Original Article

Prediction of Risk of Cesarean Delivery using Transvaginal Ultrasonography in Evaluation of Lower Uterine Segment Thickness of Singleton Pregnancy in Late third Trimester

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Abstract

Background: The rising rates of cesarean delivery (CD) worldwide poses concerns regarding maternal and neonatal morbidity. Lower uterine segment (LUS) thickness has been studied as a predictor of uterine rupture during trial of labor in previous CD, but for predicting CD in women with spontaneous labor, the evidence remains inconclusive. **Objective:** This study aimed to evaluate LUS thickness measured via transvaginal ultrasound (TVS) during the late third trimester as a predictive factor for CD due to labor dystocia in singleton pregnancies. **Method:** In this prospective cohort study, 130 pregnant women with singleton pregnancies at 34-36+6 weeks of gestation were assessed using TVS at the antenatal care (ANC) unit of HRH Princess Maha Chakri Sirindhorn Medical Center, Thailand. LUS thickness was measured three times by using a protocol and the thinnest segment of the LUS thickness was recorded. The demographic and clinical data was recorded at enrollment. Delivery outcomes were analyzed, and the predictive accuracy of LUS thickness for CD was assessed using the area under the receiver operating characteristic (ROC) curve. **Results:** The mean LUS thickness for vaginal deliveries (VD) was 6.69 mm., while in CD was 7.01 mm., though this difference was not statistically significant (p value = 0.56). ROC yielded an AUC of 0.57 (95% CI: 0.45-0.70), indicating limited predictive value. Excluding non-reassuring fetal heart rate and fetal distress, the LUS thickness for cut-offs ≥ 6.5 mm. showed the moderate sensitivity (48.1%), specificity (41.5%), positive predictive value (PPV) of 19.1% and negative predictive value (NPV) of 73.6%. **Conclusion:** LUS thickness measurement alone has limited predictive capacity for CD due to labor dystocia in singleton pregnancies. The findings suggest that it should be combined with other clinical or ultrasound factor for increasing predictive accuracy for CD.

Keywords: Lower Uterine Segment Thickness, Transvaginal Ultrasound, Cesarean Delivery, Labor Dystocia.

Introduction

Cesarean delivery (CD), also known as cesarean section, is a surgical procedure performed to deliver a baby through incisions made in the mother's abdomen and uterine tissue. This procedure is typically performed when vaginal delivery (VD) poses significant risks to either the mother or the fetus, or when complications arise during labor that make VD unsafe.[1] Over the past three decades, the global rate of CD has risen dramatically, indicating significant changes in both obstetric practices and maternal health

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trends. In 1991, the global rate of CD was 7%, which increased to 21% by 2021.[2] In Thailand, this trend is even more striking, with CD rates reaching an alarming 43.37% in 2023, highlighting the growing reliance on this surgical intervention during childbirth.[3] Among the many indications for CD, labor dystocia—defined as abnormal or prolonged labor—is one of the most common reasons for an emergency CD. At HRH Princess Maha Chakri Sirindhorn Medical Center (MSMC), Faculty of Medicine, Srinakharinwirot University, intrapartum CD rates due to labor dystocia are particularly high, reaching a staggering 70%.

Although CD is a life-saving intervention in many cases, it also carries significant implications for both maternal and neonatal health. Compared to VD, intrapartum CD is generally associated with higher risks of both short-term and long-term complications for mothers. For instance, the odds ratio (OR) of hospital stay > 7 days was high (OR 2.22, 95% CI; 1.45–3.40), requiring a blood transfusion was elevated (OR 1.39, 95% CI; 1.10–1.76), and the need for postpartum antibiotics usage was increased (OR 5.53, 95% CI; 3.77–8.10).[4-6] In more severe cases, complications of CD may necessitate interventions such as a cesarean hysterectomy (OR 4.73, 95% CI; 2.79–8.02) or result in an admission into the ICU (OR 2.22, 95% CI; 1.45–3.40). As previously mentioned, neonates delivered via CD also face heightened risks. In fact, CD increases the risk of persistent pulmonary hypertension in the newborn by 0.37% (OR 4.6) compared with VD ($p < 0.001$).[7] Moreover, intrapartum CD increased risks of maternal morbidity and mortality compared with elective CD with a RR of 5.2 (95% CI; 4.8–5.6).[8]

As a consequence, ongoing research try to identify valid predictors for predicting CD in women undergoing spontaneous labor. Many studies have been using various maternal and fetal characteristics and imaging techniques to analyze factors associated with CD such as cephalopelvic disproportion (CPD) although the results are still vague and inconclusive.[9,10] Despite all the investigations, ultrasonography is the most useful in predicting CD risk in spontaneous labor as well as it is non-invasive especially cervical length (CL) and occiput-spine angle (OSA). A previous study demonstrated that a CL greater than 32 mm. is associated with a 27% of CD, however the low sensitivity (41%) and a relatively high false-positive rate (24%) limits its use.[11] Similarly, a fetal OSA less than 126° is associated with longer labors and increased rates of CD.[12] Further research is required to confirm the validity of mentioned discoveries. Despite the large amount of knowledge new studies have brought into the field of research, a definitive and universally accepted method for accurately predicting CD risk still remains to be explored.

