within 24 h following IOL at our institution. A retrospective analysis of deliveries induced between January 2021 and December 2022 showed that 45.19% of women achieved a VD within 24 h. Assuming this prevalence and aiming to obtain an interval estimate with a 95% confidence interval and a 5% precision, the estimated required sample size was 381 women. [20]. To account for a potential 5% dropout rate, the final target was set at 400 enrollments. However, 83 women experienced a spontaneous onset of labor before the scheduled induction, making them ineligible for the analysis of IOL outcomes. Therefore, the final analysis was conducted on 317 women who actually underwent labor induction. Despite this reduction, this sample size allowed to estimate the 95% confidence interval of the VD prevalence with a precision of 5.5%.

Results

Between June 1st 2023 and November 30th 2024 a total of 2,415 women delivered at the Department of obstetrics and gynecology of the University Hospital of Udine. During this period, 400 women were enrolled in the study using a nonconsecutive, convenience sampling approach, following their provision of informed consent. Transvaginal ultrasound examinations were performed within 7 days prior to the scheduled IOL, while the BS was assessed immediately before the initiation of IOL or upon admission for spontaneous labor onset. Although 400 women were initially enrolled in the study, 83 experienced a spontaneous onset of labor before the scheduled induction. Therefore, the final analysis of IOL outcomes was conducted on 317 women who actually underwent the induction process, of whom 280 achieved a VD (Figure 2). Table 1 shows the main clinical maternal and neonatal outcomes, including the sonographic measurements of the different cervical parameters and the BS.

We performed a univariable and multivariable regression analysis for factors associated with the IOL-to-VD interval. The univariable regression analysis revealed significant associations between the IOL-to-VD interval and the CL (β = 29.19; 95% CI 16.16, –42.23; $p < 0.001$), the CCI (β = 12.60; 95% CI 3.95, 21.24; $p = 0.004$), the BS (β = –211.15; 95% CI –271.59, –150.71; $p < 0.001$). The multivariable regression analysis confirmed significant associations between the IOL-to-VD interval and the CL (β = 13.89; 95% CI 0.35, 27.44, $p = 0.044$), the BS (β = –183.96; 95% CI –249.66, –118.27; $p < 0.001$) (Table 2).

Then we divided our cohort according to the parity and we repeated the regression analysis.

For nulliparous women the univariable regression analysis revealed significant associations between the IOL-to-VD interval and the CL (β = 36.59; 95% CI 18.43, 54.75; $p < 0.001$), the BS (β = –164.09; 95% CI –246.01, –82.18; $p < 0.001$). These results were highly confirmed by the multivariable regression analysis, showing a significant association between IOL-to-VD interval and the CL (β = 25.15; 95% CI 4.98,45.33; p:0.018), the BS (β = –111.79; –202.76, 20.83; $p = 0.016$) (Supplementary Table S1).

For parous women the univariable regression analysis revealed significant associations between the IOL-to-VD interval and the CL (β = 37.44; 95% CI 20.17, 54.72; $p < 0.001$), the CSS (β = –582; 95% CI –1014.05, 151.20; $p = 0.009$), the CCI (β = 15.43; 1.75,29.11; $p = 0.027$), the BS (β = –227.06; 95% CI –315.57, –140.35; $p < 0.001$). However, the multivariable regression analysis only partially confirmed these results, presenting a significant association between IOL-to-VD interval and the CL (β = 22.23; 95% CI 3.84,40.62; $p = 0.018$), the BS (β = –175.0; 95% CI –271.27, –78.73; $p < 0.001$) (Supplementary Table S2).

