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Research Article

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Ultrasound Elastography of the Maternal Cervix in the Prediction of Spontaneous Preterm Birth: A Prospective Cohort Study

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ABSTRACT

Background: Spontaneous preterm birth (sPTB) remains a leading cause of neonatal morbidity and mortality worldwide, with India contributing disproportionately to the global burden. Accurate prediction of women at risk is essential for timely interventions. Conventional methods, such as cervical length (CL) measurement, have limited predictive value. Ultrasound shear wave elastography (SWE) offers a quantitative assessment of cervical stiffness, potentially improving risk stratification.

Objective: To evaluate the diagnostic accuracy of transabdominal shear wave elastography of the maternal cervix in predicting spontaneous preterm birth.

Methods: A prospective observational study was conducted on 51 pregnant women with singleton gestations between 18 and 36 weeks at VMMC & Safdarjung Hospital, New Delhi. SWE and shear wave speed (SWS) values were recorded at the internal and external cervical os using a convex transducer. Participants were followed until delivery, and pregnancy outcomes were documented.

Results: Nine participants (17.64%) experienced sPTB, higher than both the global (10%) and national (13%) rates. SWS at the internal os ≤1.4 m/s demonstrated the best predictive performance, with sensitivity and negative predictive value (NPV) of 100%. At the external os, SWS ≤1.32 m/s achieved sensitivity of 88.9% and NPV of 94.7%. SWE values showed similar trends, with high sensitivity (77.8–88.9%) and excellent NPVs (>92%).

Conclusion: Transabdominal cervical SWE is a promising, non-invasive screening tool for predicting spontaneous preterm birth. Its high sensitivity and NPV suggest strong potential for clinical use, particularly in ruling out risk and guiding preventive strategies.

Keywords: Shear-Wave Elastography, Cervix, Preterm Birth, Ultrasound, Elasticity

Introduction

Preterm birth, defined by the World Health Organisation as delivery occurring before 37 completed weeks of gestation, remains a leading cause of neonatal morbidity and mortality worldwide [1]. Preterm labour is now recognised as a multifactorial syndrome involving infection, inflammation, uteroplacental ischemia, uterine overdistension, stress, and immunological mechanisms [2]. Despite advances in obstetric care, the accurate prediction of spontaneous preterm birth remains challenging.

Currently, cervical length measurement and fetal fibronectin testing are the most widely used tools for risk stratification [3]. Demonstrated a strong inverse relationship between cervical length and gestational age at delivery, establishing cervical shortening as an important marker of preterm birth risk [4]. However, cervical length assesses only morphologic change and fails to capture early biochemical and biomechanical cervical remodelling.

Cervical remodelling is a continuous process encompassing softening, ripening, dilation, and postpartum repair [5]. Premature cervical softening without uterine contractions, clinically termed cervical insufficiency, is a recognised contributor to spontaneous preterm birth. Traditional assessment of cervical consistency relies on subjective digital examination as part of the bishop score, which lacks objectivity [6].

Ultrasound elastography provides a non-invasive method for quantifying tissue stiffness. Shear-wave elastography (SWE)

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measures tissue stiffness by evaluating shear-wave propagation velocity, which decreases in softer tissues [7]. Recent studies suggest that cervical elastography may detect biomechanical changes earlier than cervical shortening, offering improved predictive potential. The present study aimed to evaluate the role of transabdominal cervical shear-wave elastography in predicting spontaneous preterm birth.

Materials and Methods

Study Design and Setting

A prospective observational cohort study was conducted in the Department of Radiodiagnosis in collaboration with the Department of Obstetrics and Gynaecology. The study protocol received approval from the institutional ethical committee (IEC/VMMC/SJH/Cert./02-2024/298). Written informed consent was obtained from all patients.

Study Participants

A total of 51 Pregnant women with singleton pregnancies between 18 and 36 weeks of gestation were enrolled after informed consent. Women with a history of cervical surgery, prior preterm birth, premature rupture of membranes, multifetal gestation, autoimmune disease, and congenital fetal anomalies were excluded from the study.