During pregnancy, the lower uterine segment (LUS) which is a part of myometrium undergoes physiological changes. The upper uterine segment prepares for contractions meanwhile the LUS progressively gets thinner and thinner as labor approaches.[13] LUS thinning, starting around gestational weeks of 28 can be measured using ultrasonography. Studies by Fukuda *et al.*[14] and Ginsberg *et al.*[15] have suggested that the LUS thickness is potentially useful as a predictive marker, particularly in uterine rupture during VBAC. For example, in the study by Bujold *et al.*[16], LUS thickness less than 2.3 mm. was significantly associated with uterine rupture at an OR of 4.66 (95% CI; 1.04–20.91). A meta-analysis has been cleared that LUS thickness can be used for the prediction of certain kinds of uterine defects like dehiscence and rupture.[17]

Recent studies have examined the benefit of LUS thickness from brocades perspective in predicting CD outcomes. For example, among women induced into labor shows that LUS thickness was associated with a higher risk of CD for labor dystocia (OR 1.15, 95% CI; 1.03–1.28).[18] On the other hand, women with spontaneous labor remain uncertain. Therefore, the need for further research to establish whether LUS thickness which is measured during late third trimester can be an effective predictor for the risk of CD in these populations.

From previous literature, this study aims to evaluate the predictive value of LUS thickness for CD in women undergoing spontaneous labor. Also determining whether LUS thickness can effectively differentiate between CD and VD outcomes. Simultaneously, the average LUS thickness in these two groups could able to be explored. The study hopes to provide insights and improve risk assessment, optimize labor management, and potentially reduce unnecessary CDs, improving overall maternal and neonatal outcomes.

Literature Review

CD is a complex medical intervention that different researchers have been trying to understand various factors that contribute to it. Burke *et al.*[10] study observed characteristics of maternal and fetal traits such as maternal age, body mass index (BMI), height, fetal abdominal circumference(AC), and fetal head circumference (HC) in 2,336 term nulliparous women to attempt predicting CD. The findings revealed that short maternal height was the most strongly associated with CD compared to VD (OR of 1.72, 95% CI: 1.52-1.93), as well as increased BMI (OR 1.29, 95% CI: 1.17-1.43); large fetal HC (OR 1.27, 95% CI: 1.14-1.42); large fetal AC (with OR 1.23, 95% CI: 1.10-1.38); and advanced maternal age (OR 1.21, 95% CI: 1.09-1.34). These findings showed the interactive influence between maternal and fetal characteristics on delivery outcome while indicating the limitations of relying solely on baseline characters which may lack the precision needed in actual clinical practice. In contrast, Korhonen *et al.*[9] investigated 274 pregnant women studying the fetal pelvic index to assess CPD using X-ray or MRI showing that the optimal fetal pelvic index was -0.65. However, the authors concluded that this index was not clinically useful in predicting CD. Therefore, underlines the need for a more clinically practical and beneficial method in predicting CD.

Ultrasonography is widely used because of its known safety and objective, has been targeted as another potential tool in the prediction of CD. CL was evaluated in 212 pregnant women at 37 weeks of gestation showing that CL >32 mm. had the highest risk for CD (27%) though it was only 41% sensitive in predicting CD, with a high false-positive rate (24%).[11] Another ultrasonographic parameter is fetal occiput-spine angle (OSA) which has been assessed in 400 pregnant women by Maged *et al.*[12] and they reported that an OSA < 126° had significantly longer durations for both the first and second stages of labor, from 1.89 ± 0.85 to 6.8 ± 2.1 hours, respectively, as well as an increased CD rate (46.3% vs. 5.7%).Despite these promising results for OSA in predicting labor outcomes, the authors emphasized the need for further studies to validate its applicability in a true clinical setting. In spite of the multitude of evidence provided by the literatures above, the use of ultrasonography to predict CD outcomes in pregnant women undergoing spontaneous labor remains challenging in clinical practice due to its limited reliability and a small number of studies. However, LUS thickness, a potential parameter, has not yet been widely investigated and reproducibility of LUS thickness showed excellent interobserver agreement for the measurement of LUS thickness (intraclass correlation coefficient (ICC), 0.96 (95% CI, 0.93-0.98), making it a promising candidate to help predict delivery outcome. There is, however, a significant gap in this literature topic; the LUS predictive value for CD, more specifically in the context of spontaneous labor, has not been thoroughly investigated – which limits the current evidence to support its intended use during this time.

