



2D Shear Wave Elastography: An Evolving Technique for Comparison of Placental Elasticity in Normal and Preeclamptic Pregnancy

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Abstract

Objective This article evaluates differences in placental elasticity between normal and preeclamptic pregnancies using shear wave elastography and assesses the potential of the placental elasticity values in predicting preeclampsia.

Materials and Methods The study included 60 pregnant women, 30 diagnosed with preeclampsia and 30 with normal pregnancies, in their second and third trimesters. Shear wave elastography was performed to assess placental elasticity. Both mean (average) and maximum elasticity values were recorded and cutoff values were determined using receiver operating characteristic (ROC) curve analysis to evaluate their potential in predicting preeclampsia.

Results Placental elasticity values were significantly higher in preeclamptic women (group A) compared with healthy pregnant women (group B). The mean elasticity in group A was 15.74 ± 3.51 kPa, with a maximum elasticity of 27.4 ± 4.66 kPa; whereas in group B, the corresponding values were 4.42 ± 1.93 and 7.13 ± 3.05 kPa, respectively ($p < 0.0001$). In preeclampsia cases, the shear wave modulus was higher in the central region of the placenta than at the edges. ROC curve analysis evaluated a mean elasticity cutoff value of 8.1 kPa, with a sensitivity of 100%, specificity of 96.67%, positive predictive value of 96.8%, negative predictive value of 100%, and a diagnostic accuracy of 98.33%.

Conclusion The study revealed significant differences in placental elasticity between preeclamptic and healthy pregnancies, highlighting the potential of shear wave elastography as a valuable tool for early prediction of preeclampsia. Early prediction using this method could significantly reduce maternal and perinatal mortality and morbidity, especially in developing countries, by identifying cases before the onset of clinical symptoms.

Keywords

- ▶ 2D-shear wave elastography (2D-SWE)
- ▶ kilopascals (kPa)
- ▶ point shear wave elastography (p-SWE)
- ▶ preeclampsia (PE)
- ▶ acoustic radiation force impulse (ARFI)

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Introduction

Preeclampsia (PE) is a common medical complication of pregnancy that significantly contributes to maternal and perinatal morbidity and mortality. It is recognized as a leading cause of preterm births, accounting for approximately 5 to 8% of cases, and is responsible for 1 to 3% of perinatal deaths globally.¹ In India, the prevalence of PE is estimated to be 9 to 10% according to the National Health Portal.²

Uteroplacental insufficiency is widely considered a major factor contributing to higher rates of perinatal morbidity and mortality associated with PE.³ Doppler ultrasound assessment of uterine artery velocimetry during the first two trimesters may offer indirect evidence of abnormal trophoblast invasion into spiral arterioles and thus serve as a potential predictive tool for PE.⁴ Although various flow velocity waveforms have been investigated for predicting PE, none of them has been found completely suitable for clinical use.⁴ In fact, uterine artery Doppler has low predictive value for both early as well as late onset PE.⁵

Several serum markers, including pregnancy-associated plasma protein A (PAPP-A), inhibin A, and activin A, have been investigated to predict the development of PE before the clinical symptoms.⁶ However, these markers have proved to be of very little significance.⁶

Early prediction of PE in high-risk pregnant women is essential to allow timely intervention management to reduce maternal and perinatal morbidity and mortality.

Placental elasticity is expected to decrease in PE due to abnormalities such as inflammation, infarction, and fibrosis.⁷ Fibrous tissue deposition in the placenta may lead to increased stiffness, thereby reducing its elasticity. With advancements in the field of ultrasonography, tissue elasticity can now be measured using elastography.

Screening for PE based on maternal characteristics and clinical history can detect approximately 35% of cases, with a false positive rate of 10%.⁸ A combination of maternal biochemical markers, Doppler imaging, and elastography may improve overall prediction of PE.⁹

The purpose of our study was to assess differences in placental elasticity between preeclamptic and healthy pregnancies and to determine the shear wave modulus cutoff value for predicting PE.

Materials and Methods

Study Population

This study was conducted after obtaining approval from the Institute Review Board Committee. A total of 60 pregnant women in their second and third trimester of pregnancy were included in the study. The sample size was determined based on the study by Cimsit et al¹⁰ study as a reference with 95% power and 5% level of significance. Written informed consent was obtained from all participants.