We then divided our cohort in 2 groups, according to the success rate of IOL and we compared the measurements of each ultrasonographic cervical parameter and the BS among the 2 groups. The CL, the CCI and the BS turned out to be significantly different between

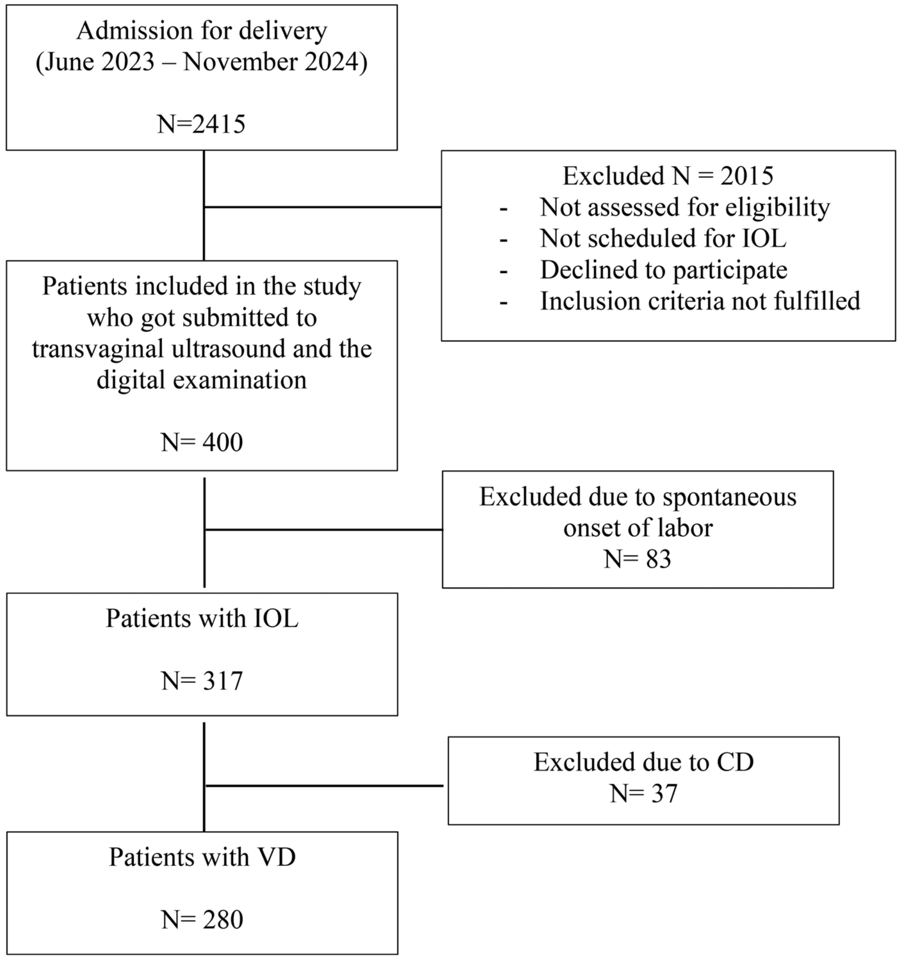

Figure 2. Flowchart (according to the STROBE guideline) of patient enrollment of a nonconsecutive series of singleton term pregnancies, planned for labor induction, who got submitted to transvaginal ultrasound to assess the cervical length, the utero-cervical angle, the cervical sliding sign, the cervical consistence index and the Bishop score.

the 2 groups (CL 26 (19,32) vs 30 (24,36), $p < 0.001$), CCI 61 (51,70) vs 65 (53,74); p: 0.038; BS 3 (2,4) vs 2 (1,3) $p < 0.001$) (Table 3). We then repeated the same analysis for nulliparous and parous women, separately. Both analyses confirmed the results only partially, revealing a significant difference in CL and BS between women with a successful and unsuccessful IOL: nulliparous CL 23 (18,29) vs 29 (23,35), $p < 0.001$; BS 3 (2,4) vs 2 (1,3), $p < 0.001$ (Supplementary Table S3); parous women CL 29 (20,35) vs 36 (29,41), $p = 0.003$; BS 3 (2,5) vs 2 (1,3), $p = 0.009$ (Supplementary Table S4).

Discussion

This prospective cohort study found that shorter CLs are consistently associated with shorter IOL-to-VD intervals and higher IOL success rates, with similar trends observed in both nulliparous and parous women.

