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Placental Stiffness as a Window to Fetoplacental Health: Elastographic Insights in High-Risk Pregnancy

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Abstract

Background: Placental dysfunction forms the pathological basis of several high-risk pregnancy conditions including pregnancy-induced hypertension (PIH), intrauterine growth restriction (IUGR), and post-dated pregnancy. Conventional ultrasound and Doppler studies provide indirect assessment of placental function and often detect abnormalities at a later stage. Placental elastography, by evaluating placental stiffness, offers a non-invasive method for direct assessment of placental tissue characteristics.

Objectives: To evaluate placental stiffness using elastography in pregnancies between 20 and 42 weeks of gestation, correlate elastographic findings with Doppler parameters, and assess the diagnostic performance of placental elastography.

Materials and Methods: A prospective observational study was conducted on 25 pregnant women between November 2025 and January 2026. Placental elastography findings were correlated with umbilical artery Doppler indices and cerebroplacental ratio. Statistical analysis included ANOVA, correlation analysis, and calculation of sensitivity and specificity.

Results: Placental stiffness was significantly higher in pregnancies complicated by PIH, IUGR, and post-dated gestation compared to normal pregnancies. Increased placental stiffness showed strong correlation with abnormal Doppler indices. Placental elastography

demonstrated high sensitivity and specificity for detecting Doppler-defined placental insufficiency.

Conclusion: Placental elastography is a sensitive and specific adjunct to Doppler ultrasound for evaluating fetoplacental health in high-risk pregnancies.

Keywords: Placental elastography, placental stiffness, PIH, IUGR, post-dated pregnancy, Doppler studies

Introduction

The placenta is a vital organ that facilitates maternal–fetal exchange of oxygen, nutrients, and metabolic waste, thereby ensuring normal fetal growth and development. Structural or functional placental abnormalities underlie several high-risk pregnancy conditions and significantly contribute to maternal and fetal morbidity.

Intrauterine growth restriction (IUGR) is defined as failure of the fetus to achieve its genetically determined growth potential and is primarily attributed to placental insufficiency[1]. Pregnancy-induced hypertension (PIH) is also characterized by abnormal placentation and impaired uteroplacental perfusion, resulting in placental ischemia and increased vascular resistance[2]. In post-dated pregnancies, placental senescence and progressive reduction in placental efficiency may compromise fetoplacental circulation.

Conventional obstetric ultrasound evaluates fetal biometry, amniotic fluid volume, and placental morphology, while Doppler velocimetry of uterine and fetal vessels provides indirect assessment of placental hemodynamics[3]. However, Doppler abnormalities often reflect late hemodynamic consequences rather than early placental pathology[4].

Placental elastography is an emerging ultrasound-based technique that evaluates tissue stiffness based on the principle that pathological tissues exhibit altered mechanical properties[5]. Placental ischemia, fibrosis, infarction, and calcification lead to increased placental stiffness, which can be quantified using elastography[6]. By directly assessing placental biomechanics, elastography provides a unique window into fetoplacental health and may complement Doppler studies in the evaluation of high-risk pregnancies.

Materials and Methods

Study Design and Setting

This prospective observational study was conducted in the Department of Obstetrics and Gynecology in collaboration with the Department of Radiology at a tertiary care teaching hospital.

Study Period

November 2025 to January 2026.

Study Population and Sample Size

A total of 25 pregnant women between 20 and 42 weeks of gestation were enrolled.

Risk Factors Studied

- Pregnancy-induced hypertension (PIH)
- Intrauterine growth restriction (IUGR)
- Post-dated pregnancy

Inclusion Criteria

- Singleton pregnancy
- Gestational age between 20 and 42 weeks
- Normal and high-risk pregnancies
- Informed consent obtained

Exclusion Criteria

- Multiple gestation
- Placenta previa or morbidly adherent placenta
- Posterior placental location
- Major fetal congenital anomalies
- Intrauterine fetal demise
- Maternal connective tissue disorders

Ultrasound and Doppler Assessment

All participants underwent detailed obstetric ultrasound for fetal biometry, estimated fetal weight, and placental assessment. Doppler evaluation included umbilical artery pulsatility index (PI), middle cerebral artery PI, and cerebroplacental ratio (CPR).

Placental Elastography Technique

Placental elastography was performed using a high-resolution ultrasound system equipped with elastography software and a convex transducer. Regions of interest were placed in homogeneous placental parenchyma, avoiding placental margins, cord insertion, placental lakes, and calcifications. Multiple measurements were obtained, and mean placental stiffness values were recorded in kilopascals (kPa).

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequencies and percentages. Comparison of placental stiffness across groups was performed using one-way ANOVA. Correlation between placental stiffness and Doppler indices was assessed using Pearson's correlation coefficient. Doppler abnormality was considered the reference standard for placental insufficiency, and sensitivity and specificity of placental elastography were calculated. A p-value < 0.05 was considered statistically significant.

