International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Placental Acoustic Radiation Force Impulse (ARFI) Elastography in Prediction of Pre Eclampsia in High-Risk Pregnancy Patients

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Abstract: ***Background: Pre-eclampsia (PE) is a significant hypertensive disorder of pregnancy, posing risks to maternal and fetal health. Early prediction remains a challenge, especially in high-risk pregnancies. Acoustic Radiation Force Impulse (ARFI) elastography has emerged as a non-invasive method to assess placental stiffness, potentially offering an early marker for PE. Objective: This study aimed to evaluate the role of ARFI elastography in predicting pre-eclampsia in high-risk pregnancies by assessing placental stiffness through shear wave velocity (SWV). Methods: A prospective observational study was conducted at Silchar Medical College and Hospital, Assam, involving 53 high-risk pregnant women. SWV measurements were taken at two gestational intervals (18-22 weeks and 34-36 weeks) using ARFI elastography. Participants were divided into two groups: those who developed pre-eclampsia (Group B) and those who did not (Group A). Data were analyzed using SPSS, and diagnostic accuracy was assessed using ROC curves. Results: Significantly higher SWV values were found in Group B at both gestational intervals (18-22 weeks: $p < 0.001$; 34-36 weeks: $p < 0.01$). At 18-22 weeks, the SWV cutoff of 1.07 m/s demonstrated 88.9% sensitivity and 90.9% specificity. The progression of SWV values from early to late gestation in Group B indicated worsening placental stiffness with disease advancement. Conclusion: ARFI elastography is a reliable, non-invasive technique for early prediction of pre-eclampsia, offering high sensitivity and specificity. Its ability to detect increased placental stiffness supports its potential as a screening tool, particularly in high-risk pregnancies, enhancing early diagnosis and management.***

Keywords: Pre-eclampsia, ARFI elastography, Placental stiffness

1. Introduction

Pre-eclampsia (PE) is a serious hypertensive disorder of pregnancy, contributing significantly to maternal and perinatal morbidity and mortality, especially in developing nations such as India. It arises after 20 weeks of gestation and is often linked to abnormal placentation. Conventional diagnostic methods like blood pressure monitoring and Doppler ultrasound offer indirect assessment, often detecting the disease only after clinical symptoms appear. There is a pressing need for non-invasive, early-predictive tools, especially in high-risk pregnancies, which include women with a history of hypertension, diabetes, renal disorders, or autoimmune diseases.

Acoustic Radiation Force Impulse (ARFI) elastography is a promising technique that assesses tissue stiffness by measuring shear wave velocity (SWV). When applied to the placenta, it can help quantify placental elasticity a property that may change early in pregnancies complicated by PE. Stiffer placentas show higher SWV values, suggesting underlying structural or vascular abnormalities.

A recent Indian study conducted by Elango et al. assessed placental SWV in 30 pre-eclamptic and 30 healthy pregnant women. The mean SWV was significantly higher in the PE group (1.99 m/s vs. 0.99 m/s), and a threshold of 1.325 m/s provided high sensitivity and specificity in detecting PE, making ARFI a strong candidate for routine screening in high-risk pregnancies [1].

Alan et al. conducted a prospective study involving 86 women and found that SWV values were significantly elevated in both mild and severe PE compared to normotensive controls. The SWV also correlated with disease severity, providing diagnostic as well as prognostic utility [2]. This ability to stratify disease severity adds an important clinical dimension to ARFI imaging.

Similarly, Hefeda and Zakaria reported that in high-risk pregnancies including those complicated by hypertension, diabetes, and renal disease—SWV values were notably higher than in normal pregnancies. Their study confirmed that placental stiffness increases significantly in PE, with mean values rising above 2.1 m/s in the second and third trimesters [3]. Yuan et al. carried out a large-scale study in China comparing placental SWV across 487 normal pregnancies and 51 with severe PE. They observed that while gestational age had minimal effect on placental stiffness in healthy cases, significant elevations in SWV occurred in pre-eclamptic placentas, with strong correlation to pathological changes [4].