So far, the results of studies that relate pre-induction ultrasonographic evaluation of the CL are controversial. In 2015, a systematic review and meta-analysis included two randomized studies, one involving women of mixed parity and the other focusing solely on nulliparous women [21]. Both studies highlighted the benefits of using sonographic CL to assess the cervix before IOL, particularly for nulliparous women [22,23]. However, the meta-analysis introduced methodological bias by not stratifying based on parity and using inconsistent cutoffs for the BS and CL, making the results harder to interpret. Our findings align with the World Association of Perinatal Medicine (WAPM) guidelines, that indicate that a shorter CL is significantly associated with a shorter IOL-to-delivery interval and a higher probability of achieving VD within 24 h [24].

Furthermore, our data may suggest that the pre-induction ultrasonographic assessment of the cervical position lacks predictive value for the IOL-to-VD interval and the successful IOL. The physiological basis of the UCA follows the principles of gravity and trigonometry. The force of the gravid uterus is transmitted

Table 1. Main maternal and neonatal outcomes (including sonographic measurements of the different cervical parameters and Bishop score) of two different groups of women, representing respectively 400 women enrolled in the study and 320 women who had a labor induction.

Characteristic	N = 400	Only induced patients $N = 317$
Induced patients, n (%)	317 (79%)	317 (100%)
GA at ultrasonographic evaluation, weeks, median (IQR)	39.57 (38.71, 40.57)	39.29 (38.71, 40.43)
CL, mm, median (IQR)	27 (20, 34)	28 (22, 35)
UCA, °, median (IQR)	103 (91, 117)	104 (91, 117)
CSS present, n/N (%)	312/399 (78%)	237/316 (75%)
CCI, %, median (IQR)	63 (53, 72)	63 (52, 72)
GA at IOL, weeks, median (IQR)	40.00 (39.29, 41.00)	39.86 (39.29, 41.00)
BS, median (IQR)	3.00 (1.00, 4.00)	2.00 (1.00, 3.00)
Low dosage Misoprostol, n (%)		147 (46%)
Dinoprostone pessary, n (%)		2 (0.6%)
CRB, n (%)		21 (6.6%)
CRB + Oxytocin, n (%)		25 (7.9%)
CRB + low dosage Misoprotol, n (%)		78 (25%)
Amniorexi, n (%)		105 (33%)
Oxytocin, n (%)		179 (56%)
IOL – delivery interval < 24 h, n/N (%)	164/317 (52%)	164 (52%)
IOL – VD interval, min, median (IQR)	1258 (681, 1935)	1264 (694, 1940)
Duration active phase I stage of labor, min, median (IQR)	115 (60, 240)	120 (63, 250)
Duration of II stage of labor, min, median (IQR)	45 (20, 90)	50 (21, 99)
Epidural use, n (%)	279/398 (70%)	239 (75%)
epidural – delivery interval, min, median (IQR)	443 (246, 721)	459 (259, 747)
VD, n (%)	304 (76%)	234 (74%)
OVD, n (%)	56 (14%)	46 (15%)
CD, n (%)	40 (10%)	37 (12%)
Episiotomy, n (%)	89/399 (22%)	77/316 (24%)
Vagino-perineal tears, n/N (%)		
0	149/394 (38%)	125/311 (40%)
1	132/394 (34%)	93/311 (30%)
2	107/394 (27%)	91/311 (29%)
3	6/394 (1.5%)	2/311 (0.6%)
Female gender, n (%)	203 (51%)	158 (50%)
pH cord blood at birth, median (IQR)	7.28 (7.23, 7.35)	7.28 (7.23, 7.34)
BE cord blood at birth, median (IQR)	−3.5 (−5.6, −1.6)	−3.7 (−5.8, −1.6)
APGAR 1′ min, median (IQR)	8.00 (8.00, 9.00)	8.00 (8.00, 9.00)
APGAR 5′ min, median (IQR)	9.00 (9.00, 9.00)	9.00 (9.00, 9.00)
Neonatal weight at birth, gr, median (IQR)	3484 (3173, 3768)	3478 (3174, 3756)
Placental weight, gr, median (IQR)	570 (495, 650)	570 (495, 650)
Admission to NICU, n/N (%)	8/398 (2.0%)	6/315 (1.9%)
Parous women, n (%)	161 (40%)	112 (35%)
Successful IOL (VD within 24 h), n/N (%)	155/316 (49%)	155 (49%)
n (%); Median (Q1, Q3)		

