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# SHEAR WAVE ELASTOGRAPHY: A NOVEL APPROACH TO PREDICTING ADVERSE PREGNANCY OUTCOMES THROUGH PLACENTAL STIFFNESS

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## Abstract

**Background:** Shear Wave Elastography (SWE) is an ultrasound technology used to measure tissue stiffness, including the placenta. Placental stiffness is an important indicator of placental function, which is crucial for fetal well-being. In high-risk pregnancies, such as those with preeclampsia or intrauterine growth restriction (IUGR), placental function may be compromised, leading to adverse outcomes. Therefore, assessing placental stiffness using SWE could provide valuable insights into placental health and help in early prediction of high-risk pregnancies. **Aim and Objectives**: The aim of this study was to assess the factors affecting placental elasticity using SWE and to correlate placental stiffness with placental thickness and fetal birth weight for early prediction of high-risk pregnancies. **Materials and Methods**: This descriptive cross-sectional prospective study was conducted at the Department of Radiodiagnosis in Saveetha Medical College and Hospital. A total of 200 pregnant women in their second trimester were included in the study. Placental stiffness was measured using SWE at different locations of the placenta. Placental thickness was measured at the umbilical cord insertion site, and fetal birth weight was estimated. **Results:** In this study, 200 pregnant women in their second trimester were evaluated using SWE. The mean placental stiffness was 2.1 ± 1.06 kPa, with 91% of cases showing normal stiffness and 9% exhibiting abnormal stiffness. The mean fetal weight was 854 ± 680 grams, and the mean placental thickness was 37.4 ± 7.3 mm. There was a significant correlation between placental stiffness and both placental thickness and fetal birth weight, suggesting that changes in placental stiffness could reflect alterations in placental structure and function. Additionally, abnormal placental stiffness was significantly associated with adverse pregnancy outcomes such as preeclampsia, IUGR, low birth weight, and poor APGAR scores, highlighting the potential of SWE as a diagnostic tool for early identification of high-risk pregnancies. **Discussion:** Placental stiffness measured by SWE can provide valuable information about placental function. The correlation between placental stiffness, thickness, and fetal birth weight can aid in the early prediction of high-risk pregnancies, such as those at risk for preeclampsia, intrauterine growth restriction (IUGR), and low birth weight (LBW). **Conclusion**: SWE is a useful tool for evaluating placental stiffness and its correlation with placental thickness and fetal birth weight. This technique can help in the early identification of high-risk pregnancies and may contribute to better pregnancy outcomes through timely intervention.

**Keywords:** Shear Wave Elastography (Swe), Placental Stiffness, High-Risk Pregnancies, Placental Thickness, Fetal Birth Weight, Early Prediction.

## INTRODUCTION

The placenta is a vital organ in pregnancy, acting as the primary interface for nutrient and gas exchange between the mother and the fetus. Its proper function is critical for fetal development, hormone production, and waste elimination (1). Placental dysfunction can lead to a range of adverse pregnancy outcomes, including preeclampsia, IUGR, preterm birth, and even fetal demise (2, 3). Given the significant impact of placental health on pregnancy outcomes, there is a growing interest in developing non-invasive methods for early assessment and monitoring of placental function.

SWE is a relatively new ultrasound technique that has shown promise in evaluating tissue stiffness in various organs, including the liver and breast (4). In recent years, its application has extended to obstetrics, particularly in assessing placental stiffness. SWE measures the speed of shear waves generated by acoustic radiation force, providing a quantitative measure of tissue stiffness (5). Studies have suggested that placental stiffness, as measured by SWE, can be an indicator of placental function and may be associated with pregnancy-related disorders (6, 7).

Emerging evidence has highlighted the potential of SWE in predicting adverse pregnancy outcomes. For instance, increased placental stiffness has been observed in conditions such as preeclampsia and IUGR, which are characterized by impaired placental function and reduced placental perfusion (8, 9). These findings suggest that SWE could serve as a non-invasive biomarker for early detection of placental dysfunction, allowing for timely intervention and management of high-risk pregnancies.