Complementing these findings, a study by Çim et al. explored the use of ARFI elastography to predict placental invasion anomalies. Though their focus was different, they found that elevated placental SWV consistently corresponded with tissue-level abnormalities, underlining the broader diagnostic sensitivity of ARFI for placental pathology [5].

Yeh et al. discussed ARFI's potential in obstetrics, noting that placental stiffness assessed by this method correlates strongly with hypertensive disorders like PE. They suggested that, unlike grayscale ultrasound and Doppler indices, ARFI provides direct insight into placental biomechanical properties [6]. In a recent paper, Tian et al. evaluated the combination of ARFI-derived elastography with three-dimensional power Doppler indices. This multi-parametric approach improved predictive accuracy for PE, suggesting a future path where ARFI forms part of a larger diagnostic toolkit [7].

A study by Sugitani et al. examined ex vivo placental stiffness in fetal growth restriction (FGR) and pregnancy-induced hypertension. The shear wave velocities were significantly higher in FGR cases, and SWV negatively correlated with fetal birthweight z-scores, suggesting clinical usefulness in predicting poor neonatal outcomes [8].

Another unique angle comes from maternal organ involvement. A study by Çetin et al. evaluated liver stiffness using ARFI in pre-eclamptic patients. They reported that both severe PE and HELLP syndrome were associated with significantly elevated liver SWV scores, pointing to the systemic nature of vascular stiffness in these conditions [9]. Finally, a descriptive study by Çetin et al. also investigated ARFI measurements in Rh-alloimmunized pregnancies. The study found increased placental stiffness in cases with hydrops fetalis, demonstrating that ARFI can be used across a variety of high-risk pregnancy conditions, further validating its reliability and versatility [10].

The growing body of evidence suggests that placental ARFI elastography is a powerful, non-invasive tool for early prediction of pre-eclampsia in high-risk pregnancies. By quantifying tissue stiffness through SWV, it offers a direct and sensitive measure of placental health, paving the way for earlier diagnosis, risk stratification, and improved clinical outcomes particularly in resource-constrained settings like India.,

This study aims to evaluate the role of Acoustic Radiation Force Impulse (ARFI) elastography in predicting pre-eclampsia in high-risk pregnancies by assessing placental stiffness through shear wave velocity, and to determine its diagnostic accuracy and clinical utility as a non-invasive screening tool.

2. Methodology

1) Study Design
This was a prospective observational study designed to evaluate the role of ARFI elastography in predicting pre-eclampsia among high-risk pregnant women by assessing placental stiffness over time.

2) Study Setting
The study was conducted in the Department of Radiodiagnosis at Silchar Medical College and Hospital, Assam, using a Samsung RS80A ultrasound system. It was done in collaboration with the Department of Obstetrics and Gynecology, which provided access to high-risk pregnancies.

3) Study Duration
The study was carried out over 12 months. Participants were evaluated at two gestational intervals 18 to 22 weeks and 34 to 36 weeks—and followed through to delivery for outcome assessment.

4) Participants – Inclusion & Exclusion Criteria
Eligible participants were women with singleton pregnancies at 18–22 weeks who had risk factors for pre-eclampsia such as primiparity, high BMI, or diabetes. Exclusion criteria included posterior placenta, multiple gestation, fetal anomalies, and missed follow-up.

5) Study Sampling
Convenience sampling was used. High-risk pregnant women attending the antenatal clinic were identified and enrolled after providing written informed consent.

6) Study Sample Size
Fifty-nine women were initially enrolled, but six were excluded due to incomplete follow-up, leaving a final sample size of 53 for analysis.

7) Study Groups
Participants were divided into two groups: those who developed pre-eclampsia (Group B) and those who did not (Group A), based on clinical outcomes at delivery.

8) Study Parameters
Parameters included fetal biometry, placental thickness and texture, and shear wave velocity (SWV) measurements at central and peripheral placental regions using ARFI elastography.

9) Study Procedure
After enrollment, participants underwent ultrasound and ARFI elastography at two time points. SWV was recorded at both placental regions, and follow-up data were collected until delivery.