In other obstetric contexts, LUS thickness has also been examined in multiple studies. Bujold *et al.*[16] investigated the LUS thickness to predict uterine rupture involving 236 pregnant women who attempted vaginal birth after cesarean delivery (VBAC). The results indicated that LUS thickness less than 2.3 mm. was linked to a 9.1% uterine rupture. Moreover, Del Campo *et al.*[18] studied the investigation of LUS thickness to predict the rate of CD involving 265 term pregnant women who underwent induction of labor (IOL). The results showed that the thinner the measurements, the higher the risk for CD due to labor dystocia (OR 1.15, 95% CI: 1.03–1.28), the mean of LUS thickness for VD was 7.3 mm. (95% CI: 3.9-9.6) and in CD was 5.2 mm. (95% CI: 3.5-6.7). The difference was statistically significant ($p<0.01$) and the area under the ROC curve showed good discriminatory power of 0.761 (95% CI: 0.692-0.829) in predicting CD. Although further research is needed to fully elaborate on the potential utility in the predicting CD in women in spontaneous labor. As previously stated, this research aims to discuss the possible use of LUS thickness as one of the predictive indicators of CD using transvaginal ultrasonography since it is more sensitive compared to the transabdominal approach. The study will be designed to assess the reliability of LUS thickness as a predictive tool for intrapartum CD in singleton pregnancies during the late third trimester. Also assess the mean LUS thickness in women who had CD against those with VD making this study develop a more accurate risk assessment model for CD delivery in spontaneous labor.

Material and Methods

This prospective cohort observational study was conducted on pregnant women who had had antenatal care (ANC) at HRH Princess Maha Chakri Sirindhorn Medical Center (MSMC), Faculty of Medicine, Srinakharinwirot University, during March 2024 to October 2024. The eligible candidates for inclusion in this study include singleton pregnancies ranging from gestational age of 34 weeks to 36 weeks and 6 days. To maintain uniformity and relevance to the study's objectives, the inclusion criteria was created which included both nulliparous and multiparous pregnancies who had birthed a live fetus with cephalic presentation at the day of recruitment without a history of prior CD and no history of preterm birth. In addition, each participants' GA was corrected by an ultrasonographic study before GA 22^{+0} weeks. Furthermore, an anatomical scan was also done between GA 18 -22 weeks to confirm that there were no obvious fetal anatomical defects. To ensure that all cases could potentially proceed to VD under standard clinical circumstances, pregnant women who had non-cephalic fetal presentation as well as those with contraindications for VD, such as placenta previa, in the current pregnancy were excluded from this study. Participants who had undergone CD with an indication other than labor dystocia or those who had preterm delivery before GA 37^{+0} weeks were also excluded from this study. The labor dystocia described in this study included CPD, non-progressed labor, an unfavorable cervix, as well as a failed IOL. Using the criterions described above would ensure a homogenous study population, whilst also staying relevant to the study's objectives.

At the ANC unit, pregnant women who met the inclusion criteria were informed about the details of this study including but not limited to the study's objectives and methodology. Written informed consent was obtained from each of the participants, ensuring they fully understood the purpose and procedures of this study. Once the consent was obtained, maternal demographic data (maternal age, parity, GA at recruitment, prior obstetric history such as the number of children birthed, mode of prior deliveries, or history of abortion, history of uterine surgery, weight, height, and BMI) were then collected systematically. This baseline data set would allow for a more complete analysis of maternal and fetal characteristics in adjunct to the delivery outcomes later in the experiment.

All ultrasound examinations were performed by three highly trained and certified operators (K.T., K.R., C.C.) from the maternal fetal medicine (MFM) unit, using a Voluson E6 and P8 ultrasound system (GE Health care, Thailand) with a 4–9 MHz vaginal transducer. To measure the LUS thickness, we used transvaginal approach, which has been proven in a study to be more accurate in assessing the thickness of the lower uterine segment in comparison to its alternative method, the transabdominal ultrasound.[19] The vaginal probe 4-9 MHZ was chosen and covered with a sterile and lubricated condom. The participant was asked to void before entering the examination room and lie down in the dorsal lithotomy position to optimize imaging conditions. The vaginal probe was inserted into vagina without excessive pressure to ensure patient comfort. The probe was precisely fixed to visualize the sagittal plane of the cervix, identifying the key anatomical landmarks such as internal os, external os, cervical canal, and endocervical mucosa.