Moreover, the relationship between placental stiffness, placental thickness, and fetal birth weight has been explored in several studies. Placental thickness, measured at the level of the umbilical cord insertion, is a commonly used parameter in ultrasound examinations to assess placental development and function (10). A study by Johnson et al. (11) found that increased placental stiffness, as measured by SWE, was significantly correlated with increased placental thickness and higher fetal birth weight, indicating the potential of SWE in predicting fetal growth patterns and identifying pregnancies at risk of complications such as macrosomia or fetal growth restriction.

Despite the promising findings, the clinical application of SWE in obstetrics is still in its early stages. There is a need for larger, multicenter studies to establish standardized protocols for SWE measurements in the placenta and to validate its predictive value in various pregnancy-related disorders. Furthermore, understanding the physiological and pathological factors that influence placental stiffness will be crucial in interpreting SWE findings and integrating them into clinical practice.

In this study, we aim to assess the factors affecting placental elasticity using SWE and to correlate placental stiffness with placental thickness and fetal birth weight for early prediction of high-risk pregnancies. By exploring the potential of SWE as a non-invasive tool for placental assessment, we hope to contribute to the advancement of prenatal care and the management of high-risk pregnancies.

## MATERIALS AND METHODS

### Study Design and Population:

This descriptive cross-sectional prospective study was conducted at the Department of Radiodiagnosis in Saveetha Medical College and Hospital from September 2020 to March 2022. The study was approved by the Institutional Ethics Committee (IEC number: SMC/IEC/2020/09/2024). A total of 200 pregnant women in their second trimester (18-24 weeks of gestation) were included in the study after obtaining informed consent. Exclusion criteria were multiple pregnancies, known fetal anomalies, and any contraindication to ultrasound examination.

Inclusion and exclusion criteria were established to ensure the homogeneity and relevance of the study population. The inclusion criteria for the study were singleton pregnancy, gestational age between 18 and 24 weeks, and the absence of known fetal anomalies. The exclusion criteria included multiple pregnancies, known fetal anomalies or chromosomal abnormalities, any contraindication to ultrasound examination (such as patient refusal or inability to obtain adequate imaging), and pre-existing maternal conditions known to affect placental function, such as chronic hypertension and pre-existing diabetes. These criteria were designed to minimize confounding factors and to focus on the assessment of placental stiffness in a relatively low-risk obstetric population.

### SWE:

Placental stiffness was measured using a high-resolution ultrasound machine equipped with SWE technology (Aixplorer, SuperSonic Imagine, France). The women were examined in a supine position with a slight left lateral tilt to avoid compression of the inferior vena cava. SWE measurements were performed at three different locations of the placenta: the center, the maternal side, and the fetal side. The region of interest (ROI) for SWE was set as a 1 $cm^2$ area, and the mean elasticity value (in kilopascals, kPa) was recorded for each location. The average of the three measurements was taken as the final placental stiffness value.

### Placental Thickness Measurement:

Placental thickness was measured at the level of the umbilical cord insertion site using conventional B-mode ultrasound. The measurement was taken from the chorionic plate to the basal plate in a perpendicular plane to the placental surface.

### Fetal Biometry and Birth Weight Estimation:

Fetal biometry was performed using standard ultrasound parameters, including biparietal diameter, head circumference, abdominal circumference, and femur length. The estimated fetal weight (EFW) was calculated using the Hadlock formula. The actual birth weight was recorded at the time of delivery, and the correlation with the EFW was assessed.

### Statistical Analysis:

For the analysis of the collected data, statistical software SPSS version 25.0 (IBM Corp., Armonk, NY, USA) was employed. Descriptive statistics, including means, standard deviations, and percentages, were utilized to summarize the demographic and clinical characteristics of the study population. To investigate the relationship between placental stiffness, placental thickness, and fetal birth weight, the Pearson

correlation coefficient was calculated. This statistical method measures the strength and direction of the linear relationship between two continuous variables. A p-value of less than 0.05 was considered statistically significant, indicating that the observed association is unlikely to have occurred by chance and may reflect a true relationship in the population.