10) Study Data Collection
Clinical data (e.g., maternal age, risk factors) and ultrasound findings were recorded. Six SWV readings per placental site were taken, and delivery outcomes were documented.

11) Data Analysis
Data were analyzed using SPSS v25. Group comparisons used t-tests and Chi-square tests. ROC curves were generated to assess the diagnostic value of SWV.

12) Ethical Considerations
The study was approved by the Institutional Ethics Committee of SMCH. Written informed consent was obtained, and participant privacy and safety were ensured throughout.

3. Results

1) Age Distribution of Study Subjects
Most patients in Group A were between 21–30 years (80%), while Group B had a higher proportion of women aged ≥26 years. Age did not show a strong correlation with pre-eclampsia risk (Table 1).

Table 1: Age Distribution of Study Subjects

Age	Group A		Group B		Total	
	No. of patients	%	No. of patients	%	No. of patients	%
≤20	3	6.8	1	11.1	4	7.5
21≤25	20	45.4	2	22.2	22	41.5
26≤30	15	34.2	3	33.3	18	33.9
≥31	6	13.6	3	33.3	9	16.9
Total	44	100	9	100	53	100

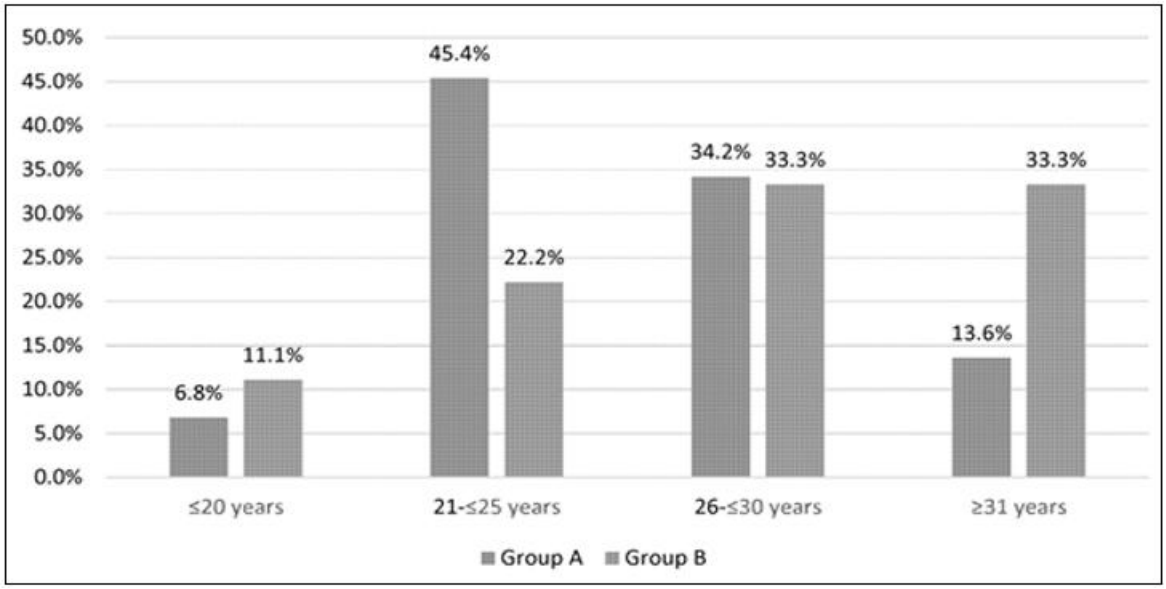

Figure 1: Age distribution of study subjects (n=53)

2) Gravidity of Study Subjects

Primigravida status was common in both groups; however, multigravida women had a higher proportion of pre-eclampsia cases (26.3%) (Table 2).