In transvaginal ultrasound, the LUS was the lower uterine wall which was connected to the cervix and posterior to the urinary bladder. The LUS consists of two layers, a hyperechogenic layer that represents the bladder wall and peritoneum, and a hypoechogenic layer that represents the myometrium. Following the technique described in a previous study, the full thickness of the LUS was used in the measurement.[16] The LUS thickness was examined longitudinally and transversely to distinguish the thinnest zone. The thinnest zone was then magnified to fill about 75% of the ultrasound screen. Measurements of the LUS thickness was made by positioning two calipers on specific anatomical landmarks. The first marker was positioned on the border between the uterine and the bladder wall, whilst the second one was positioned between the uterine wall and amniotic fluid or fetal scalp, LUS thickness was obtained measuring the distance between the calipers from inner border to inner border in mm. (Figure 1). Three consecutive measurements were made, where the lowest value was recorded to be used in the final analysis.

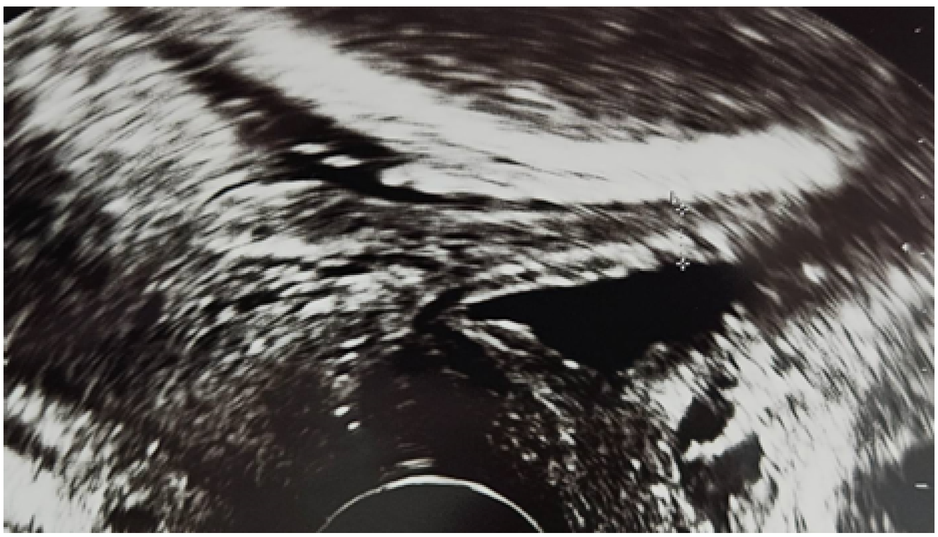

Figure 1: Ultrasound Image of the Measurement of LUS Thickness.

Demographic data were collected to evaluate the predictive value of LUS thickness in determining CD outcomes which consists of three parts, the first part included maternal baseline characteristics including age, height, pre-pregnancy weight, BMI, total weight gain during pregnancy, history of abortion, GA at the time of recruitment, GA at delivery, the interval between the ultrasound measurement and delivery. The second part included the results of the LUS thickness. The third part was the delivery outcomes including mode of delivery (VD or CD), and the clinical indications for CD.

Sample Size Estimation

The sample size required in this study was calculated to ensure that the statistical power was adequate for its use in the study. A formula was used to estimate the area under the ROC curve as the study of Hanley and McNeil[20] and other medical research identifying an optimal sample size for diagnostic studies using ROC curves. The numbers used in calculation were taken from another study which had similar variability factors with this current study.[18] Del Campo's ROC curve study was 0.82 including width of CI 0.17 and the proportion of samples having disease was 0.38. As calculated, a sample size of at least 120 participants was necessary to achieve a confidence interval of 95% in the research study. Furthermore, to take into account the possible dropouts as well as incomplete data sets that may occur once the study has progressed, a 10% allowance was adjusted for, resulting in the final target sample size to be 132 participants in total. This ensured that the study would retain sufficient statistical power generate reliable results.