Values are presented as mean ± SD or number (%).
Abbreviations. GA, gestational age; CL, cervical length; UCA, utero-cervical angle; CSS, cervical sliding sign; CCI, cervical consistence index; BS, Bishop score; CRB, Cervical ripening balloon; IOL, induction of labor; VD, vaginal delivery; OVD, operative vaginal delivery; CD, cesarean delivery; NICU, neonatal intensive care unit.

Table 2. Univariable and multivariable linear regression for factors associated with IOL-to-VD interval.

	Univariable analysis			Multivariable analysis		
	β	95% CI	*p* value	β	95% CI	*p* value
CL	29.19	16.16, −42.23	<0.001	13.89	0.35, 27.44	0.044
UCA	−0.82	−5.88, 4.23	0.748			
CSS	−166.32	−449.35, 116.70	0.248			
CCI	12.60	3.95, 21.24	0.004			
BS	−211.15	−271.59, −150.71	<0.001	−183.96	−249.66, −118.27	<0.001

Abbreviations. CL, cervical length; UCA, utero-cervical angle; CSS, cervical sliding sign; CCI, cervical consistence index; BS, Bishop score, IOL, induction of labor, VD, vaginal delivery.

to the cervix, and depending on the angle of inclination of the latter, the cervical canal is compressed to close in cases of an acute angle or to open in cases of an obtuse angle. It is interesting to note that the UCA has also been studied in the context of the risk of preterm birth, revealing that a more obtuse angle increases the risk of spontaneous preterm birth [25]. In 2020, a research group analyzed the predictive capacity of this ultrasound marker in the IOL success (defined by a latent phase duration < 720 min) and reported that both the UCA and CL correlated with a satisfactory response to IOL. [16]. These results were supported by a recent systematic review and meta-analysis, which included 57 studies for a total of

Table 3. Comparison of ultrasonographic cervical parameters and bishop score between women with successful IOL and women without successful IOL.

Characteristic	Not successful IOLN = 162[a]	Successful IOL N = 155[a]	*p* value[b]
CL	30 (24, 36)	26 (19, 32)	<0.001
UCA	104 (85, 117)	103 (93, 118)	0.740
CSS present	115/161 (72%)	121 (78%)	0.217
CCI	65 (53, 74)	61 (51, 70)	0.038
BS	2 (1,3)	3 (2,4)	<0.001

[a]Median (Q1, Q3); n (%).
[b]Wilcoxon rank sum test; Pearson's Chi-squared test.
Abbreviations. CL, cervical length; UCA, utero-cervical angle; CSS, cervical sliding sign; CCI, cervical consistence index; BS, Bishop score, IOL, induction of labor.

9,338 patients and found that among the ultrasonographic parameters with the highest diagnostic odds ratio in predicting successful IOL there was the posterior cervical angle, only preceded by the fetal head-perineum distance [11]. Our data differ from these promising results in the literature and might suggest that cervical position is a characteristic that changes in the more advanced stages of cervical maturation.

Some interesting observations could be drawn from our data when considering the cervical consistency, as reflected by the CSS and the CCI. The CSS was first proposed as a new ultrasound marker for preterm birth by the research group of Parma in 2019. [26]. The same research group subsequently tested this marker in the context of IOL, demonstrating its association with an increased likelihood of VD within 24 h, as well as a shorter IOL-to-active labor interval [17]. First proposed by Parra-Saavedra in 2011, the CCI is a measurement of cervical elastic functionality, since it measures the cervical softness by comparing the cervix's antero-posterior diameter at rest and under maximum deformation [18]. Softer tissue results in lower CCI values, meaning CCI is inversely related to softness and directly related to stiffness. Two previous studies have tested this marker in the context of preterm birth, revealing that low CCI values during the first and second trimesters were risk factors for preterm delivery [27,28]. However, in the IOL setting, a recent Spanish study, conducted on 510 women scheduled for IOL, demonstrated that this ultrasound marker is not predictive of CD due to failed induction [25].