Table 2: Gravidity of Study Subjects

Gravida	Group A		Group B		Total	
	No. of patients	%	No. of patients	%	No. of patients	%
Primigravida	30	68.2	4	44.4	34	64.1
Multigravida	14	31.8	5	55.5	19	35.9
Total	44	100	9	100	53	100

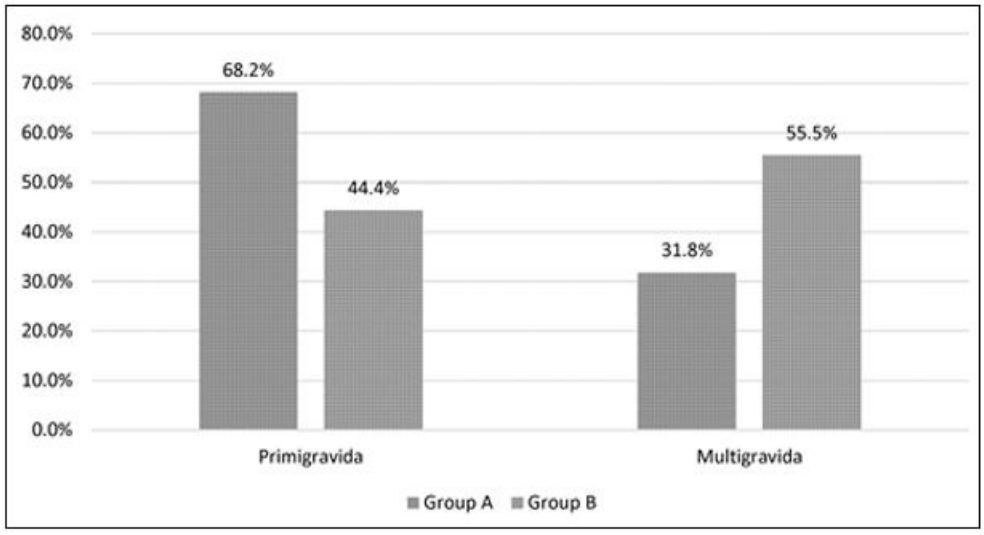

Figure 2: Gravidity of the study subjects

3) Risk Factor Distribution Among Groups

History of pre-eclampsia was a strong predictor, with 42.8% recurrence rate. Primigravida and high BP showed moderate risk (Table 3).

Table 3: Risk Factor Distribution Among Groups

Risk factors	Group A (n=44)		Group B (n=9)		Percentage of patients who developed pre-eclampsia
	No. of patients	%	No. of patients	%	%
Primigravida	20	45.4	3	33.3	13.0%
BP > 130/80 mm	9	20.4	2	22.2	18.1%
Past h/o pre-eclampsia	4	9.0	3	33.3	42.8%
Family h/o pre-eclampsia	2	4.5	0	0	0%
Pre-gestational Diabetes	6	13.6	0	0	0%
BMI > 25	3	6.8	1	11.1	25%

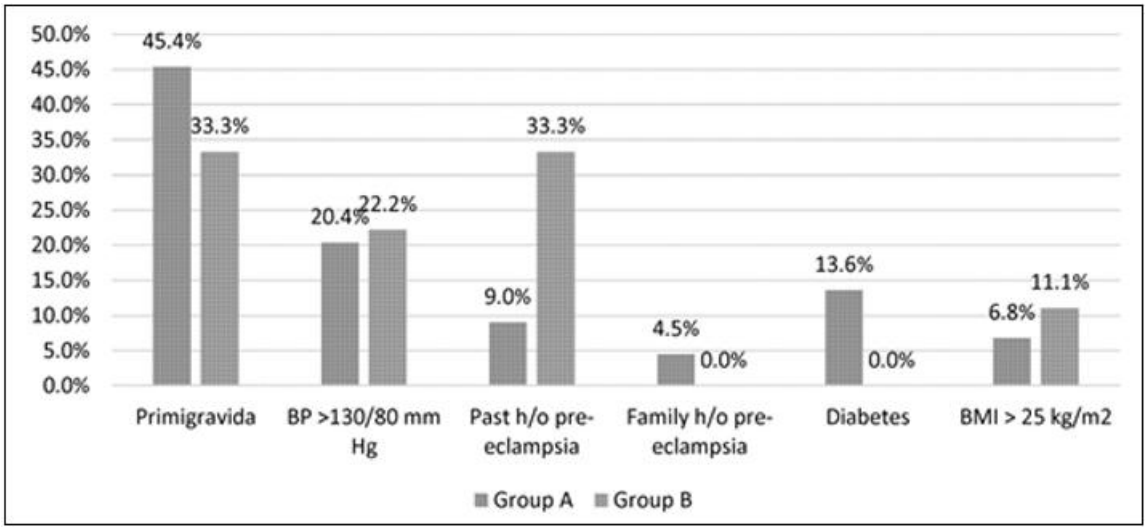

Figure 3: Distribution of various risk factors in the patients enrolled in the study