The 60 patients were divided into two groups: group A included 30 cases of PE and group B consisted of 30 healthy controls. This case-control study was conducted between April 2023 and May 2024. The cases involved pregnant women

diagnosed with PE, referred from the department of obstetrics and gynecology, based on the diagnostic criteria established by the American College of Obstetricians and Gynecologists. The control group comprised healthy pregnant women also referred from the obstetrics and gynecology department. No matching was done between the two groups.

Pregnant women with structural placental abnormalities (inadequately attached placenta, adhered placenta, or placental hematomas), fetal anomalies, and obstetric pathologies (diabetes, polyhydramnios, hydrops fetalis, single umbilical artery) were identified on gray scale examinations and excluded from the study.

Gray scale examination followed by placental shear wave elastography (SWE) measurements were performed only once for each patient at the time of recruitment. Only pregnant women with singleton pregnancies were included. Demographic characteristics, detailed antenatal, clinical history, and examination details were obtained.

The SWE measurements in the preeclamptic group (group A) were taken as early as possible following the diagnosis of PE, even before the initiation of the treatment; however, this was not feasible in every case. The gray scale imaging and SWE measurements were performed by the same radiologist to ensure consistency. All patients received standard care for the management of PE, based on the established protocols and clinical jurisdiction of obstetrician. This included anti-hypertensives, magnesium sulfate for eclamptic patients, and termination of pregnancy when medically indicated.

Ultrasound Imaging and Data Acquisition

Gray scale examination and fetal biometry was performed using a curvilinear transducer using a bandwidth of 2 to 7 MHz. Patients were positioned supine, asked to breathe gently, and remain as still as possible. Gray scale imaging was used to assess placental position and detect any placental abnormalities. Fetal biometry was conducted to confirm gestational age.

SWE was performed in the same sitting on Philips machine using ElastPQ software. A close tab was also kept on the thermal, mechanical indices ($TI < 1$ and $MI < 1.9$ as per the Food and Drug Administration) and efforts were made to complete the examination as quickly as possible adhering to the ALARA (As Low As Reasonably Achievable) principle. During SWE measurements, the placenta was divided into three parts—right $\frac{1}{4}$ part, central $\frac{2}{4}$ part, and left $\frac{1}{4}$ part. Placenta was centered in the field of view. The machine algorithm generated the elastograms, displayed as dual images, one showing a color-coded stiffness map and the other a chromatic confidence map. Based on spectral color-coded box, a region of interest fixed at 8 mm was placed in the area of the maximum stiffness (indicated in red on the stiffness map) and highest confidence (indicated in green on the confidence map). The ElastPQ software performed the calculations and provided three elasticity values: average, median, and maximum. These elasticity values were obtained for each region, center, right, and left regions of the placenta, with measurements being taken only once from each region. All readings were recorded in kilopascals (kPa).

Statistical Analysis

The presentation of the categorical variables was done in the form of number and percentage (%). On the other hand, the quantitative data were presented as the means \pm standard deviation (SD) and as median with 25th and 75th percentiles (interquartile range). The data normality was checked by using the Shapiro–Wilk test. The following statistical tests were applied for the results:

1. The comparison of the variables that were quantitative in nature was analyzed using the independent *t*-test. Paired *t*-test was used for comparison between central and right ¼, left ¼ E max (kPa), and E mean (kPa).
2. The comparison of the variables that were qualitative in nature was analyzed using the chi-square test. If any cell had an expected value of less than 5 then the Fisher's exact test was used.
3. Receiver operating characteristic (ROC) curve was used to assess the cutoff point, sensitivity, specificity, positive predictive value, and negative predictive value of E max (kPa) and E mean (kPa) for predicting PE. DeLong et al¹¹ test was used for comparison of area under the curve (AUC).

The data entry was done in Microsoft EXCEL spreadsheet and the final analysis was done with the use of Statistical Package for Social Sciences (SPSS) software (version 25.0; IBM, Chicago, Illinois, United States). For statistical significance, a *p*-value of less than 0.05 was considered statistically significant.

Results

In this cross-sectional observational study, approximately 60 patients were included: 30 with preeclamptic pregnancies (group A) and 30 healthy pregnant women (group B).

The age distribution of the study population ranged from 24 to 34 years, with a mean age of 28.15 ± 3 years. The mean gestational age of the study subjects was 30.2 ± 2.63 weeks (**Table 1**). The distribution of age, gravidity, period of gestation, and trimesters were comparable between the study and control groups. No significant difference was observed in these parameters between the two groups (**Table 2**).