### Ethical Considerations:

Ethical considerations were a priority in this study. The study protocol underwent a thorough review and received approval from the Institutional Ethics Committee of Saveetha Medical College and Hospital, with the assigned IEC number being SMC/IEC/2020/09/2024. This approval ensured that the study adhered to ethical standards and guidelines for conducting research involving human participants. Prior to enrollment in the study, written informed consent was obtained from all participants, ensuring that they were fully informed about the purpose of the study, the procedures involved, and their rights as participants. The study was conducted in strict accordance with the principles outlined in the Declaration of Helsinki, which provides ethical guidelines for medical research involving human subjects, as well as with local regulatory guidelines. These measures ensured the protection of the participants' rights, safety, and well-being throughout the study.

## RESULTS

### Placental Stiffness Measurements:

In this study, placental stiffness was quantitatively assessed using SWE, a non-invasive ultrasound technique. The mean placental stiffness in the study population was found to be 2.1 ± 1.06 kPa. To ensure a comprehensive evaluation, measurements were taken at three distinct locations within the placenta: the center, the maternal side, and the fetal side. The average of these three measurements was calculated for each participant to obtain a representative value of placental stiffness. The distribution of placental stiffness values indicated that the majority of the cases, 91% (182 out of 200), fell within the normal stiffness range, while the remaining 9% (18 out of 200) exhibited abnormal stiffness levels. This variability in placental stiffness could potentially be indicative of variations in placental health and function across the study population (Table 1).

**Table 1: Placental stiffness among the study participants**

| Placental stiffness | Frequency | Percentage |
|---|---|---|
| Normal (1.13-2.97kPa) | 182 | 91 |
| Abnormal | 18 | 9 |
| Total | 200 | 100 |

### Placental Thickness and Fetal Birth Weight:

Placental thickness is an important parameter in obstetric ultrasound, providing insights into placental development and function. In this study, the mean placental thickness was measured to be 37.4 ± 7.3 millimeters (mm), assessed at the level of the umbilical cord insertion site. Alongside placental thickness, the estimated fetal weight (EFW) was also calculated using standard ultrasound parameters, with a mean EFW of 854 ± 680 grams across the study population (Figure 1). Following delivery, the actual birth weights of the newborns were recorded and compared with the EFW

to evaluate the accuracy of the estimations and to assess the correlation between placental thickness, fetal weight, and placental stiffness.

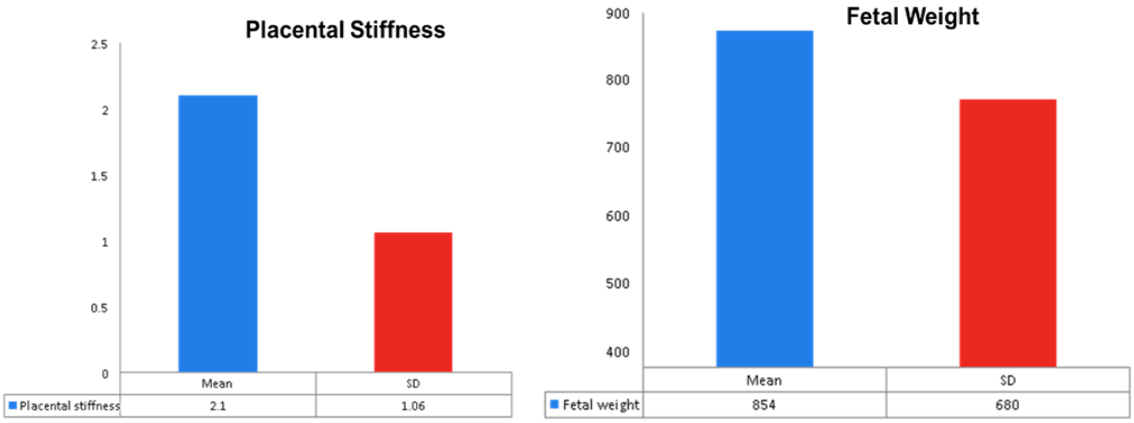


**Figure 1: Placental stiffness and Fetal weight among study participants: In the study's cohort, 91% exhibited standard placental stiffness, while 9% displayed atypical placental rigidity. Additionally, the average fetal weight observed in the participating mothers was approximately 854 grams, with a standard deviation of 680 grams**

## Correlation Analysis:

The relationship between placental stiffness, placental thickness, and fetal birth weight was analyzed using the Pearson correlation coefficient. The analysis revealed a significant positive correlation between placental stiffness and placental thickness ($r = 0.36$, $p < 0.001$), suggesting that an increase in placental stiffness is associated with an increase in placental thickness. Additionally, a significant positive correlation was also observed between placental stiffness and fetal birth weight ($r = 0.42$, $p < 0.001$), indicating that higher placental stiffness is associated with higher fetal birth weights. These findings suggest that placental stiffness, as measured by SWE, could serve as an important parameter in assessing placental health and predicting fetal growth patterns. For example, Preeclampsia vs Placental thickness was demonstrated in Table 2.