4) SWV Comparison Between Groups at 18–22 Weeks

Mean SWV was significantly higher in Group B across all regions, indicating early placental stiffness in pre-eclampsia (Table 4).

Table 4: SWV Comparison Between Groups at 18–22 Weeks

SWV (m/s)	Mean/Median	Group A (n=44)	Group B (n=9)	p value
Central SWV	Mean	0.87±0.19	1.23±0.18	<0.001
	Median (IQR)	0.82 (0.76-0.93)	1.19 (1.13-1.40)	
Peripheral SWV	Mean	0.88±0.20	1.18±0.19	<0.001
	Median (IQR)	0.84 (0.4-0.95)	1.19 (1.04-1.38)	
Total SWV	Mean	0.88±0.18	1.21±0.16	<0.001
	Median (IQR)	0.81 (0.78-0.91)	1.21 (1.10-1.35)	

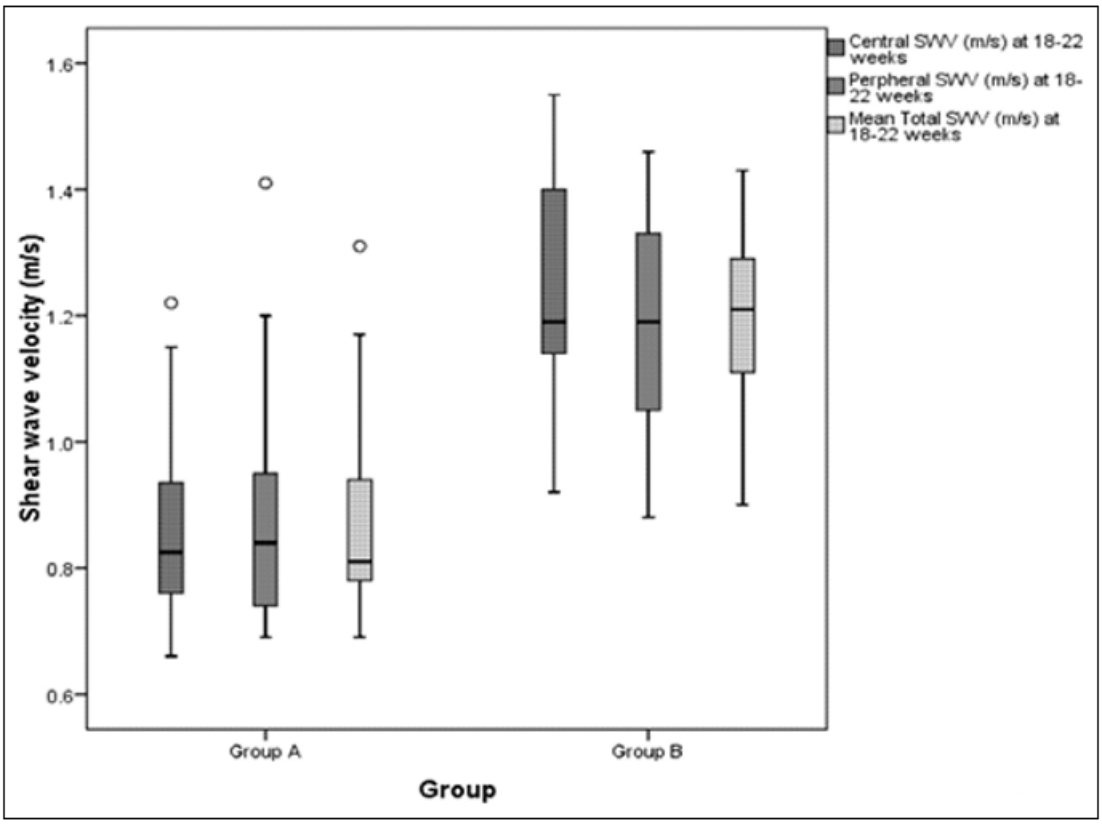

Figure 4: Boxplot showing comparison of the shear wave velocity at first ultrasound (18-22 weeks) between Group A and Group B