Statistical Analysis

For categorical variables, e.g., parity, history of abortion, mode of delivery, and clinical indications for CD, frequencies and percentages were reported. For continuous variables, e.g., maternal age, height, pre-pregnancy weight, BMI, total weight gain during pregnancy, GA at the time of recruitment, GA at delivery, the interval between the ultrasound measurement and delivery, LUS thickness, and neonatal birth body weight, the mean and standard deviation (SD) were reported for data with a normal distribution. If the data were not normally distributed, the median and interquartile range (IQR) were reported instead. The normality of the data was assessed using the Shapiro–Wilk test, visual inspection of histograms, and statistical tests to minimize the risk of incorrect conclusions due to violations of underlying statistical assumptions.

For comparative analyses, specific statistical methods were chosen based on the type and distribution of the data. Categorical variables were analyzed using either the Chi-square test or Fisher's exact test, depending on the sample size and expected frequencies within the contingency tables. Continuous variables were analyzed based on the distribution of the data: Student's t-test was used for normally distributed data, while the Mann-Whitney U test was used for non-normally distributed data.

To evaluate the diagnostic performance of LUS thickness in predicting CD outcomes, a ROC curve was constructed to determine the cut-off value of LUS thickness. The results were reported as diagnostic performance measures, including sensitivity (indicating the proportion of actual CD cases), specificity (indicating the proportion of non-CD cases), positive predictive value (PPV) (indicating the likelihood that pregnant women classified as at risk of CD truly required the procedure), and negative predictive value (NPV) (indicating the likelihood that pregnant women classified as not at risk truly avoided CD).

Statistical analysis was performed using STATA version 18.0 (StataCorp, College Station, Texas, USA), and a p-value of less than 0.05 was indicated as a statistically significant difference between the groups.

Ethical Consideration

The study received approval from the institute's ethics committee under the reference number SWUEC-661045, which ensures that all research activities complied with the ethical standards regarding human subject research. This trial was also registered on the Thai Clinical Trial Registry (TCTR20240530001) to uphold transparency and demonstrate commitment to adhere to recognized national guidelines. Additionally, this registration also aligned the research with international standards for clinical research transparency, as this allows the public to access the study's objectives, methodology, and planned analyses.

Results

Participant Characteristics

A total of 132 pregnant women were initially enrolled in the study. However, two participants were lost to follow-up, leaving 130 women who completed the study and were included in the final analysis. Of these participants, 93 women underwent VD, one required forceps-assisted VD, and 36 women underwent CD. Overall, the prevalence of intrapartum CD in this study population was 27.69%. The demographic data of maternal baseline characteristics including maternal age, height, pre-pregnancy weight, BMI, total weight gain during pregnancy, abortion history, GA at the time of recruitment, GA at delivery, the interval between the ultrasound measurement and delivery, and LUS thickness, are presented in **Table 1**. No statistically significant differences were observed between the VD (including operative VD) and CD groups in terms of maternal age, GA, pre-pregnancy weight, height, or BMI. These findings suggest that these baseline characteristics may not play a decisive role in distinguishing between the two groups in this study population. However, pregnancy weight gain was found to be significantly higher in the CD group, with a mean weight gain of 14.44 ± 6.95 kg compared to 11.39 ± 5.00 kg in the VD group (p = 0.01). This indicates that excessive gestational weight gain may be a contributing factor to the likelihood of requiring CD.

Table 1: Clinical Characteristics and Lower Uterine Thickness According to Delivery Outcome.

Characteristics	VD and Operative VD (n=94)		CD(n=36)		p-value
	mean	±SD	mean	±SD	
Age (year)	27.72	5.58	26.92	5.75	0.47
Parity (n, %)					0.02
Nulliparous	38	44.1	23	16.9	
Multiparous	56	49.9	13	19.1	
History of abortion (n, %)					0.58
Yes	11	10.1	3	3.9	
No	83	83.9	33	32.1	
GA at enrollment (weeks)	34.96	0.82	35.03	0.88	0.67
Pre-pregnancy weight (kg)	56.68	13.60	59.05	15.28	0.39
Height (cm)	156.82	6.06	156.72	5.78	0.93
BMI (kg/m^2)	22.99	5.03	24.00	6.11	0.34
Pregnancy weight gain (kg)	11.39	5.00	14.44	6.95	0.01
LUS thickness (mm.)	6.69	2.77	7.01	2.99	0.56
GA at delivery (weeks)	38.33	0.99	38.89	1.04	0.01
Interval time from enrollment to delivery (days)	23.52	9.00	26.86	8.05	0.05
Neonatal BBW (grams)	2,959.36	364.03	3,112.78	420.47	0.04

SD= standard deviation, kg=kilograms, evidence of difference (p-value)