This study indicated statistically significant differences in the placental elasticity values between the study and control group (*p*-value < 0.05) (**Figs. 1 and 2**). Mean \pm SD of E max (kPa) in the study group was 26.87 ± 8.23 kPa (right ¼), 30.58 ± 8.13 kPa (central), 25.8 ± 6.19 kPa (left ¼), and 27.4 ± 4.66 kPa (average), which were significantly higher compared with the control group: 6.93 ± 3.27 kPa (*p*-value < 0.0001), 8.58 ± 4.04 kPa (*p*-value < 0.0001), 5.98 ± 2.53 kPa (*p*-value < 0.0001), and 7.13 ± 3.05 kPa (*p*-value < 0.0001), respectively (**Table 3**).

Significant difference was also seen in E mean (kPa) for right ¼, central, left ¼, and average of mean E between the study and control groups (*p*-value < 0.05). Mean \pm SD of E mean (kPa) in the study group was 13.95 ± 4.28 kPa (right ¼), 17.65 ± 5.56 kPa (central), 15.67 ± 3.78 kPa (left ¼), and

15.74 ± 3.51 kPa (average), which were significantly higher compared with the control group: 3.76 ± 2 kPa (*p*-value < 0.0001), 5.1 ± 1.77 kPa (*p*-value < 0.0001), 3.65 ± 1.29 kPa (*p*-value < 0.0001), and 4.42 ± 1.93 kPa (*p*-value < 0.0001), respectively (**Table 4**).

Compared with the central E mean value (17.65 ± 5.56 kPa), the E mean in the right 1/4th region was significantly lower (13.95 ± 4.28 kPa, *p*-value = 0.001), while the value in the left 1/4th region was comparable (15.67 ± 3.78 kPa, *p*-value = 0.067) (**Table 5**).

Shear wave elasticity was evaluated as a diagnostic tool for predicting PE in high-risk pregnancies using ROC curve analysis. The cutoff values of E max (maximum elasticity value) at the center, right, and left edge of the placenta were found to be 16.2, 15, and 13 kPa, respectively. The average cutoff value for E max was 14.7 kPa (**Table 6**). For E mean (average elasticity value), the cutoff value at the center, right, and left edges were 7.4, 6.81, and 6.63 kPa, respectively. The average cutoff value of E mean was 8.1 kPa. The test accuracy was 98.33% in the center of the placenta and 100% at the edge with sensitivity of 100% and specificity of 96.67% (**Table 7**).

Hospitalization rates were significantly higher in the study group (53.33%) compared with the control group (*p*-value < 0.0001). Significant differences were observed in birth weight and gestational age at delivery between the study and control groups (*p*-value < 0.05). Mean \pm SD gestational age at delivery was 34.29 ± 1.7 weeks in the study group, significantly lower than in the control group (38.34 ± 1.07 weeks, *p*-value < 0.0001) (**Table 8**).

Table 1 Demographic characteristics distribution

Demographic characteristics	Frequency	Percentage
Age (y)		
24–29	40	66.67
30–34	20	33.33
Mean \pm SD	28.15 \pm 3	
Median (25th–75th percentile)	28 (26–31)	
Range	24–34	
Gravidity		
G1	25	41.67
G2	29	48.33
G3	5	8.33
G4	1	1.67
Period of gestation (wk)		
24–28	16	26.67
> 28–32	30	50.00
> 32–36	14	23.33
Mean \pm SD	30.2 \pm 2.63	
Median (25th–75th percentile)	30.36 (28–31.893)	
Range	24.86–35.57	

Abbreviation: SD, standard deviation.

Table 2 Comparison of demographic characteristics between study and control group

Demographic characteristics	Study group (n = 30)	Control group (n = 30)	Total	p-Value
Age (y)				
24–29	18 (60%)	22 (73.33%)	40 (66.67%)	0.273 [†]
30–34	12 (40%)	8 (26.67%)	20 (33.33%)	
Mean ± SD	28.83 ± 3.04	27.47 ± 2.87	28.15 ± 3.01	0.079 [‡]
Median (25th–75th percentile)	28.5 (27–31)	27 (25–29.75)	28 (26–31)	
Range	24–34	24–33	24–34	
Gravidity				
G1	12 (40%)	13 (43.33%)	25 (41.67%)	1*
G2	15 (50%)	14 (46.67%)	29 (48.33%)	
G3	2 (6.67%)	3 (10%)	5 (8.33%)	
G4	1 (3.33%)	0 (0%)	1 (1.67%)	
Period of gestation (wk)				
24–28	8 (26.67%)	8 (26.67%)	16 (26.67%)	0.811 [†]
> 28–32	14 (46.67%)	16 (53.33%)	30 (50%)	
> 32–36	8 (26.67%)	6 (20%)	14 (23.33%)	
Mean ± SD	30.36 ± 2.79	30.03 ± 2.5	30.2 ± 2.63	0.633 [‡]
Median (25th–75th percentile)	30.64 (28.143–32.071)	30.29 (28.107–31.857)	30.36 (28–31.893)	
Range	24.86–35.57	25.71–34.14	24.86–35.57	
Trimester				
Second	8 (26.67%)	6 (20%)	14 (23.33%)	0.542 [†]
Third	22 (73.33%)	24 (80%)	46 (76.67%)	