5) SWV Comparison at 34–36 Weeks

At follow-up, Group B continued to show significantly higher SWV values, confirming worsening placental stiffness with disease progression (Table 5).

Table 5: SWV Comparison at 34–36 Weeks

SWV (m/s)	Mean/Median	Group A (n=44)	Group B (n=9)	p value
Central	Mean	1.03±0.31	1.93±0.99	<0.01
	Median (IQR)	0.94 (0.84-1.10)	1.88 (1.11-2.77)	
Peripheral	Mean	1.01±0.21	1.91±0.98	<0.01
	Median (IQR)	0.96 (0.87-1.11)	1.49 (1.26-2.77)	
Total	Mean	1.01±0.24	1.92±0.95	<0.01
	Median (IQR)	0.94 (0.86-1.11)	1.69 (1.21-2.77)	

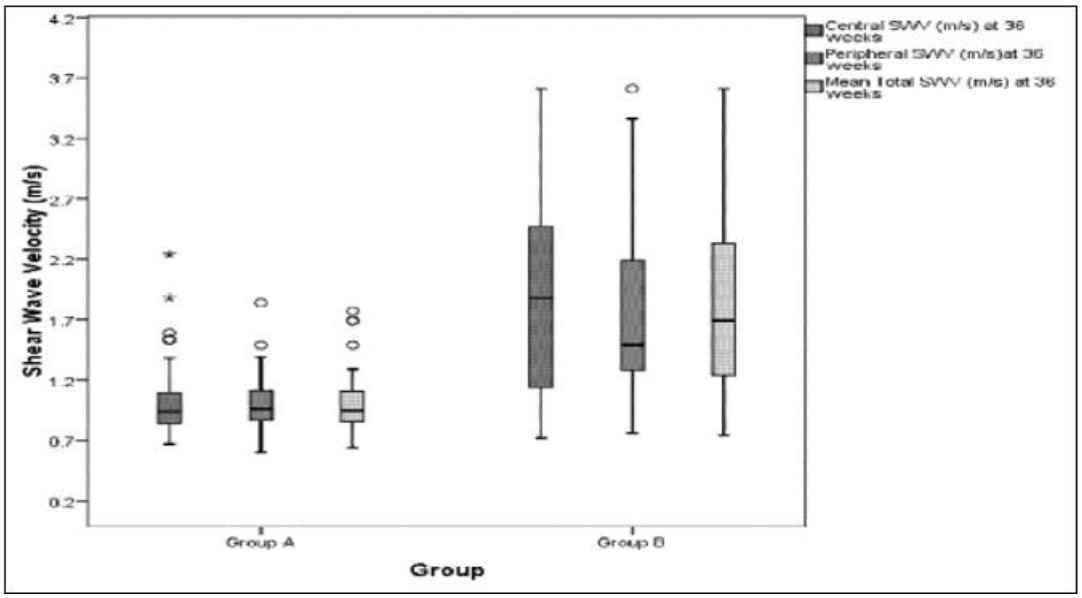

Figure 5: Boxplot showing comparison of the shear wave velocity at second ultrasound (34-36 weeks) between Group A and Group B

6) SWV Progression in Group B

In pre-eclamptic patients, SWV significantly increased from early to late gestation, supporting its role as a progressive biomarker (Table 6).