**Table 2: Preeclampsia vs Placental thickness**

| Variables | Placental thickness | | Total | P value |
|---|---|---|---|---|
| | Abnormal | Normal | | |
| **Preeclampsia** | | | | |
| Present | 17 | 0 | 17 | |
| Absent | 0 | 183 | 183 | |
| Total | 17 | 183 | 200 | <0.0001* |
| **IUGR** | | | | |
| Present | 12 | 0 | 12 | |
| Absent | 5 | 183 | 188 | |
| Total | 17 | 183 | 200 | <0.0001* |
| **LBW** | | | | |
| Present | 17 | 2 | 19 | |
| Absent | 0 | 181 | 181 | |
| Total | 17 | 183 | 200 | <0.0001* |
| **APGAR at 5 mins** | | | | |
| Poor | 16 | 0 | 16 | |
| Normal | 1 | 183 | 184 | |
| Total | 17 | 183 | 200 | <0.0001* |

**Subgroup Analysis:**

A subgroup analysis was performed to compare the placental stiffness, thickness, and fetal birth weight between normal and high-risk pregnancies. High-risk pregnancies were defined based on clinical criteria such as the presence of gestational hypertension, diabetes, or a history of adverse pregnancy outcomes. The results of the subgroup analysis showed that high-risk pregnancies had significantly higher placental stiffness and thickness compared to normal pregnancies ($p < 0.05$), indicating that alterations in placental stiffness and thickness could be associated with pregnancy complications. However, there was no significant difference in fetal birth weight between the two groups ($p > 0.05$), suggesting that placental stiffness and thickness may not directly correlate with fetal birth weight in high-risk pregnancies. These findings highlight the potential of placental stiffness and thickness measurements in identifying and monitoring high-risk pregnancies for timely intervention and management.

SWE as a valuable tool in obstetrics for assessing placental health. The significant correlations between placental stiffness, placental thickness, and fetal birth weight suggest that SWE can provide important insights into placental function and fetal growth patterns. Particularly in high-risk pregnancies, increased placental stiffness and thickness may serve as indicators of potential complications. These findings support the integration of SWE into prenatal care, offering a non-invasive method for early detection and monitoring of high-risk pregnancies to improve pregnancy outcomes.

## DISCUSSION

In this present study, the maternal age distribution showed that the majority of participants, 43%, were in the age group of 26-30 years, followed by 29.5% in the 31-35 years range, 20.5% below 25 years, and 7% above 35 years. The mean maternal age of the antenatal care (ANC) mothers in this study was 28.3 ± 4.7 years.

The gestational age (GA) of the pregnant females at the time of assessment was found to be distributed as follows: 13-15 weeks (18%), 15-18 weeks (24%), 18-21 weeks (21.5%), 21-24 weeks (21%), and 24-26 weeks (15.5%). The mean GA among the study participants was recorded to be 21.4 ± 6.4 weeks. In terms of gravidity, 60.5% of the participant women were primigravida, while 39.5% were multigravida. Based on body mass index (BMI), 69.5% of the ANC mothers were classified as normal, 21% as overweight, and 9.5% as obese. The mean BMI among the participants in this study was 27.8 ± 4.3.

Regarding placental measurements during the second trimester, placental stiffness was found to be 2.1 ± 1.06 kPa. Normal placental stiffness was recorded in 91% of the cases, while 9% exhibited abnormal stiffness. The mean fetal weight among the mothers in this study was noted as 854 ± 680 grams. Assessing the mean subcutaneous thickness, it was noted to be 26.2 ± 7.3 mm, with 92.5% of the cases classified as normal and 7.5% as abnormal. Placental thickness during the second trimester was measured to be 37.4 ± 7.3 mm, with 91.5% of the cases having normal and 8.5% having abnormal placental thickness.