Abbreviation: SD, standard deviation.

Note: † indicates that Chi square test is used for the respective categorical data to determine if there is significant difference present or not; ‡ indicates that Independent t test is used as a test of significance for the respective data.

Discussion

The present study aimed to evaluate differences in placental elasticity between preeclamptic and healthy placenta in the Indian population and to determine its usefulness in predicting PE. This case–control study included 60 participants with 30 each from both second and third trimester. In contrast, a prospective study focusing on pregnant women in the second trimester was conducted by Meena et al in 2022.¹²

The age distribution of the participants in the present study varied from 24 to 34 years. No significant difference was noted in the mean age, period of gestation, or gravidity between the study and control groups. Our study concluded that maternal age, period of gestation, and gravidity had no significant impact on the placental stiffness. These results were consistent with Spiliopoulos et al in 2020.¹³ However, the study done by Meena et al in 2022¹² found that primi-gravida are more prone to develop PE.

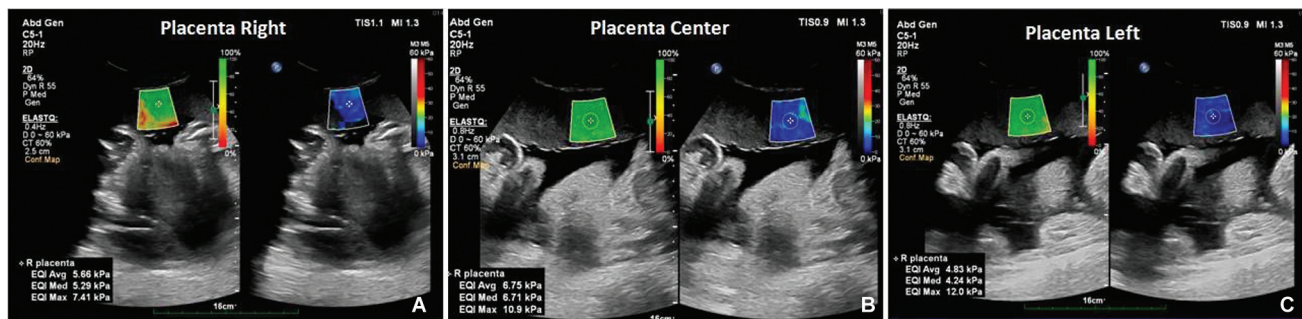


Fig. 1 Normal pregnancy. ElastoQ shear wave elastography (SWE) image of a 24-year-old pregnant women at 31 weeks of gestation. The rectangular box on image represents the stiffness spectrum, displayed in blue with the region of interest (ROI) placed in the denser area. (A) When the ROI box is placed near the right edge of the placenta, the maximum elasticity value is 7.41 kPa, median elasticity value is 5.29 kPa, and average (mean) elasticity value is 5.66 kPa. (B) When the ROI box is placed at the center of the placenta, the maximum elasticity value is 10.9 kPa, median elasticity value is 6.71 kPa, and average (mean) elasticity value is 6.75 kPa. (C) When the ROI box is placed near the left edge of the placenta, the maximum elasticity value is 12.0 kPa, median elasticity value is 4.24 kPa, and average (mean) elasticity value is 4.83 kPa.