Table 6: SWV Progression in Group B

SWV (m/s)	Mean/Median	18-22 weeks	34-36 weeks	p value
Central	Mean	1.23±0.18	1.93±0.99	<0.001
	Median (IQR)	1.19 (1.13-1.40)	1.88 (1.11-2.77)	
Peripheral	Mean	1.18±0.19	1.91±0.98	<0.001
	Median (IQR)	1.19 (1.04-1.38)	1.49 (1.26-2.77)	
Total	Mean	1.21±0.16	1.92±0.95	<0.001
	Median (IQR)	1.21 (1.10-1.35)	1.69 (1.21-2.77)	

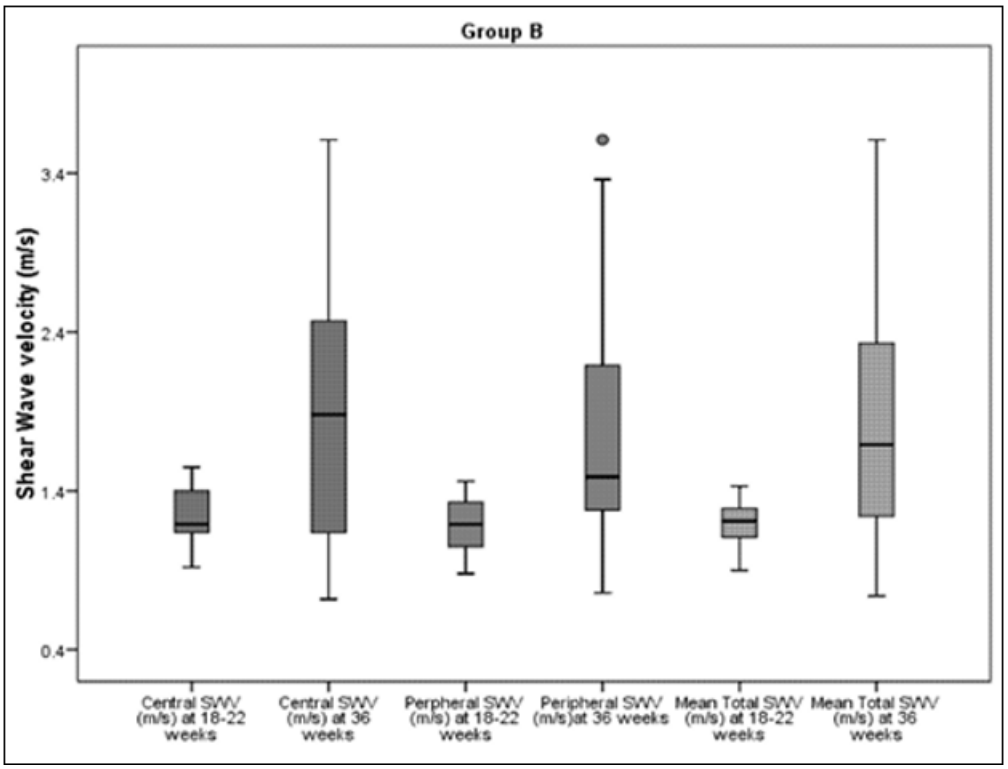

Figure 6: Boxplot showing comparison of Mean shear wave velocity at 18-22 weeks & 34-36 weeks in Group B (n=9)

7) Diagnostic Accuracy of SWV (ROC Analysis)

SWV showed high sensitivity and specificity for predicting pre-eclampsia at both time points, with AUC values of 0.92 and 0.84 (Table 7).

Table 7: Diagnostic Accuracy of SWV (ROC Analysis)

Cut off SWV	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Accuracy (95% CI)
At 18-22 weeks	88.9%	90.9%	66.7%	97.6%	90.6%
	(51.7-99.7)	(78.3-97.4)	(43.3-83.9)	(83.3-99.6)	(79.3-96.9)
At 34-36 weeks	88.9%	86.4%	57.1%	97.4%	86.8%
	(51.7-99.7)	(72.6-94.8)	(37.9-74.4)	(85.6-99.6)	(74.7-94.5)

