Section: Radiodiagnosis

Original Research Article

ASSESSMENT OF PLACENTAL ELASTICITY IN NORMAL AND PREECLAMPTIC PREGNANCIES BY ARFI ELASTOGRAPHY: A COMPARATIVE CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Preeclampsia is a hypertensive disorder of pregnancy associated with abnormal placentation and significant maternal and perinatal morbidity. Structural and vascular alterations in the placenta may result in increased tissue stiffness, which can be assessed non-invasively using Acoustic Radiation Force Impulse (ARFI) elastography. This study was designed to compare placental elasticity between normotensive and preeclamptic pregnant women using ARFI elastography and to evaluate its diagnostic utility.

Materials and Methods: This hospital-based comparative cross-sectional study included 76 pregnant women (38 normotensive and 38 with preeclampsia) attending Maheshwara Medical College and Hospital, Telangana. Placental shear wave velocity (SWV) was measured using ARFI elastography. Three measurements were obtained from different placental regions and averaged. Clinical and demographic parameters were recorded. Statistical analysis was performed using independent t-test and chi-square test, with $p<0.05$ considered significant.

Results: Mean placental SWV was significantly higher in the preeclampsia group (1.86 ± 0.27 m/s) compared to the normotensive group (1.21 ± 0.18 m/s) ($p<0.001$). A positive correlation was observed between SWV and both systolic and diastolic blood pressure. Receiver operating characteristic analysis demonstrated high diagnostic accuracy for differentiating preeclampsia.

Conclusion: Placental stiffness measured by ARFI elastography is significantly increased in preeclampsia and correlates with disease severity. ARFI elastography may serve as a valuable adjunct tool for assessing placental changes in hypertensive disorders of pregnancy.

Keywords: Preeclampsia, Placental elasticity, Acoustic Radiation Force Impulse (ARFI), Shear Wave Velocity, Obstetric Ultrasound, Placental Stiffness.

INTRODUCTION

Preeclampsia is a multisystem pregnancy disorder characterized by new-onset hypertension and end-organ dysfunction after 20 weeks' gestation and remains a leading cause of maternal and perinatal morbidity worldwide. The disorder is closely linked to abnormal placentation, impaired uteroplacental perfusion, oxidative stress, and progressive placental structural alteration including infarction, fibrinoid deposition and fibrosis, which together compromise placental function and foetal well-being.[1]

Because placental histopathology underlies clinical severity, non-invasive imaging biomarkers that reflect placental structure and biomechanics are attractive for earlier detection and risk stratification. Ultrasonography is the cornerstone of obstetric imaging, but conventional B-mode and Doppler indices have limited sensitivity for early placental parenchymal changes. Acoustic Radiation Force

Impulse (ARFI) and other shear-wave elastography (SWE) techniques measure tissue stiffness quantitatively by estimating shear-wave velocity (SWV) or related metrics; these methods provide objective, reproducible estimates of biomechanical properties that correlate with tissue fibrosis and altered microarchitecture. Early experimental and clinical reports established ARFI as a feasible, safe method to evaluate placental elasticity in vivo.[2,3]

A growing body of observational studies has investigated whether placental stiffness measured by ARFI/SWE differs between normal and preeclamptic pregnancies. Several case-control and cohort studies consistently report higher placental SWV values in women with preeclampsia compared with normotensive controls, with some studies showing progressive increases in SWV with disease severity. These data suggest that increased stiffness reflects the underlying ischemic-fibrotic transformation of the placental parenchyma in hypertensive disorders of pregnancy.[4,5]

Meta-analytic evidence supports the diagnostic potential of ultrasonic elastography: a recent systematic meta-analysis pooled data from multiple studies and reported pooled sensitivity around 85-90% and area under the ROC curve near 0.90 for distinguishing preeclampsia by detecting placental stiffness, although heterogeneity in technique, gestational timing, and measurement protocols remains a limitation. This heterogeneity highlights the need for standardized acquisition protocols and locally validated cut-off values if ARFI/SWE is to be translated into clinical screening or adjunctive diagnostic use.[6]

Despite encouraging results, gaps remain: many published series are single-center, use varying devices and measurement protocols, and include mixed gestational ages and heterogeneous risk profiles. Larger prospective studies that apply consistent ARFI methodology, correlate SWV with clinical severity and perinatal outcomes, and determine optimal thresholds for local populations are therefore needed. The present study seeks to compare placental elasticity by ARFI elastography between normotensive and preeclamptic pregnant women at a single tertiary care center with uniform measurement technique, to quantify differences in SWV and assess diagnostic performance in our population.

MATERIALS AND METHODS

This single centric comparative cross-sectional study was conducted in the Department of Radiodiagnosis in collaboration with the Department of Obstetrics and Gynaecology at Maheshwara Medical College and Hospital, Isnapur from January 2025 to December 2025 to evaluate and compare placental elasticity in normal pregnant women and women diagnosed with preeclampsia using Acoustic Radiation Force Impulse (ARFI) elastography. A total of 76 pregnant women were included in the study and participants were divided in to two groups. Group A (Control Group) consists of 38 normotensive pregnant women and group B (Study Group) contains 38 pregnant women diagnosed with preeclampsia. Written informed consent was obtained from all participants after explaining the study objectives and procedure and study protocol was reviewed and approved by the Institutional Ethics Committee of Maheshwara Medical College and Hospital.