Ultrasound Elastography Protocol

Ultrasound was performed using a Philips Affiniti 70 system with a 2-5 MHz convex transducer. Cervical length was measured in the sagittal plane from the internal to the external os. Quantitative SWE was performed with the cervix centred in the sagittal plane. A fixed 1 × 0.5 cm region of interest (ROI) was placed adjacent to the endocervical canal at both the internal and external os. Two measurements were obtained at each site, and mean elasticity (kPa) and shear-wave speed (m/s) were recorded. (Figure 1) Participants were followed up until delivery. Spontaneous preterm birth was defined as delivery before 37 weeks.

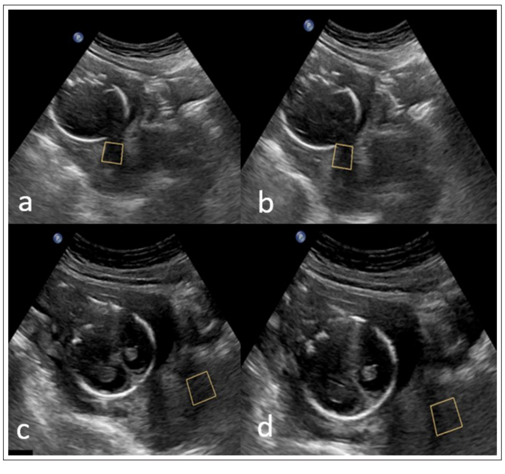

Figure 1: A 20-year-old female with GA 18 weeks + 4 days at the time of scan. Transabdominal Shear Wave Elastography (a-b) ROI at the internal os SWE (3.2 kPa and 5.1 kPa) and SWS (1.03 m/s and 1.12 m/s). (c-d) ROI at the external os SWE (3.1 kPa and 5.7 kPa) and SWS (1.1 m/s and 1.3 m/s). The patient had a preterm delivery at 30 weeks + 2 days via CS

Statistical Analysis

Data was coded and recorded in an MS Excel spreadsheet program. SPSS v21 (IBM Corp.) was used for data analysis. The association between two categorical variables was explored using the Chi-squared test. In case the expected frequency in the contingency tables was found to be < 5 for >25% of the cells, Fisher's Exact test was used instead. Sensitivity, specificity, PPV, NPV, and diagnostic accuracy were calculated for the investigation under study to assess its diagnostic performance, and ROC curves were plotted to determine the diagnostic performance and best cut-off for continuous variables (shear wave elastography values and shear wave speed) in predicting a dichotomous outcome (presence or absence of spontaneous preterm birth). Statistical significance was kept at $p < 0.05$.

Results

Study Population

A total of 51 pregnant women with singleton gestations between 18 and 36 weeks were included in the final analysis. The mean maternal age was 26.08 ± 4.23 years, with a median age of 26 years (IQR: 23.75-29). The age range of the study population was 18–36 years. Most participants belonged to the 18–30-year age group, reflecting the typical reproductive age distribution in the study setting. The mean gestational age at the time of ultrasound examination was 21.27 ± 2.24 weeks, with a median of 20.79 weeks (IQR: 20.07-21.86). The gestational age ranged from 16.14 to 30.71 weeks, indicating that most examinations were performed during the early to mid-second trimester.

Pregnancy Outcomes

Out of the 51 participants, 9 women (17.6%) experienced spontaneous preterm birth (<37 weeks), while 42 women (82.4%) delivered at term. The mean gestational age at delivery did not differ significantly across maternal age groups or mode of delivery. Vaginal delivery and caesarean section were evenly distributed between the preterm and term birth groups, and no statistically significant association was observed between delivery mode and elastography parameters.

Cervical Shear-wave Elastography Measurements

Quantitative cervical elastography measurements were successfully obtained in all participants using the standardised protocol. At the internal cervical os, the mean shear-wave elasticity (SWE) was 5.84 ± 4.48 kPa, with a median value of 4.55 kPa (IQR: 3.29-6.82). The corresponding mean shear-wave speed (SWS) was 1.32 ± 0.44 m/s, with a median of 1.23 m/s (IQR: 1.04-1.51). At the external cervical os, the mean SWE was 5.13 ± 2.97 kPa (median: 4.90 kPa; IQR: 3.37–6.20), while the mean SWS was 1.25 ± 0.35 m/s (median: 1.19 m/s; IQR: 1.01–1.40). (Table 1)