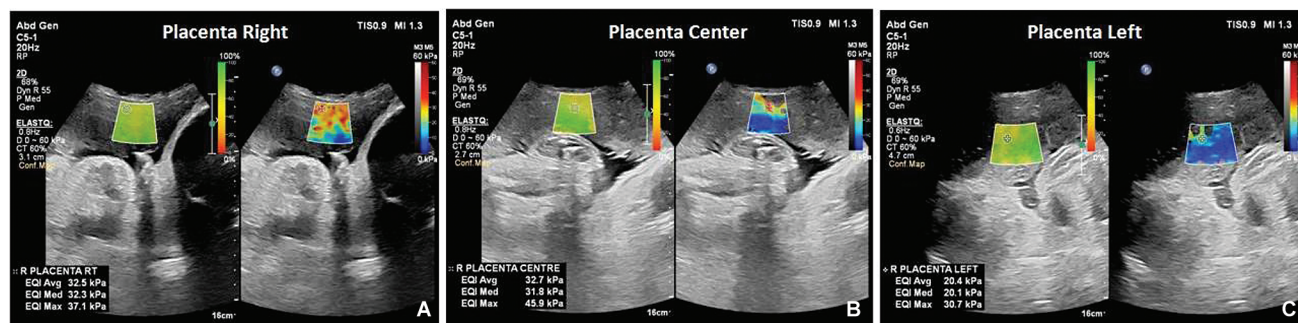


Fig. 2 Preeclampsia pregnancy. ELastoQ shear wave elastography (SWE) image of a 29-year-old pregnant women at 33 weeks of gestation. The rectangular box on image represents the stiffness spectrum displayed in blue with the region of interest (ROI) placed in the denser area. (A) When the ROI box is placed near the right edge of the placenta, the maximum elasticity value is 37.1 kPa, median elasticity value is 32.3 kPa, and average (mean) elasticity value is 32.5 kPa. (B) When the ROI box is placed at the center of the placenta, the maximum elasticity value is 45.9 kPa, median elasticity value is 31.8 kPa, and average (mean) elasticity value is 32.7 kPa. (C) When the ROI box is placed near the left edge of the placenta, the maximum elasticity value is 30.7 kPa, median elasticity value is 20.1 kPa, and average (mean) elasticity value is 20.4 kPa.

We compared both the maximum placenta elasticity (E max) and the average placental elasticity (E mean) values between the control (► Fig. 1) and the study group (► Fig. 2). While previous studies have primarily focused on average placental elasticity values only. The average of E max value was 27.4 ± 4.66 kPa in the preeclamptic group and 7.13 ± 3.05 kPa in the control group. Similarly, the average of E mean value was 15.74 ± 3.51 kPa in the preeclamptic group and 4.42 ± 1.93 kPa in the control group. We found a statistically significant difference (p -value < 0.0001) in both E max and E mean values between the two groups. Similarly, a study conducted by Fujita et al¹⁴ in 2018, reported a significant difference ($p < 0.001$) in placental stiffness between healthy individuals and those diagnosed with PE.

In the present study, both E max and E mean values were higher in the central region of the placenta compared with the edges. However, the difference in E mean was statistically significant between the central region and the right ¼ part. These findings suggest that the effect of PE on placental stiffness is not uniform, and the central region being more affected than the peripheral edges. A similar study performed by Meena et al¹² in second trimester pregnancies stated that significant difference existed between the values at the center and edge of the placenta, with higher values observed in the center as compared with edges.

In present study, the cutoff value for average E max value was found to be 14.7 kPa, while the cutoff value for average E mean was 8.1 kPa. The test accuracy was determined to be

Table 3 Comparison of E max (kPa) between study and control group

E max (kPa)	Study group (n = 30)	Control group (n = 30)	Total	p-Value
Right 1/4				
Mean ± SD	26.87 ± 8.23	6.93 ± 3.27	16.9 ± 11.82	< 0.0001 ^a
Median (25th–75th percentile)	25.45(21.9–30.2)	6.5(4.387–7.35)	15.8(6.55–25.275)	
Range	16.6–55.1	1.6–15	1.6–55.1	
Central				
Mean ± SD	30.58 ± 8.13	8.58 ± 4.04	19.58 ± 12.79	< 0.0001 ^a
Median (25th–75th percentile)	28.05(24.825–34.15)	7.45(6.705–9.65)	19.95(7.475–27.975)	
Range	19.8–48	2.4–20.5	2.4–48	
Left (¼)				
Mean ± SD	25.8 ± 6.19	5.98 ± 2.53	15.89 ± 11.04	< 0.0001 ^a
Median (25th–75th percentile)	24(22.25–29.6)	5.26(4.34–6.708)	14.45(5.282–24)	
Range	15.9–48	1.9–13	1.9–48	
Average of max E				
Mean ± SD	27.4 ± 4.66	7.13 ± 3.05	17.27 ± 10.94	< 0.0001 ^a
Median (25th–75th percentile)	27.45 (23.202–30.05)	6.35 (5.3–8.47)	17.85 (6.375–27.425)	
Range	21–39.63	2.37–14.7	2.37–39.63	

Abbreviations: kPa, kilopascals; SD, standard deviation.