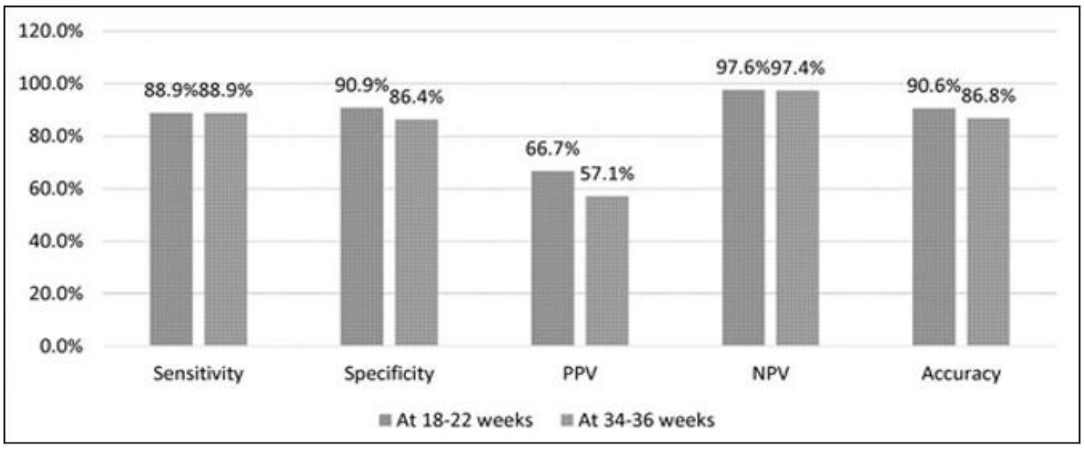

Figure 7: Sensitivity, specificity, PPV, NPV and Diagnostic Accuracy of SWV in differentiating pre-eclampsia from normal study subjects

4. Discussion

This study evaluated the utility of Acoustic Radiation Force Impulse (ARFI) elastography for predicting pre-eclampsia in high-risk pregnancies by assessing placental stiffness through shear wave velocity (SWV). The findings demonstrated significantly higher SWV values in women who developed pre-eclampsia, both in early (18–22 weeks) and late gestation (34–36 weeks), compared to those who did not, supporting the role of placental stiffness as a predictive biomarker.

These results align with several previous studies that have reported increased placental stiffness in pre-eclampsia cases. For example, Manganaro et al. (2018) found significantly elevated SWV values in the placentas of women with pre-eclampsia and suggested that ARFI elastography could non-invasively detect these changes [11]. Similarly, Hwang et al. (2016) showed that placental SWV increases in the third trimester, especially in abnormal pregnancies, and proposed SWV measurement as a useful adjunct to routine ultrasound [12].

In our study, the SWV cutoff at 18–22 weeks (1.07 m/s) showed 88.9% sensitivity and 90.9% specificity, with an AUC of 0.92. This is comparable to the diagnostic accuracy reported by Zimerman et al. (2022), who found that higher SWV in the second trimester could predict hypertensive disorders with strong diagnostic accuracy [13]. Furthermore, our study showed a progressive increase in SWV values from the second to third trimester in pre-eclamptic patients, indicating disease advancement. This is supported by Ahmadi et al. (2022), who demonstrated rising stiffness in cases with worsening placental pathology [14].
However, unlike Hwang et al. (2016), we found that multigravida women in our sample had a slightly higher rate of pre-eclampsia, possibly due to a smaller cohort size and referral bias [12]. Also, our study did not find statistically significant differences in placental thickness or amniotic fluid index, which contrasts with findings by Manganaro et al. (2018), suggesting that elastography may be more sensitive than conventional B-mode parameters [11].

Our study reinforces the evidence that ARFI elastography is a promising, non-invasive tool for early prediction of pre-eclampsia, particularly in high-risk pregnancies, and aligns with international findings supporting its diagnostic utility.

5. Conclusion

This study demonstrates that Acoustic Radiation Force Impulse (ARFI) elastography is a promising, non-invasive tool for early prediction of pre-eclampsia in high-risk pregnancies. Significantly higher shear wave velocities (SWV) in pre-eclamptic cases at both early and late gestational stages support the use of ARFI in identifying placental stiffness. The technique shows high sensitivity, specificity, and diagnostic accuracy, offering a potential adjunct to routine screening, particularly in resource-limited settings, for improved maternal and fetal outcomes.

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