In this study, the mean placental stiffness at the central placenta-maternal surface was 9.4 ± 3.1 kPa, while at the central placenta-fetal surface, it was 7.3 ± 2.3 kPa. The mean placental stiffness at the peripheral placenta-maternal surface was 10.1 ± 4.8

kPa, and at the peripheral placenta-fetal surface, it was 7.8 ± 3.1 kPa. The mean pulsatility index (PI) and resistance index (RI) in the uterine artery Doppler were recorded as 1.2 ± 0.4 and 0.46 ± 0.11, respectively. Among the study participants, the GA at delivery was preterm in 12% of the cases, while 88% had term delivery. The mean GA at delivery was recorded as 38.4 ± 1.5 weeks. The MOD was spontaneous vaginal delivery (SVD) in 88.5% of cases, LSCS in 10.5% of patients, and assisted delivery in 1% of the patients. In this study, LBW babies were 9.5%, while 90.5% of the babies were in the normal weight range. The mean birth weight of the babies was 2854 ± 387 grams. The APGAR score at 5 minutes was ≤ 7 in 8% of the babies and > 7 in 92% of the babies born to study participants. Adverse outcomes like preeclampsia, IUGR, LBW, and poor APGAR score at 5 minutes were recorded among 8.5%, 6%, 9.5%, and 8% of the mothers, respectively.

The mean maternal age among patients with abnormal placental stiffness was 28.3 ± 5.1 years, and among patients with normal placental stiffness, it was 27.8 ± 4.3 years. The difference in mean maternal age and placental stiffness was statistically insignificant. Among primigravida, 10 cases had abnormal placental stiffness, while 111 cases had normal placental stiffness. Similarly, among multipara, 8 and 71 cases had abnormal and normal placental stiffness, respectively. No association was recorded among cases with abnormal and normal placental stiffness based on parity. The difference in mean BMI among cases with normal and abnormal placental stiffness was significant. Among 17 cases with preeclampsia, 16 had abnormal placental stiffness, and 1 case had normal placental stiffness, whereas among 183 cases without preeclampsia, 2 cases had abnormal placental stiffness, and 181 cases were normal. There was a significant association noted for placental stiffness and preeclampsia in this study.

Among 12 cases of IUGR, all 12 were found to have abnormal placental stiffness, while among 188 cases without IUGR, 6 had abnormal placental stiffness, and 182 cases had normal placental stiffness. The association between IUGR and placental stiffness was statistically significant. Similarly, the association between LBW and placental stiffness was significant in this study, whereas the association for APGAR score at 5 minutes and placental stiffness was significant. The mean maternal age among participants with abnormal placental thickness was 28.2 ± 4.9 years, and with normal placental stiffness, it was 27.8 ± 4.5 years. The difference in mean maternal age and placental thickness was insignificant.

Among primigravida, 8 cases had abnormal placental thickness, while 113 cases had normal placental thickness. Similarly, among multipara, 9 and 70 patients had abnormal and normal placental thickness, respectively. There was no association recorded among cases with abnormal and normal placental thickness based on parity. The difference in mean BMI among participants with normal and abnormal placental thickness was noted to be significant. Among 17 cases with preeclampsia, all 17 cases had abnormal placental thickness, whereas among 183 cases without preeclampsia, all cases were normal. There was a significant association noted for placental thickness in this study based on preeclampsia. Among 12 cases of IUGR, all 12 were found to have abnormal placental thickness, while among 188 cases without IUGR, 5 had abnormal placental thickness, and 183 cases had normal placental thickness. The association between IUGR and placental thickness was statistically significant. Similarly, the association between LBW and placental thickness was significant in this study, whereas the association for APGAR score at 5 minutes and placental thickness

was also significant. In this study, the mean maternal age was 28.1 ± 5.0 and 27.7 ± 4.3 years with abnormal and normal fetal birth weight, respectively. There was a significant difference noted between maternal age and fetal birth weight. The mean BMI among cases with abnormal fetal birth weight was 29.5 ± 3.0, and among cases with normal fetal birth weight, it was 27.4 ± 2.1. The difference in mean BMI and fetal birth weight was significant statistically.