Results

Table 1: Distribution of study population

Pregnancy Category	Number (n)	Percentage (%)
Normal pregnancies	8	32
IUGR	10	40
PIH	5	20
Post-dated pregnancy	2	8
Total	25	100

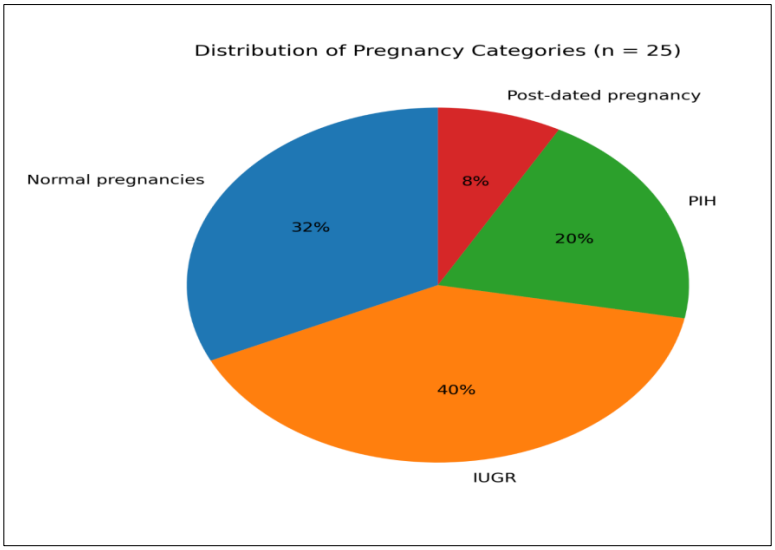

Figure 1: Distribution of pregnancy categories in the study population (n = 25).

The pie chart illustrates the proportional distribution of participants included in the study. Intrauterine growth restriction (IUGR) constituted the largest subgroup (40%), followed by normal pregnancies (32%), pregnancy-induced hypertension (PIH) (20%), and post-dated pregnancies (8%).

Table 2: Gestational age distribution of the study population

Gestational Age (weeks)	Number (n)	Percentage (%)
20–27 weeks	4	16
28–33 weeks	7	28
34–36 weeks	6	24
37–42 weeks	8	32
Total	25	100

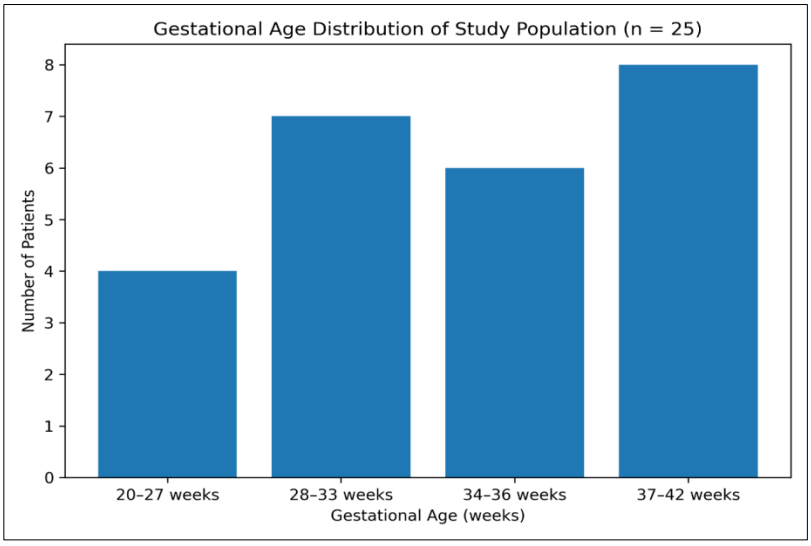

Figure 2: Gestational age distribution of the study population (n = 25).

The bar diagram illustrates the distribution of participants across different gestational age groups, ranging from 20 to 42 weeks. The graph demonstrates that the largest proportion of study participants were in the 37–42 weeks gestational age group (32%), followed by 28–33 weeks (28%) and 34–36 weeks (24%). Early gestational age (20–27 weeks) constituted the smallest subgroup (16%). This distribution reflects inclusion of both mid- and late-gestation pregnancies, enabling evaluation of placental stiffness across a broad gestational age range.