^aIndependent t-test.

Table 4 Comparison of E mean (kPa) between study and control group

E mean (kPa)	Study group (n = 30)	Control group (n = 30)	Total	p-Value
Right 1/4				
Mean ± SD	13.95 ± 4.28	3.76 ± 2	8.86 ± 6.11	< 0.0001 ^a
Median (25th–75th percentile)	12.5 (10.775–15.15)	3.41 (2.75–3.975)	9.08 (3.415–12.45)	
Range	9.08–23.9	1.2–11.5	1.2–23.9	
Central				
Mean ± SD	17.65 ± 5.56	5.1 ± 1.77	11.37 ± 7.53	< 0.0001 ^a
Median (25th–75th percentile)	16.55 (12.4–22.375)	4.9 (4.14–5.73)	9.6 (4.9–16.275)	
Range	9.1–28.1	1.6–11.7	1.6–28.1	
Left (1/4)				
Mean ± SD	15.67 ± 3.78	3.65 ± 1.29	9.66 ± 6.68	< 0.0001 ^a
Median (25th–75th percentile)	14.4 (13–18.475)	3.22 (3.1–4.358)	8.36 (3.232–14.35)	
Range	10.1–25.2	1.1–6.63	1.1–25.2	
Average of mean E				
Mean ± SD	15.74 ± 3.51	4.42 ± 1.93	10.08 ± 6.36	< 0.0001 ^a
Median (25th–75th percentile)	15.35 (12.622–17.882)	3.93 (3.398–4.94)	11.15 (3.93–15.325)	
Range	10.96–24	1.3–11.34	1.3–24	

Abbreviations: kPa, kilopascals; SD, standard deviation.

^aIndependent t-test.**Table 5** Descriptive statistics of E mean (kPa)

E mean (kPa)	Mean ± SD	Median (25th–75th percentile)	Range	p-Value
Central	17.65 ± 5.56	16.55 (12.4–22.375)	9.1–28.1	–
Right 1/4	13.95 ± 4.28	12.5 (10.775–15.15)	9.08–23.9	0.001 ^a
Left (1/4)	15.67 ± 3.78	14.4 (13–18.475)	10.1–25.2	0.067 ^a

Abbreviations: kPa, kilopascals; SD, standard deviation.

^aPaired t-test.**Table 6** Receiver operating characteristic curve of E max (kPa) for predicting preeclampsia

Variables	Right 1/4 E max (kPa)	Central E max (kPa)	Left (1/4) E max (kPa)	Average of E max (kPa)
Area under the ROC curve (AUC)	100.00%	99.80%	1	1
Standard error	0	0.00271	0	0
95% confidence interval	1.000 to 1.000	0.992 to 1.000	1.000 to 1.000	1.000 to 1.000
p-Value	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Cutoff	> 15	> 16.2	> 13	> 14.7
Sensitivity (95% CI)	100% (88.4–100.0%)	100% (88.4–100.0%)	100% (88.4–100.0%)	100% (88.4–100.0%)
Specificity (95% CI)	100% (88.4–100.0%)	96.67% (82.8–99.9%)	100% (88.4–100.0%)	100% (88.4–100.0%)
PPV (95% CI)	100% (88.4–100.0%)	96.8% (83.3–99.9%)	100% (88.4–100.0%)	100% (88.4–100.0%)
NPV (95% CI)	100% (88.4–100.0%)	100% (88.1–100.0%)	100% (88.4–100.0%)	100% (88.4–100.0%)
Diagnostic accuracy	100.00%	98.33%	100.00%	100.00%

Abbreviations: AUC, area under the curve; CI, confidence interval; kPa, kilopascals; NPV, negative predictive value; PPV, positive predictive value.