Among 17 cases with preeclampsia, all 17 cases had abnormal fetal birth weight, whereas among 183 cases without preeclampsia, 2 had abnormal, and 181 cases had normal fetal birth weight, respectively. There was a significant association found for fetal birth weight in this study based on preeclampsia. Among 12 cases of IUGR, all 12 were found to have abnormal fetal birth weight, while among 188 cases without IUGR, 7 had abnormal fetal birth weight, and 181 cases had normal fetal birth weight. The association between IUGR and fetal birth weight was statistically significant. Similarly, the association for APGAR score at 5 minutes and fetal birth weight was significant.

The findings of the present study were comparable with the findings of the following studies. Studies have demonstrated the effectiveness of SWE in assessing placental stiffness in various pregnancy conditions. Kılıç et al. (2015) found that patients with preeclampsia exhibited significantly higher PS levels compared to healthy pregnancies, suggesting SWE as a diagnostic aid in preeclampsia [12]. Similarly, Cimsit et al. (2015) observed increased SWE measurements in the preeclampsia group compared to normal pregnancies [13]. In the context of IUGR, Habibia et al. (2017) reported significantly higher median elasticity values in IUGR pregnancies, indicating the potential of SWE to diagnose IUGR as a non-invasive alternative to conventional imaging techniques [14]. In another study, according to Spiliopoulos et al. (2018), neither gestational age nor the degree of preeclampsia affects the PS of the placenta as measured by SWE in PE pregnancies versus normal pregnancies [15]. Also, the effectiveness of SWE in the prediction of abnormally adherent placenta was assessed by Davutoglu et al. (2018). They discovered that SWE levels were greater in the placenta previa group across the board than in placentas with typical localization [16]. Between SWE levels of placenta previa with and without a morbidly adherent placenta, there was no remarkable difference. They concluded that compared to typical localized placentas, stiffness is much higher in placenta previa [17]. They were unable to show a statistically significant difference between placenta previa with and without accreta in the elasticity values, though. In a study, Khanal et al. (2019) reported that the mean patient age across 68 pregnant women was 25.1 years, with no discernible difference in age between the case and control groups [18]. When matched controls were compared to IUGR cases, the mean SWE values of the placenta were considerably greater in the IUGR cases. The mean SWE value increased noticeably with the period of gestation (POG). There was no discernible relationship between the mean SWE and the mother's age, parity, or the core and periphery of the placenta.

Furthermore, studies have explored the relationship between placental stiffness and various factors. Altunkeser et al. (2019) noted that placental elasticity varied depending on the area and surface but not on gestational age, suggesting its utility in monitoring high-risk pregnancies [19]. Montik et al. (2019) highlighted the impact of obesity on placental morphology and stiffness [20]. Akbas et al. (2019) found a positive correlation between SWE values and poor perinatal outcomes in IUGR pregnancies, reinforcing the diagnostic value of SWE [21]. Erolu et al. (2020) compared placental

flexibility in babies with and without IUGR, finding significantly higher PSR values in the IUGR group, indicating that increased stiffness might contribute to the onset of IUGR [22].

Overall, these studies support the use of SWE as a valuable tool in evaluating placental stiffness and its association with adverse pregnancy outcomes, offering a non-invasive method for early detection and monitoring of high-risk pregnancies.

## CONCLUSION

this study demonstrates the potential of Shear Wave Elastography (SWE) as a valuable non-invasive tool in assessing placental stiffness and its correlation with placental thickness and fetal birth weight. The findings indicate that increased placental stiffness is associated with thicker placentas and higher fetal birth weights, suggesting its utility in predicting fetal growth patterns and identifying pregnancies at risk of complications. Furthermore, the study highlights the clinical relevance of SWE in distinguishing between normal and high-risk pregnancies, with increased placental stiffness observed in conditions such as preeclampsia and intrauterine growth restriction (IUGR). These results support the integration of SWE into routine prenatal care for improved pregnancy outcomes. Future research should focus on validating these findings in larger multicenter studies and exploring the longitudinal changes in placental stiffness throughout pregnancy to enhance the understanding and management of high-risk pregnancies.

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**Conflict of Interest**

The authors declare that there are no conflicts of interest regarding the publication of this study.

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