Table 3: Mean placental stiffness among pregnancy groups

Group	Mean Placental Stiffness (kPa)	Range (kPa)
Normal pregnancies	11.8 ± 2.1	9–15
IUGR	22.5 ± 3.4	18–26
PIH	24.2 ± 3.8	20–29
Post-dated pregnancy	19.4 ± 2.6	16–23

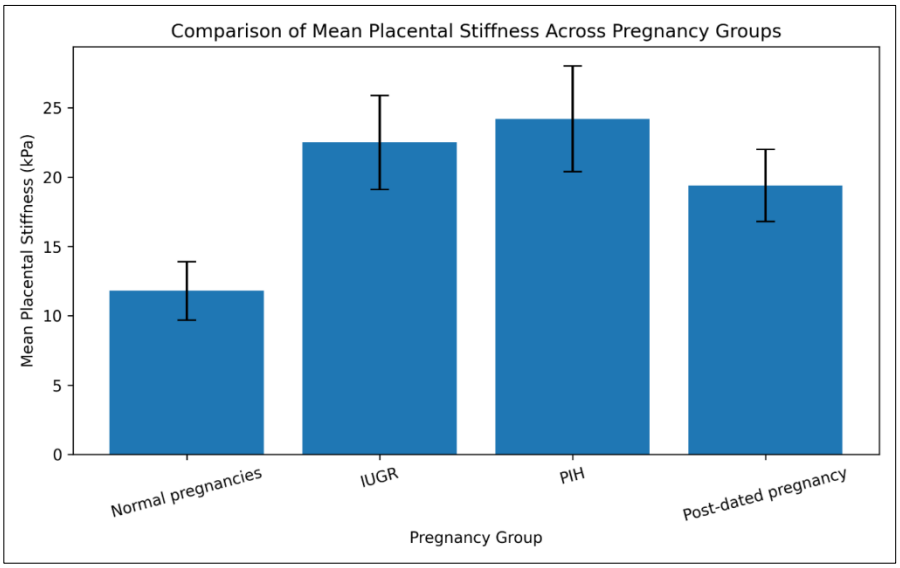

Figure 3: Comparison of mean placental stiffness across pregnancy groups

The bar diagram shows mean placental stiffness values (kPa) with standard deviation error bars in normal pregnancies, IUGR, pregnancy-induced hypertension (PIH), and post-dated pregnancies. Placental stiffness is lowest in normal pregnancies and markedly higher in IUGR and PIH, reflecting increasing placental dysfunction in high-risk pregnancies.

The graph demonstrates a significant increase in mean placental stiffness in pregnancies complicated by IUGR and PIH compared to normal pregnancies. Post-dated pregnancies showed moderately increased placental stiffness, likely reflecting placental senescence. The progressive rise in stiffness across high-risk groups supports the role of placental elastography as a marker of placental dysfunction.

Table 4: Correlation between placental elastography and doppler findings

Elastography Finding	Umbilical Artery Doppler	Cerebroplacental Ratio
Normal stiffness	Normal PI	Normal
Moderately increased stiffness	Raised PI	Reduced
Severely increased stiffness	AEDF / REDF	Markedly reduced

Table 5: Correlation Analysis between Placental Stiffness and Doppler Parameters

Parameter Compared	Correlation Coefficient (r)	p-value
Placental stiffness vs UA PI	+0.71	< 0.001
Placental stiffness vs CPR	−0.66	< 0.001

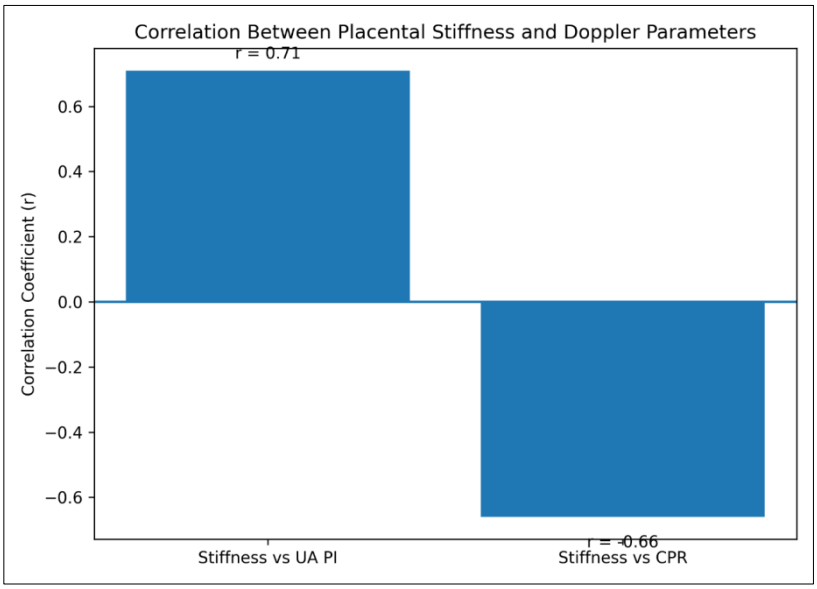

Figure 4: Correlation between placental stiffness and Doppler parameters.