Correlation With Gestational Age at Imaging

A statistically significant negative correlation was observed between gestational age at imaging and cervical elastography values at both the internal and external os. At the internal os, gestational age demonstrated a weak but significant inverse correlation with SWE ($\rho = -0.26$, $p = 0.021$) and SWS ($\rho = -0.29$, $p = 0.011$) Similarly, at the external os, gestational age showed SWE correlation of $\rho = -0.26$ ($p = 0.021$) and SWS correlation of $\rho = -0.29$ ($p = 0.012$). These findings indicate a progressive reduction in cervical stiffness with advancing gestation, consistent with physiological cervical remodelling.

Table 1: Association between Gestational Age at Delivery (Weeks) and Parameters

Variable	Parameter	Total	Gestational Age at Delivery		Difference (95% CI)	Significance
			<37 Weeks	≥37 Weeks		
Mean SWE (Int os) (kPa)	Mean ± SD	5.84 ± 4.48	4.24 ± 1.42	7.05 ± 5.35	-2.81 (-4.73 to -0.90)	W = 126.000 p = 0.124
	Median (IQR)	4.55 (3.29 - 4.75)	4.19 (3.63 - 4.75)	5.42 (3.67 - 8.38)		
Mean SWE (Ext os) (kPa)	Mean ± SD	5.13 ± 2.97	4.20 ± 2.03	5.82 ± 3.31	-1.62 (-3.39 to 0.16)	W = 126.500 p = 0.126
	Median (IQR)	4.90 (3.37 - 5.09)	4.22 (2.36 - 5.09)	5.20 (3.79 - 6.65)		
Mean SWS (Int os) (m/s)	Mean ± SD	1.32 ± 0.44	1.15 ± 0.20	1.45 ± 0.47	-0.30 (-0.50 to -0.10)	W = 117.500 p = 0.079
	Median (IQR)	1.23 (1.04 - 1.25)	1.16 (1.10 - 1.25)	1.31 (1.14 - 1.67)		
Mean SWS (Ext os) (m/s)	Mean ± SD	1.25 ± 0.35	1.16 ± 0.28	1.34 ± 0.35	-0.18 (-0.41 to 0.05)	W = 137.000 p = 0.203
	Median (IQR)	1.26 (1.05 - 1.30)	1.19 (0.96 - 1.30)	1.27 (1.12 - 1.49)		

Association Between Elastography Parameters and Preterm Birth

Women who experienced spontaneous preterm birth demonstrated lower mean cervical stiffness values compared with those who delivered at term. At the internal os, mean SWS was 1.15 ± 0.20 m/s in the preterm group, compared with 1.45 ± 0.47 m/s in the term group. Although this difference did not reach statistical significance, a clear trend toward reduced stiffness was evident in the preterm group. Mean internal-os SWE was also lower in preterm births (4.24 ± 1.42 kPa) compared with term births (7.05 ± 5.35 kPa). At the external os, both SWE and SWS values were lower in the preterm group; however, the discriminatory ability was inferior to that observed at the internal os.

Diagnostic Performance and ROC Analysis

Receiver operating characteristic (ROC) curve analysis was performed to evaluate the diagnostic performance of cervical elastography parameters for predicting spontaneous preterm birth. Among all evaluated parameters, internal-os SWS demonstrated the highest diagnostic accuracy, with an AUROC of 0.689. An optimal cutoff value of ≤1.4 m/s yielded a sensitivity of 100%, specificity of 42.9%, negative predictive value (NPV) of 100% and positive predictive value (PPV) of 27.3%. (Figure 2) Internal-os SWE demonstrated an AUROC of 0.667, while external-os SWE and SWS yielded AUROC values of 0.665 and 0.638, respectively. (Table 2) These findings indicate that although the overall discriminatory ability of SWE is modest, internal-os SWS exhibits excellent sensitivity and NPV, supporting its role as a screening parameter for spontaneous preterm birth.

Discussion

This prospective cohort study evaluated the role of transabdominal cervical shear-wave elastography (SWE) in predicting spontaneous preterm birth, demonstrating that quantitative elastography parameters, particularly shear-wave speed (SWS) at the internal cervical os, exhibit moderate discriminatory ability with high sensitivity and an excellent negative predictive value. These findings support the evolving concept that premature cervical softening, rather than cervical shortening alone, represents a critical biomechanical pathway leading to spontaneous preterm birth [2,3].