Table 7 Receiver operating characteristic curve of E mean (kPa) for predicting preeclampsia

Variables	Right 1/4 E mean (kPa)	Central E mean (kPa)	Left (1/4) E mean (kPa)	Average of E mean (kPa)
Area under the ROC curve (AUC)	0.988	0.995	1	0.999
Standard error	0.0126	0.00544	0	0.00157
95% confidence interval	0.963 to 1.000	0.984 to 1.000	1.000 to 1.000	0.996 to 1.000
p-Value	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Cutoff	> 6.81	> 7.4	> 6.63	> 8.1
Sensitivity (95% CI)	100% (88.4–100.0%)	100% (88.4–100.0%)	100% (88.4–100.0%)	100% (88.4–100.0%)
Specificity (95% CI)	96.67% (82.8–99.9%)	96.67% (82.8–99.9%)	100% (88.4–100.0%)	96.67% (82.8–99.9%)
PPV (95% CI)	96.8% (83.3–99.9%)	96.8% (83.3–99.9%)	100% (88.4–100.0%)	96.8% (83.3–99.9%)
NPV (95% CI)	100% (88.1–100.0%)	100% (88.1–100.0%)	100% (88.4–100.0%)	100% (88.1–100.0%)
Diagnostic accuracy	98.33%	98.33%	100.00%	98.33%

Abbreviations: AUC, area under the curve; CI, confidence interval; kPa, kilopascals; NPV, negative predictive value; PPV, positive predictive value.

Table 8 Comparison of outcome between study and control group

Outcome	Study group (n = 30)	Control group (n = 30)	Total	p-Value
Hospital stays				
No	14 (46.67%)	29 (96.67%)	43 (71.67%)	< 0.0001 ^a
Yes	16 (53.33%)	1 (3.33%)	17 (28.33%)	
Birth weight (kg)				
Mean ± SD	2.29 ± 0.29	3.16 ± 0.19	2.73 ± 0.5	< 0.0001 ^b
Median (25th–75th percentile)	2.3 (2.1–2.5)	3.15 (3–3.29)	2.82 (2.3–3.145)	
Range	1.7–2.9	2.8–3.51	1.7–3.51	
Gestational age at the time of delivery (wk)				
Mean ± SD	34.29 ± 1.7	38.34 ± 1.07	36.32 ± 2.48	< 0.0001 ^b
Median (25th–75th percentile)	34.33 (33.167–35.583)	38.33 (37.667–38.958)	36.75 (34.333–38.333)	
Range	30.5–37.5	36.33–40.67	30.5–40.67	

Abbreviation: SD, standard deviation.

^aFisher's exact test.

^bIndependent t-test.

98.33% in the center region of the placenta and 100% at the edge, with a sensitivity of 100% (88–100) and specificity of 96.67%. No statistically significant difference was observed between AUCs of the average of E max and E mean values for predicting PE.

The present study also compared the perinatal outcome between the study and control groups. Subjects with PE had a mean gestational age of 34.29 ± 1.7 weeks at the time of delivery, while individuals without PE delivered at a normal mean gestational age of 38.34 ± 1.07 weeks (*p*-value < 0.001). Similar study conducted by Akbas et al¹⁵ in 2019, reported that women with PE delivered at an average gestational age of 36.73 ± 2.26 weeks, while the control group had a mean gestational age of 38.2 ± 1.94 weeks at delivery. The control group had a mean birth weight of 3.16 ± 0.19 kg compared

with 2.29 ± 0.29 kg in the preeclamptic group (*p*-value < 0.0001). A similar study by Xiong et al¹ in 2002 reported a significant reduction in birth weight among infants born to mothers with PE. Furthermore, infants in the preeclamptic group showed higher rates of hospital admissions after delivery and these variations were statistically significant. About 53.33% of babies born to the preeclamptic group required long-term hospital admissions following delivery, compared with only 3.33% in the control group babies.

To the best of our knowledge, only two studies, namely, Kılıç et al¹⁶ and Spiliopoulos et al,¹³ have utilized two-dimensional (2D) SWE using color-coded box to measure placental elasticity. In 2015, Kılıç et al¹⁶ conducted a similar study involving 50 participants (23 healthy and 27 with PE) reporting a cutoff for the average of E mean of 7.35 kPa with

diagnostic accuracy of 88%, sensitivity of 86%, and specificity of 82%. The cutoff value in our study was comparable to that reported by Kılıç et al.¹⁶ In 2020, Spiliopoulos et al¹³ conducted a 2D SWE study involving 47 participants (24 healthy and 23 with PE). The cutoff value reported was 16.3 kPa, with a sensitivity of 75% and specificity of 83%. This cutoff value was higher than that observed in our study. A likely reason for this difference is the inclusion of 12 patients with severe PE among the 23 preeclamptic cases in their study. In contrast, our study included only a few cases of severe PE.