Lower Uterine Segment (LUS) Thickness and Delivery Mode

The mean LUS thickness measured across all participants was 6.78 mm (SD = 2.82). When stratified by delivery mode, the mean LUS thickness in the VD group was 6.69 mm (SD = 2.77), while the mean LUS thickness in the

CD group was slightly higher at 7.01 mm (SD = 2.99). However, this difference was not statistically significant (p = 0.56), suggesting that LUS thickness alone may not be able to accurately differentiate between delivery modes. When cases of intrapartum CD due to non-reassuring fetal heart rate (FHR) patterns and fetal distress were excluded from the analysis, the mean LUS thickness in the CD group increased to 7.40 mm (SD = 3.14). Despite this increase, the difference in LUS thickness between the VD and CD groups remained statistically insignificant (p = 0.26), as shown in Tables 1 and 2. These findings underscore the complexity of predicting delivery outcomes based solely on LUS thickness.

The most common indication for intrapartum CD was CPD, which accounted for 58.33% of cases. This was followed by a non-reassuring FHR (22.22%) and other factors, including an unfavorable cervix, a failed IOL, and fetal distress, as detailed in Table 3. This distribution highlights the multifactorial nature of intrapartum CD indications.

Table 2: Clinical Characteristics and LUS Thickness According to Delivery Outcome Exclude Emergency CD due to Abnormal FHR Pattern.

Characteristics	VD and operative VD (n=94)		CD (n=27)		p-value
	mean	±SD	mean	±SD	
Age (year)	27.72	5.58	26.92	5.75	0.47
Parity (n, %)					0.02
Nulliparous	38	44.1	23	16.9	
Multiparous	56	49.9	13	19.1	
History of abortion (n, %)					0.58
Yes	11	10.1	3	3.9	
No	83	83.9	33	32.1	
GA at enrollment (weeks)	34.96	0.82	35.03	0.88	0.67
Pre-pregnancy weight (kg)	56.68	13.60	59.05	15.28	0.39
Height (cm)	156.82	6.06	156.72	5.78	0.93
BMI (kg/m^2)	22.99	5.03	24.00	6.11	0.34
Pregnancy weight gain (kg)	11.39	5.00	14.44	6.95	0.01
LUS thickness (mm.)	6.69	2.77	7.40	3.14	0.26
GA at delivery(weeks)	38.33	0.99	39	1.07	<0.01
Interval time from enrollment to delivery (days)	38.33	0.99	39.48	1.07	<0.01
Neonatal BBW (grams)	2,959.36	364.03	3,112.78	420.47	0.04

SD= standard deviation, kg=kilograms, evidence of difference (p-value)

Table 3: Indication for Intrapartum CD.

Indication	n (%)
CPD	21 (58.33)
Unfavorable cervix	3 (8.33)
Failed IOL	3 (8.33)
Non-reassuring FHR	8 (22.22)
Fetal distress	1 (2.78)

Predictive Value of LUS Thickness for CD

To evaluate the predictive performance of LUS thickness for CD due to labor dystocia, a ROC curve analysis was performed. The analysis yielded an area under the ROC curve of 0.57 (95% CI: 0.45–0.70), indicating that LUS thickness may not be a reliable standalone predictor for CD outcomes due to its poor discriminatory abilities, as illustrated in Figure 2. Despite its limited accuracy, the optimal cut-off value for LUS thickness was determined to be 6.2 mm, based on the ROC curve. At this cut-off, the sensitivity, specificity, PPV, and NPV were 52.8%, 44.7%, 26.8%, and 71.2%, respectively. These metrics suggest that while LUS thickness has a moderately acceptable sensitivity and NPV, its specificity and PPV remain low, limiting its clinical utility in predicting CD.

When cases involving abnormal FHR patterns and fetal distress were excluded, the optimal cutoff for LUS thickness shifted to 6.5 mm. At this threshold, the sensitivity, specificity, PPV, and NPV were slightly different, at 48.1%, 41.5%, 19.1%, and 73.6%, respectively. Although the exclusion of these cases improved the NPV marginally, the overall predictive accuracy of LUS thickness still remained limited, as demonstrated in Table 4.

These results highlight the need for a multifactorial approach to predicting CD, incorporating additional maternal, fetal, and ultrasonographic parameters to enhance accuracy and reliability. LUS thickness alone, as demonstrated by its low area under the curve and predictive values, is insufficient for robust prediction of CD due to labor dystocia.