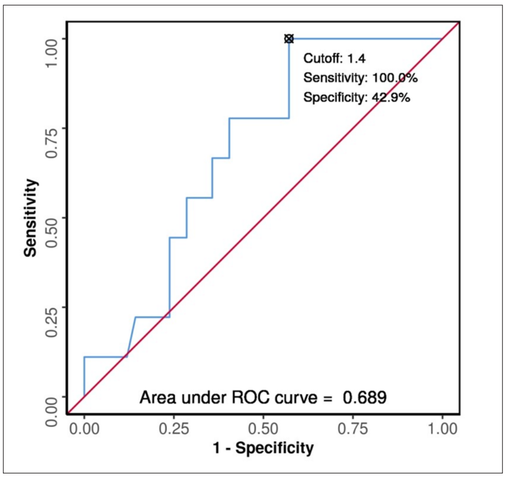

Figure 2: ROC Curve Analysis of Mean SWS (Int OS) (m/s) in Predicting Gestational Age at Delivery: <37 Weeks vs ≥37 Weeks. AUROC was 0.689 (95% CI: 0.528 - 0.85); not statistically significant (p = 0.079). At a cutoff of Mean SWS (Int OS) (m/s) ≤1.4, it predicts Gestational Age at Delivery: <37 Weeks with a sensitivity of 100%, and a specificity of 43%

Table 2: Performance of Study Parameters for Predicting Gestational Age at Delivery: <37 weeks vs ≥37 weeks

Variable	Sensitivity	Specificity	NPV	NPV	Diagnostic Accuracy
Mean SWE (Int OS) (kPa) (Cutoff: 4.75 by ROC)	77.8%	59.5%	29.2%	92.6%	62.7%

Mean SWE (Ext OS) (kPa) (Cutoff: 5.23 by ROC)	88.9%	50.0%	27.6%	95.5%	56.9%
Mean SWS (Int OS) (m/s) (Cutoff: 1.4 by ROC)	100.0%	42.9%	27.3%	100.0%	52.9%
Mean SWS (Ext OS) (m/s) (Cutoff: 1.32 by ROC)	88.9%	42.9%	25.0%	94.7%	51.0%

Cervical Biomechanics and Gestational Age

A significant inverse correlation was observed between gestational age at imaging and both SWE (kPa) and SWS (m/s) values at the internal and external os. This observation is consistent with established models of cervical remodelling, wherein progressive collagen disorganisation, increased water content, and reduced tensile strength occur well before morphological shortening becomes apparent on ultrasound [5]. Consequently, cervical length measurement, while clinically valuable, captures a relatively late manifestation of cervical change and may fail to identify early biomechanical vulnerability [6].

Prior elastography studies have reported similar gestation-dependent reductions in cervical stiffness. O'Hara et al. demonstrated a progressive decline in transabdominal SWS across gestation, with the most pronounced changes occurring at the internal os, underscoring its biomechanical significance [8]. Hernandez-Andrade et al. further established that cervical softness measured by SWE is independently associated with spontaneous preterm birth, even in women without a short cervix or prior preterm delivery [9].

Internal os as the Principal Biomechanical Marker

In the present study, elastography parameters obtained at the internal os consistently outperformed external-os measurements in predicting spontaneous preterm birth. Internal-os SWS demonstrated the highest AUROC and was lower among women who delivered preterm compared with those delivering at term. (Figure 3) This finding is biologically plausible, as the internal os represents the region of maximal mechanical stress during pregnancy and is the earliest site of cervical remodelling. Several studies support the superior predictive value of internal-os elastography. Du et al. reported significantly higher strain values at the internal os in the second trimester among women who subsequently delivered preterm, whereas external-os measurements showed weaker associations [10]. Similarly, Nguyen-Hoang et al. demonstrated significantly reduced SWE values at the internal cervical lip as early as the first trimester in pregnancies complicated by spontaneous preterm birth [11].