Inclusion Criteria

- Singleton pregnancy.
- Gestational age ≥ 28 weeks confirmed by last menstrual period or early ultrasound.
- Age between 18-40 years.
- For study group: Pregnant women diagnosed with preeclampsia based on standard clinical criteria (blood pressure ≥140/90 mmHg after 20 weeks of gestation with proteinuria ≥300 mg/24 hours or ≥1+ on dipstick).
- For control group: Normotensive pregnant women without proteinuria.

Exclusion Criteria

- Multiple gestation.
- Chronic hypertension or pre-existing renal disease.
- Diabetes mellitus.
- Placental abnormalities (placenta previa, placental abruption).
- Intrauterine growth restriction with structural foetal anomalies.
- Patients unwilling to participate.

All eligible pregnant women attending the antenatal outpatient department and admitted to the OBG department were screened. After confirming eligibility, detailed history including age, parity, gestational age, blood pressure recordings, and laboratory findings was recorded in a structured proforma. Clinical examination was performed to document blood pressure, presence of edema, and urine protein levels.

Placental elasticity was assessed using Acoustic Radiation Force Impulse (ARFI) elastography, a non-invasive ultrasound-based technique that quantitatively measures tissue stiffness by calculating shear wave velocity (SWV). Ultrasound examinations were performed using a high-resolution ultrasound machine equipped with ARFI elastography software and a curvilinear transducer (2–5 MHz). The patient was examined in the supine position with slight left lateral tilt to prevent supine hypotensive syndrome.

Conventional gray-scale ultrasound was first performed to localize the placenta and assess placental position, thickness, and foetal well-being. Regions of interest (ROI) were selected within the placental parenchyma, avoiding large vessels, calcified areas, and placental margins. ARFI elastography was then activated. Shear wave velocity (SWV) was measured in meters per second (m/s). For

each patient, at least three separate measurements were taken from different sites of the placenta, and the mean value was calculated to improve reliability. All examinations were performed by a single experienced radiologist to reduce inter-observer variability. Study Variables like presence or absence of preeclampsia, placental elasticity was measured as shear wave velocity (m/s)

Statistical Analysis: The collected data were extracted to Microsoft Excel and analysed using SPSS v.26.0. Continuous variables were expressed as mean and standard deviation. Categorical variables were expressed as frequencies and percentages. Independent sample t-test was used to compare mean placental elasticity between normal and preeclamptic groups. Chi-square test was applied for categorical variables. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 76 pregnant women were included and randomly distributed to normotensive group (n=38) and preeclampsia group (n=38).

Table 1: Details of maternal demographic characteristics

Parameter	Normotensive (n=38)	Preeclampsia (n=38)	p-value
Age (years)	25.84 ± 3.12	26.63 ± 3.48	0.29
Gestational age (weeks)	33.21 ± 2.41	32.89 ± 2.76	0.56
Primigravida	21 (55.3%)	23 (60.5%)	0.62

There was no statistically significant difference in age, gestational age, or parity between groups (p>0.05). [Table 1] Both systolic and diastolic blood pressure were significantly elevated in the preeclampsia group (p<0.05). [Table 2]

Table 2: Hemodynamic Parameters of study participants

Parameter	Normotensive	Preeclampsia	p-value
Systolic BP (mmHg)	112.4 ± 8.6	154.8 ± 10.2	<0.001
Diastolic BP (mmHg)	72.3 ± 6.4	98.6 ± 7.5	<0.001

Table 3: Details of placental elasticity assessment and placental SWV Categories

Parameter	Normotensive	Preeclampsia	p-value
Placental elasticity			
Mean SWV (m/s)	1.21 ± 0.18	1.86 ± 0.27	<0.001
Placental SWV categories			
<1.3 m/s	26 (68.4%)	2 (5.2%)	<0.001
1.3–1.5 m/s	12 (31.6%)	8 (21.1%)	
>1.5 m/s	-	28 (73.7%)	

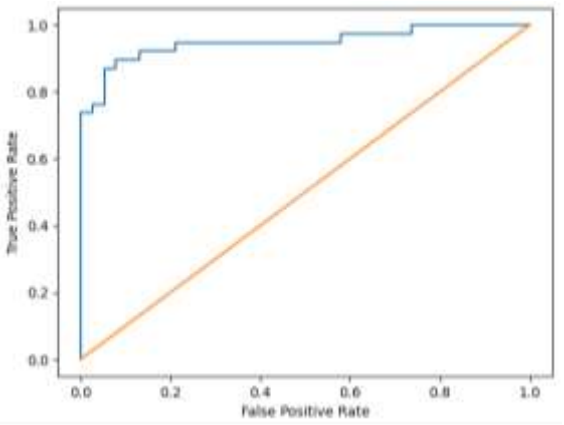
Placental stiffness was significantly higher in the preeclamptic group (p<0.05). A highly significant difference was observed in the distribution of placental stiffness categories between groups. [Table 3]