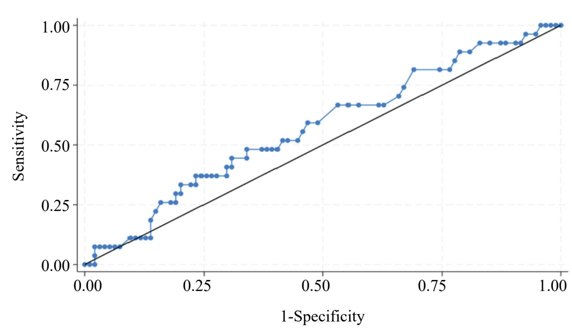

Figure 2: The Area Under ROC Curve for Predicting CD of LUS Thickness Measurement.

(the area under ROC curve = 0.57 with 95% CI: 0.45-0.70)

Table 4: Predictive Value of LUS Thickness for Predicting CD.

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
LUS thickness >= 6.5 mm. *1	48.1	41.5	19.1	73.6
LUS thickness >= 6.2 mm. *2	52.8	44.7	26.8	71.2

*1 CD excluding non-reassuring FHR and fetal distress, *2 all CD

Discussion

In essence, this study investigated the predictive value of LUS thickness for intrapartum CD due to labor dystocia in singleton pregnant women during the late third trimester by TVS. The most significant LUS thickness of this study was assessed by using the ROC curve analysis which showed an area under the ROC curve of 0.57 (95% CI: 0.45–0.70), with cut-off value more than 6.2 mm has a poor diagnostic performance of LUS thickness as an indicator for predicting intrapartum CD outcomes with sensitivity, specificity, PVV, NVV of 52.8%, 44.7%, 28.6%, and 71.2%, respectively. These findings suggest that while measuring LUS thickness may be able to provide useful insights into the physiological changes occurring in the uterus during late pregnancy, it is not a reliable standalone predictor in determining the likelihood of CD due to labor dystocia.

Comparison with Previous Studies

Previous studies have primarily explored the role of LUS thickness as a predictive marker for uterine rupture or CD, particularly in women attempting VBAC. For example, Bujold *et al.*[16] reported a strong association between thicker LUS measurements and the risk of uterine rupture in VBAC cases. Their findings demonstrated the clinical usefulness of LUS thickness in high-risk populations with prior uterine scar. However, the study population in this paper focuses on pregnant women without previous CD which may differ from their results. The results did not show any significant differences in LUS thickness among pregnant women who underwent CD and VD ($p = 0.26$) with the mean LUS thickness in pregnant women who underwent CD as 7.40 ± 3.14 mm. compared to 6.69 ± 2.77 mm. in the VD group. These findings demonstrated the limitation of LUS thickness as a clinical predictor for intrapartum CD outcome, more specifically in population without previous uterine surgery. While LUS thickness may provide important information about uterine adaptations during late pregnancy, intrapartum CD outcomes are still poorly predicted with LUS alone as a predictor. Additionally, several studies have proven the potential relevance of LUS thickness in other areas of the obstetrics context including induction of labor (IOL). For instance, Del Campo *et al.*[18] reported that increased thickness of LUS is directly associated with the possibility of CD during pregnancy among women undergoing IOL. This shows that although LUS thickness alone may not be reliable in predicting labor dystocia in women experiencing spontaneous labor, there could be other clinical uses for it in women undergoing IOL.

Clinical Implications

The results obtained from this study have several important clinical implications such as the low sensitivity and specificity observed for LUS thickness at the optimized cut-off value of LUS thickness indicates that solely relying on this measurement alone may be inadequate to predict CD outcomes. To show this, at the optimal cut-off value, the sensitivity was 52.8% and the specificity was 44.7%. These values suggest that a single measurement of LUS thickness does not provide sufficient accuracy for reliable decision-making for clinical use, where the overestimation or underestimation of CD risk can lead to the use of unnecessary interventions or a missed opportunity for timely surgical delivery.

To improve predictive accuracy, future researches should explore the integration of LUS thickness with other maternal and fetal characteristics, such as maternal age, parity, BMI, fetal head circumference, and estimated fetal weight or combination of LUS thickness alongside other ultrasonographic parameters, including CL or fetal OSA. This could improve the results of the overall predictive value of LUS thickness in the prognosis of intrapartum CD in pregnant women who underwent spontaneous labor. The use of subgroup analyses may also be beneficial. For example, investigating populations with higher baseline risks for CD, such as women of advanced maternal age or those with obesity, could yield insights into specific scenarios where LUS thickness may have greater predictive utility. By identifying certain subgroups where LUS thickness proves to be more relevant, clinicians would be able to refine the current risk assessment models for individual pregnant women, which would reduce unnecessary CD and improve maternal and neonatal outcomes.