Notably, in our study, when analyzing the IOL-to-VD interval for nulliparous and parous women separately, the univariable regression analysis indicates that CSS and CCI may help predict a shorter IOL-to-VD interval specifically in parous women. These findings provide a fresh perspective, suggesting that the predictive value of cervical ultrasound parameters may differ between nulliparous and parous women. However, the estimated effect of CSS in this analysis showed a wide confidence interval, suggesting the need for larger studies. For parous women, parameters reflecting cervical softness, such as CSS and CCI, could play a more significant role in predicting IOL outcomes. In contrast, for nulliparous women, effacement-related parameters might be the only ones with meaningful predictive value.

Strengths and limitations

The primary strength of this study resides in its prospective methodology and a rigorously determined sample size, powered to detect differences in VD rates within 24 h. Importantly, the study did not influence clinical decisions regarding IOL, as both the patients and the healthcare providers responsible for IOL were blinded to the ultrasound findings. Moreover, this work fostered heightened clinician engagement with ultrasonography as an evaluative tool in the IOL setting. Of note, a recent Italian survey underscored that, despite compelling evidence favoring ultrasound over manual examination for fetal position and station assessment, its routine intrapartum application remains suboptimal even among practitioners certified in obstetric ultrasound [29].

This study has several limitations that should be addressed. Firstly, it was conducted at a single institution, potentially limiting the generalizability of the findings to other settings. Secondly, the nonconsecutive enrollment and the use of convenience sampling may introduce selection bias. Participants were recruited based on availability and consent rather than through randomized or consecutive inclusion, which may skew the representation of clinical characteristics and, by extension, the observed associations. Therefore, caution is warranted when extrapolating these results to other settings or populations. Third, although a standardized induction protocol utilizing low-dose misoprostol was employed, the adjunctive use of alternative pharmacologic agents may have contributed to treatment heterogeneity. Fourth, the heterogeneity among the studied groups, particularly in terms of the indications for medical induction and gestational ages at IOL, could have influenced the results. Lastly, transvaginal ultrasound and digital cervical assessment were performed at different time points, which may have influenced their comparability in predicting IOL outcomes.

Clinical implications and future perspectives

Given that labor induction is associated with mental and physical stress to pregnant women and healthcare providers and with increased economic burden because of long hospital stays, it is becoming increasingly important to provide patients with information regarding IOL outcomes. Futures studies should address the focus on multivariable prediction models that include different ultrasonographic cervical parameters, differently tailored for parity, in order to increase the potential predictive value of the transvaginal ultrasound.

In conclusion, our study demonstrated that among the transvaginal ultrasonographic parameters reflecting cervical effacement, position and consistency, CL is a reliable predictor of IOL outcomes either for nulliparous and for parous women.

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Author contributions

CRediT: **Serena Xodo**: Conceptualization, Data curation, Investigation, Methodology, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing; **Maria De Martino**: Data curation, Formal analysis, Methodology, Supervision, Writing – review & editing; **Giovanni Baccarini**: Data curation, Investigation, Methodology, Visualization, Writing – review & editing; **Elisa Rizzante**: Methodology, Resources, Supervision, Writing – review & editing; **Valentina Zanin**: Methodology, Resources, Writing – review & editing; **Stefania Liviero**: Methodology, Resources, Writing – review & editing; **Lisa Celante**: Data curation, Methodology, Resources, Supervision, Writing – review & editing; **Marta Angelini**: Methodology, Supervision, Writing – review & editing; **Lorenza Driul**: Conceptualization, Resources, Writing – review & editing.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, [S.X.], upon reasonable request.

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