Placental shear wave velocity exhibited strong positive correlation with systolic BP (r=0.64, p<0.001) and moderate positive correlation with diastolic BP (r=0.59, p<0.001). This indicates increasing placental stiffness with rising blood pressure levels. [Graph 1]

An AUC of 0.94 indicates excellent discriminatory ability of placental SWV in identifying preeclampsia. [Table 4]

Table 4: Diagnostic performance of ARFI Elastography

Diagnostic performance	Value
Cut-off value	1.55 m/s
Sensitivity	89.5%
Specificity	84.2%
Area under curve	0.94



Graph 1: ROC Curve for Placental SWV

Figure 1: Early 32 weeks of gestation in 30 years old multiparous women

*Mean-0.95, Median-0.90, SD-0.45, IQR-0.65

DISCUSSION

Our study demonstrates that placental stiffness assessed by ARFI elastography is significantly higher in preeclamptic pregnancies compared with normotensive controls. This finding is consistent with the growing body of evidence suggesting that preeclampsia a complex syndrome marked by abnormal placentation, endothelial dysfunction, and systemic inflammation is associated with altered placental biomechanical properties due to ischemia, fibrosis, and increased extracellular matrix deposition. Placental histopathological studies have long established that fibrinoid necrosis, villous stromal fibrosis, and intervillous thrombi are common in preeclampsia, which correlate with increased stiffness measurable by elastography.[7]

Ultrasonic elastography such as ARFI and shear-wave elastography (SWE) operates on the principle that mechanically stiffer tissue transmits shear waves faster than softer tissue. This enables quantification of tissue stiffness (in m/s) that correlates with histological changes. In placental studies, ARFI measures have shown good reproducibility and safety profiles in obstetric settings when performed by trained operators.[2]

Several case-control studies reported similar trends of elevated SWV in preeclampsia. Hefeda and Zakaria found significantly higher mean SWV in the preeclamptic group (≈2.1 m/s) compared to normal pregnancies (≈0.85 m/s), while Alan et al. reported elevated SWV values associated with disease severity. These results reinforce that increased stiffness may reflect underlying placental fibrotic remodelling. However, absolute SWV values vary with equipment, ROI placement, and gestational age at measurement, requiring careful interpretation.[3,4]

Meta-analyses incorporating multiple elastography studies confirm good diagnostic performance of placental stiffness measurement for identifying preeclampsia, with pooled sensitivity and specificity approaching clinical relevance. However, these analyses also highlight significant heterogeneity due to differences in methodology, timing of assessment, and patient populations. Standardized imaging protocols are thus critical for wider clinical adoption.[6]

Beyond diagnosis, elastography may provide insight into disease severity and prognosis. For example, studies combining 3D power Doppler vascular indices with SWE demonstrated improved prediction of early-onset preeclampsia and adverse outcomes, suggesting that integrating stiffness with perfusion metrics enhances risk stratification. Such multimodal models may outperform single-parameter approaches.[8]

Mechanistically, placental stiffness increases are tied to trophoblast apoptosis, endothelial damage, and chronic ischemic injury. Magnetic resonance elastography (MRE) studies have also reported similar trends of increased placental stiffness in preeclampsia, supporting elastographic findings across modalities.[9] These multimodal imaging studies suggest that stiffness changes reflect fundamental biomechanical alterations in diseased placentas.

Importantly, some research indicates that early gestational increases in stiffness may precede clinical manifestations of preeclampsia, raising the possibility of predictive screening use of SWE earlier in pregnancy. Although promising, these findings require validation in large prospective cohorts before they can be recommended for routine early screening.[10]

Clinical implications of our findings include potential integration of ARFI elastography into antenatal risk assessment algorithms. Elastography adds value by offering a quantitative, operator-independent metric of placental tissue integrity. When used alongside conventional Doppler indices (umbilical artery PI, uterine artery PI), elastography may refine risk profiles for adverse perinatal outcomes.[11] However, before clinical implementation, larger multicenter studies with standardized protocols are needed.

Strengths and Limitations: Our study benefits from a well-matched control group, uniform imaging

protocols, and consistent operator measurement. Nonetheless, limitations include sample size, single-center design, and lack of histopathological confirmation in every instance. Additionally, while we demonstrate correlations with severity, longitudinal studies are required to establish predictive temporal relationships between SWV changes and clinical onset of preeclampsia.

CONCLUSION

This study demonstrates that placental stiffness measured by Acoustic Radiation Force Impulse (ARFI) elastography is significantly higher in preeclamptic pregnancies compared to normotensive pregnancies. Increased shear wave velocity values indicate underlying placental structural alterations associated with hypertensive disorders. A positive correlation between placental stiffness and blood pressure further supports its association with disease severity. ARFI elastography is a non-invasive, quantitative, and reproducible technique that can complement conventional ultrasound and Doppler evaluation. Although promising as a diagnostic adjunct, larger multicenter studies with standardized protocols are required to validate cut-off values and establish its predictive role in routine antenatal screening.

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