Diagnostic Performance and Clinical Interpretation

Although AUROC values in this study (0.63–0.69) indicate modest overall discrimination, the diagnostic profile of SWE is notable for very high sensitivity and NPV, particularly for internal-os SWS. An internal-os SWS cutoff of ≤1.4 m/s achieved 100% sensitivity and 100% NPV, suggesting that SWE may be particularly effective as a screening or rule-out tool. This diagnostic pattern mirrors prior evidence. A meta-analysis by Wang et al. reported pooled sensitivities of 0.81–0.84 and NPV exceeding 90%, emphasising the clinical utility of cervical elastography in identifying women unlikely to deliver preterm [12]. The relatively low positive predictive values observed in this and other studies likely reflect the multifactorial nature of preterm birth, in which cervical softening represents a final common pathway rather than a disease-specific marker.

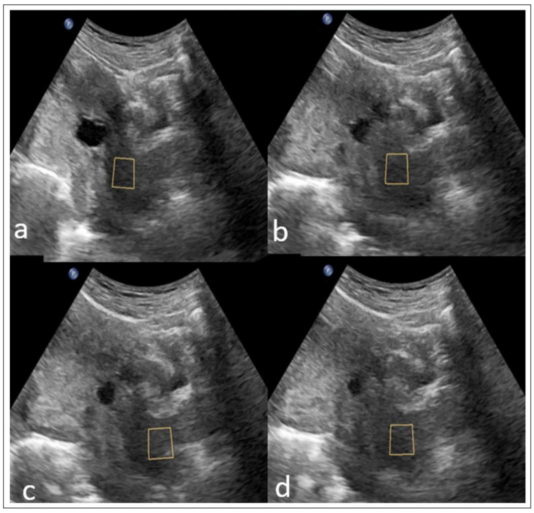

Figure 3: A 26-year-old female with GA 20 weeks + 4 days at the time of scan. Transabdominal Shear Wave Elastography (a-b) ROI at the internal os SWE (4.2 kPa and 5.6 kPa) and SWS (1.2 m/s and 1.39 m/s). (c-d) ROI at the external os SWE (3.2 kPa and 6.6 kPa) and SWS (1.1 m/s and 1.4 m/s). The patient had a term normal vaginal delivery at 38 weeks + 5 days

Clinical Relevance of the Transabdominal Approach

A key strength of the present study is the exclusive use of the transabdominal approach, which offers greater patient acceptability and broader feasibility than transvaginal techniques. Transabdominal SWE can be seamlessly incorporated into routine antenatal ultrasound examinations without additional invasiveness or patient discomfort. O'Hara et al. demonstrated that transabdominal SWE yields reliable measurements, particularly at the anterior internal os, findings that are corroborated by the present study [8]. This has important implications for population-level screening, especially in low-resource settings or regions where transvaginal ultrasound may be culturally sensitive.

Strengths and Limitations

The strengths of this study include its prospective design, standardised elastography protocol, and comprehensive diagnostic accuracy analysis. However, several limitations merit consideration. The sample size was modest, limiting statistical power and precluding multivariable modelling. The study was conducted at a single centre, which may affect generalisability. Additionally, elastography measurements were obtained at a single time point; longitudinal assessment may better capture dynamic cervical remodelling.

Future research should focus on larger, multicentre cohorts with gestation-specific reference ranges, longitudinal SWE trajectories, and integrated prediction models incorporating cervical length, elastography, uterocervical angle, and biochemical markers.

Clinical Implications

Despite these limitations, the findings support transabdominal cervical SWE as a valuable adjunctive screening tool. The high negative predictive value of internal-os SWS suggests utility in identifying low-risk pregnancies, optimising surveillance strategies, and avoiding unnecessary interventions.

Conclusion

Integrating cervical stiffness parameters provides a more comprehensive assessment of cervical remodelling, significantly improving the sensitivity and accuracy of sPTB predictions. Elastography can detect biomechanical changes (cervical softening) that precede measurable shortening of the cervix, allowing for earlier identification of high-risk pregnancies. In essence, cervical elastography helps us see that a cervix can become soft before it gets short, making it a powerful partner to traditional length checks for catching preterm birth risk early.

Conflict of Interest

The authors declare that they have no conflict of interest

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Availability of Data and Material

The data supporting this study are available from the corresponding author on request.

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