The bar graph illustrates the strength and direction of correlation between placental stiffness and umbilical artery pulsatility index (UA PI), and between placental stiffness and cerebroplacental ratio (CPR). Placental stiffness shows a strong positive correlation with UA PI ($r = +0.71$, $p < 0.001$) and a strong negative correlation with CPR ($r = -0.66$, $p < 0.001$).

Table 6: Diagnostic Performance of Placental Elastography

Diagnostic Parameter	Value (%)
Sensitivity	88
Specificity	82
Positive Predictive Value (PPV)	85
Negative Predictive Value (NPV)	86
Overall diagnostic accuracy	84

Table 7: Severity of Placental Stiffness and Doppler Correlation

Placental Stiffness Category	Doppler Interpretation
Normal stiffness	Normal fetoplacental circulation
Mild–moderate increase	Increased placental resistance
Severe increase	Marked placental insufficiency

Table 8: Diagnostic Performance of Placental Elastography Alone

Diagnostic Parameter	Value (%)
Sensitivity	88
Specificity	82
Positive Predictive Value (PPV)	85

Negative Predictive Value (NPV)	86
Overall Diagnostic Accuracy	84

Placental elastography alone demonstrates high sensitivity and good specificity in detecting placental dysfunction.

Table 9: Diagnostic Performance of Doppler Ultrasound Alone

Diagnostic Parameter	Value (%)
Sensitivity	76
Specificity	85
Positive Predictive Value (PPV)	83
Negative Predictive Value (NPV)	79
Overall Diagnostic Accuracy	80

Doppler ultrasound shows good specificity but comparatively lower sensitivity, indicating that some cases of placental dysfunction may not be detected in early stages

Table 10: Diagnostic Performance of Combined Placental Elastography and Doppler

Diagnostic Parameter	Value (%)
Sensitivity	94
Specificity	90
Positive Predictive Value (PPV)	92
Negative Predictive Value (NPV)	93
Overall Diagnostic Accuracy	92

The combined use of placental elastography and Doppler ultrasound provides the highest diagnostic performance, with improved sensitivity and specificity compared to either modality alone.

Placental stiffness values were lowest in normal pregnancies and significantly higher in pregnancies complicated by PIH, IUGR, and post-dated gestation. One-way ANOVA demonstrated a statistically significant difference in placental stiffness among the study groups ($p < 0.001$).

A progressive increase in placental stiffness correlated with worsening Doppler abnormalities. Normal placental stiffness was associated with normal umbilical artery PI and normal CPR. Moderately increased stiffness correlated with raised umbilical artery PI and reduced CPR, while severely increased stiffness was associated with absent or reversed end-diastolic flow and markedly reduced CPR.

Correlation analysis showed a strong positive correlation between placental stiffness and umbilical artery PI ($r = 0.71$, $p < 0.001$) and a strong inverse correlation between placental stiffness and CPR ($r = -0.66$, $p < 0.001$).

Using Doppler abnormality as the reference standard, placental elastography demonstrated a sensitivity of 88%, specificity of 82%, positive predictive value of 85%, and negative predictive value of 86%, indicating good diagnostic performance.

Discussion

This study demonstrates that placental stiffness assessed by elastography increases significantly in pregnancies complicated by PIH, IUGR, and post-dated gestation. These findings reflect underlying placental ischemia,

fibrosis, and abnormal vascular remodeling, which reduce placental compliance and increase tissue stiffness[6],[7].

The strong correlation between placental stiffness and Doppler abnormalities supports the complementary role of elastography. While Doppler studies evaluate downstream hemodynamic consequences of placental dysfunction, elastography directly assesses placental tissue integrity, offering upstream insight into placental pathology[5].

In post-dated pregnancies, increased placental stiffness likely reflects placental senescence, highlighting the potential role of elastography in late-gestation surveillance. The high sensitivity and specificity observed in this study suggest that placental elastography may reliably identify placental dysfunction and enhance diagnostic confidence when used alongside Doppler studies.

Conclusion

Placental stiffness assessed by elastography serves as a valuable window into fetoplacental health. Increased placental stiffness correlates significantly with Doppler abnormalities in pregnancies complicated by PIH, IUGR, and post-dated gestation. Placental elastography is a sensitive and specific adjunct to conventional ultrasound and Doppler in the evaluation of high-risk pregnancies.

Summary

This prospective observational study conducted between November 2025 and January 2026 among pregnancies between 20 and 42 weeks of gestation demonstrates that placental elastography provides quantitative assessment of placental health. Placental stiffness correlates strongly with Doppler indices, and elastography shows high sensitivity and specificity for detecting placental dysfunction, supporting its role as a complementary imaging tool in high-risk pregnancy evaluation.

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