Our study suggests that shear wave elasticity could be a valuable noninvasive tool for predicting PE in high-risk pregnancies.

Strength of our study: Measurements were taken not only from a single region of the placenta but from both the center and the periphery. This approach ensured a comprehensive assessment of placental stiffness while minimizing sampling bias. Additionally, we used 2D SWE for measurements; unlike other studies that utilized point SWE for measurement of placental stiffness.

Limitation of our study: The pregnant women with a posteriorly positioned placenta were excluded due to limitation of SWE measurements, which are restricted to a maximum depth of 8 cm. Besides, the influence of maternal abdominal thickness on SWE readings was not evaluated. Moreover, we were not able to assess the correlation between placental elasticity value and the severity of PE.

Conclusion

Preeclamptic pregnancies exhibit significant variations in placental elasticity, with both maximum and mean shear wave modulus values being notably higher compared with healthy controls. Real-time SWE could potentially detect structural changes in the placenta before clinical signs of PE appear, enabling early intervention and improved maternal and fetal outcomes. Integrating elastography with other parameters, such as uterine artery Doppler, serum levels of activin A and inhibin A, and maternal risk factors, could significantly enhance the early detection and management of PE, ultimately improving outcomes for both mother and child.

Conflict of Interest

None declared.

References

- Xiong X, Buekens P, Pridjian G, Fraser WD. Pregnancy-induced hypertension and perinatal mortality. *J Reprod Med* 2007;52(05):402–406[Internet]
- Dhinwa M, Gawande K, Jha N, Anjali M, Bhadoria AS, Sinha S. Prevalence of hypertensive disorders of pregnancy in India a systematic review and meta-analysis. *J Med Evid* 2021;2(02):105–112
- Harmon QE, Huang L, Umbach DM, et al. Risk of fetal death with preeclampsia. *Obstet Gynecol* 2015;125(03):628–635
- Conde-Agudelo A, Romero R, Roberts JM. Tests to predict preeclampsia. In: Chesley's Hypertensive Disorders in Pregnancy. Elsevier; 189–211
- Clossen JS, Morris RK, ter Riet G, et al. Use of uterine artery Doppler ultrasonography to predict pre-eclampsia and intrauterine growth restriction: a systematic review and bivariable meta-analysis. *CMAJ* 2008;178(06):701–711
- Espinoza J. Recent biomarkers for the identification of patients at risk for preeclampsia: the role of uteroplacental ischemia. *Expert Opin Med Diagn* 2012;6(02):121–130
- Soma H, Yoshida K, Mukaida T, Tabuchi Y. Morphologic changes in the hypertensive placenta. *Contrib Gynecol Obstet* 1982;9:58–75
- Wright D, Syngelaki A, Akolekar R. Competing risks model in screening for preeclampsia by maternal characteristics and medical history. *Am J Obstet Gynecol* 2015;213:e62–e63
- O'Gorman N, Wright D, Syngelaki A, et al. Competing risks model in screening for preeclampsia by maternal factors and biomarkers at 11–13 weeks gestation. *Am J Obstet Gynecol* 2016;214(01):103.e1–103.e12
- Cimsit C, Yoldemir T, Akpınar İN. Shear wave elastography in placental dysfunction: comparison of elasticity values in normal and preeclamptic pregnancies in the second trimester. *J Ultrasound Med* 2015;34(01):151–159
- DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics* 1988;44(03):837–45
- Meena R, Malik A, Jain S, Batra A. Placental elastography in second trimester preeclampsia prediction: a prospective study. *Ultrasound* 2022;30(03):228–235
- Spiliopoulos M, Kuo C-Y, Eranki A, et al. Characterizing placental stiffness using ultrasound shear-wave elastography in healthy and preeclamptic pregnancies. *Arch Gynecol Obstet* 2020;302(05):1103–1112[Internet]
- Fujita Y, Nakanishi TO, Sugitani M, Kato K. Placental elasticity as a new non-invasive predictive marker of pre-eclampsia. *Ultrasound Med Biol* 2019;45(01):93–97
- Akbas M, Koyuncu FM, Artunç-Ulkumen B. Placental elasticity assessment by point shear wave elastography in pregnancies with intrauterine growth restriction. *J Perinat Med* 2019;47(08):841–846
- Kılıç F, Kayadibi Y, Yüksel MA, et al. Shear wave elastography of placenta: in vivo quantitation of placental elasticity in preeclampsia. *Diagn Interv Radiol* 2015;21(03):202–207