Strengths

This study has several major strengths. Firstly, the choice to use a prospective cohort study in this research has allowed for the standardized measurement in all of the participants included. Furthermore, the single ultrasonographic protocol, which was used by three independent and certified operators, demonstrated intra-observer reliability and repeatability in this study. Secondly, the study was conducted in a well-defined population with the use of a clear inclusion and exclusion criteria, Certain exclusions include those with contraindications for VD, non-cephalic presentations, and prior uterine surgeries, which overall allowed the study to minimize confounding factors and focus on pregnant women are at risk for labor dystocia. Thirdly, this specific study had a low dropout rate, with only 2 participants (1.53%) who lost follow-up, allowing the study to truly represent the target population, increasing the validity and accuracy of the final results. Finally, this study uses widely available 2D ultrasound machines, which would allow this technique to be easily replicated in other settings, including clinical practice.

Limitations

Despite its strengths, this study has some limitations. Firstly, this study has a low prevalence of CD (27.69%), which may limit generalizability of the results in populations with a higher CD rate or a different obstetric risk profile. For example, a population with a higher rate of maternal obesity or advanced maternal age may have a different the predictive value for LUS thickness. Secondly, the landmark for LUS thickness measurement is relatively small, which may introduce variability of measurements in those not familiar with this operation. Further studies with larger sample sizes, more diverse populations, and experienced operators are needed to validate the current findings and improve the limitations found.

Future Trends in Research

Specific fields of obstetric research continue to progress, with opportunities for discovery new prediction and management of CD outcomes. Future studies will most probably be directed at refining predictive models by integrating emerging technologies and diverse datasets to address the limitations identified in current methodologies. One important trend involves the integration of artificial intelligence (AI) and machine learning (ML) into predictive analytics. These may be beneficial in term of analyze large data sets of maternal and fetal baseline characteristics, ultrasonographic parameters, and labor progression metrics. AI-driven models can identify complex patterns through sophisticated algorithms and interdependencies that might improve the prediction of risk of CD. It can be said that the integration of ultrasonographic measurements-for example, LUS thickness-along with real-time fetal monitoring and other maternal health data may improve predictive tools at present with an uplift of accuracy and reliability.

Moreover, advances in imaging technology especially 3D and 4D ultrasonography open new perspectives for a more detailed and accurate evaluation of uterine and fetal features. These can provide good visualization of the LUS and its relation to surrounding anatomical structures. Consequently, this may lead to improved and more precise measurement, as well as better correlation with CD risk. Further validation of these technologies in clinical settings will be a critical turning point. Another promising avenue is the exploration of biomolecular markers in adjunct to imaging-based predictors. Hormonal and inflammatory markers, as well as genetic predispositions, may offer additional insights into labor progression and uterine dynamics. Combining such biomarkers with traditional clinical assessments may lead to a more holistic understanding of CD risk and its factors.

Personalized medicine is also expected to gain more interest of those within the obstetrics field. When combined with other maternal baseline characteristics, such as maternal age, parity, BMI, and other medical and obstetric history, personal medicine could prove beneficial for high-risk populations, including advanced maternal age, maternal obesity, or pre-existing medical conditions, through improving risk assessment and aid doctors in making decisions within clinical practice.

Lastly, collaborative research initiatives across regions and institutions will be instrumental in addressing the variability of CD predictors in different populations. Large-scale, multicenter studies would be able to provide diverse datasets, improving the generalizability of these predictive models. Furthermore, such collaborations can facilitate the development of standardized protocols for ultrasonographic measurements and the interpretation of results, ensuring consistency and reliability upon clinical application.

Conclusion

In conclusion, this study looks into the use of LUS thickness, measured through TVS ultrasonography, in predicting the risk of CD due to labor dystocia, more specifically during the late third trimester of women with singleton pregnancies. The results of the study reveals that its clinical application may be limited due to a low-level of diagnostic performance, where the area under the ROC curve of 0.57 provided an optimal cut-off value of LUS thickness 6.2 mm, which has a sensitivity, specificity, PPV, and NPV of 52.8%, 44.7%, 26.8%, and 71.2%, respectively. The results demonstrated no difference of LUS thickness between the groups of CD and VD, with a mean and SD of 7.4 ± 3.14 mm in CD group, and 6.69 ± 2.77 mm in VD group (p-value = 0.26). These findings suggest the need for a combination of others maternal and fetal baseline characteristics, or others ultrasonographic parameters, to improve the accuracy in predicting CD in these circumstances. Further research which integrate additional variables and those that conduct subgroup analysis may improve the diagnostic performance of LUS thickness for its use in clinical practice.

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