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EVALUATING THE PREDICTIVE EFFICACY OF FIRST-TRIMESTER UTERINE ARTERY DOPPLER IN IDENTIFYING ADVERSE PREGNANCY OUTCOMES

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Abstract

Background: Early identification of high-risk pregnancies is essential to reduce maternal and fetal morbidity and mortality. Pre-eclampsia (PE) and fetal growth restriction (FGR) are major contributors to adverse outcomes and are often linked to impaired placentation. First-trimester uterine artery Doppler ultrasonography provides a non-invasive assessment of uteroplacental perfusion and may serve as a useful screening tool.

Objective: To evaluate the predictive value of first-trimester uterine artery Doppler parameters—particularly Pulsatility Index (PI) and early diastolic notch—in forecasting adverse pregnancy outcomes including PE, FGR, low birth weight (LBW), preterm delivery, and oligohydramnios.

Methods: A prospective cohort study was conducted on 121 antenatal women between 11 and 13+6 weeks of gestation. Uterine artery Doppler was performed to measure PI and detect early diastolic notching. Participants were followed until delivery, and pregnancy outcomes were documented. Diagnostic performance was assessed using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), likelihood ratios, and Youden Index.

Results: Elevated PI (>2.4) was observed in 26.4% of participants; early diastolic notch was detected in 2.5%. Adverse outcomes occurred in 19.8% of cases, with PE in 12.4%, FGR in 6.6%, LBW in 13.2%, preterm delivery in 12.4%, and oligohydramnios in 8.3%. PI >2.59 predicted PE with 60% sensitivity and 85.8% specificity. PI >2.22 predicted FGR with 100% sensitivity and 63.7% specificity. The highest Youden Index was observed for FGR (0.64) and oligohydramnios (0.51). The presence of early diastolic notch was significantly associated with FGR, LBW, and preterm birth.

Conclusion: First-trimester uterine artery Doppler is a valuable screening modality for predicting adverse pregnancy outcomes, particularly placenta-mediated disorders such as PE and FGR. Elevated PI and early diastolic notch are reliable indicators of impaired placentation and should be integrated

into routine antenatal screening protocols to enhance early risk stratification, especially in resource-limited settings.

Keywords: Uterine artery Doppler, Pulsatility Index, Pre-eclampsia, Fetal Growth Restriction, First trimester screening, Pregnancy outcomes

INTRODUCTION

Antenatal care plays a pivotal role in reducing maternal and fetal morbidity and mortality by enabling early detection and timely management of pregnancy-related complications. Among these, **pre-eclampsia (PE)** and **fetal growth restriction (FGR)** are particularly critical, contributing substantially to adverse maternal and neonatal outcomes. Early-onset PE, in particular, has been associated with a significantly higher risk of maternal mortality, stillbirth, and neonatal morbidity[1]. FGR, often linked to placental insufficiency, is a leading cause of perinatal complications and long-term developmental challenges[2]. The pathogenesis of both PE and FGR frequently involves **defective trophoblastic invasion** and **incomplete remodeling of the spiral arteries**, resulting in increased vascular resistance and impaired uteroplacental perfusion. These abnormalities can be non-invasively assessed by **uterine artery Doppler ultrasonography**, which allows evaluation of blood flow impedance during early gestation[3]. This technique provides valuable insight into placental development and vascular adaptation and is increasingly considered a promising screening tool in the first trimester[4]. The **Pulsatility Index (PI)** is the most widely utilized Doppler parameter, offering reliable quantification of uterine artery resistance. Elevated PI values suggest abnormal placental development. Similarly, the **presence of an early diastolic notch** has been associated with suboptimal uteroplacental perfusion and is considered an additional indicator of impaired placentation[5-10]. **Despite its proven potential, uterine artery Doppler has not yet been universally adopted in first-trimester screening protocols.** Most existing studies primarily focus on its predictive value for pre-eclampsia, with limited data evaluating its role in predicting a broader spectrum of complications such as **low birth weight (LBW), preterm delivery, and oligohydramnios**, especially in low-resource settings. This lack of comprehensive, region-specific evidence creates a significant gap in clinical practice.

Therefore, this study was conducted to evaluate the predictive utility of first-trimester uterine artery Doppler in identifying pregnancies at risk of adverse outcomes. Specifically, it aims to determine whether abnormal Doppler findings—defined as elevated PI and/or the presence of an early diastolic notch—can reliably predict outcomes such as PE, FGR, LBW, preterm delivery, and oligohydramnios. The study also assesses the sensitivity and specificity of these parameters in risk stratification during the first trimester.

MATERIALS AND METHODS

Study Design and Setting

This study employed a prospective cohort design, conducted over an 18-month period in the Department of Obstetrics and Gynaecology at Hind Institute of Medical Sciences, Barabanki, India. The setting is a tertiary care teaching hospital that serves a diverse obstetric population, enabling a representative evaluation of early pregnancy screening tools**.**

Study Population

A total of 121 antenatal women presenting for routine first-trimester screening between 11 weeks and 13+6 weeks of gestation were enrolled. Participants were selected through convenience sampling. The inclusion criteria consisted of singleton pregnancies within the specified gestational range and willingness to participate. Women were excluded if they had multiple gestations, pregnancies achieved via assisted reproductive technologies (ART), fetuses with congenital anomalies, or if they had pre-existing maternal medical conditions such as chronic hypertension, diabetes mellitus,

systemic lupus erythematosus (SLE), thrombophilia, or other autoimmune or cardiovascular disorders.

Procedures and Data Collection

All enrolled participants underwent standard first-trimester ultrasonographic evaluations, including nuchal translucency (NT) and nasal bone (NB) assessments. Additionally, bilateral uterine artery Doppler ultrasound was performed in accordance with the International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) guidelines. The Pulsatility Index (PI) was measured for each uterine artery, and the presence or absence of an early diastolic notch was documented. A PI value greater than 2.4 was classified as abnormal in this study.

Outcome Measures

Participants were followed through the course of pregnancy until delivery. The primary outcomes recorded included the occurrence of pre-eclampsia (PE), fetal growth restriction (FGR), low birth weight (LBW) defined as <2.5 kg, preterm delivery (<37 weeks gestation), and oligohydramnios. The presence of one or more of these conditions was considered an adverse pregnancy outcome.

Statistical Analysis

Data analysis was conducted using IBM SPSS Statistics, Version 21. Descriptive statistics were used to summarize demographic variables and outcome frequencies. Inferential statistics, including the Chi-square test, were applied to assess associations between Doppler findings and pregnancy outcomes. Additionally, Receiver Operating Characteristic (ROC) curve analysis was performed to evaluate the predictive accuracy of Doppler parameters (PI and diastolic notch). A p-value < 0.05 was considered statistically significant throughout the analysis.

RESULTS

Participant Characteristics

A total of 121 pregnant women meeting the inclusion criteria were enrolled in the study. The majority of participants (43.8%) were between 25 and 29 years of age. Most deliveries were conducted vaginally (80.2%), and all participants underwent first-trimester Doppler screening between 11 and 13+6 weeks of gestation. The demographic and obstetric characteristics are summarized in Table 1.

Uterine Artery Doppler Findings

Among the study participants, 89 women (73.6%) exhibited a normal Pulsatility Index (PI < 2.4), while 32 women (26.4%) had an elevated PI (> 2.4). The early diastolic notch was identified in only 3 participants (2.5%), suggesting limited prevalence in early gestation. Detailed findings are shown in Table 2.

Pregnancy Outcomes

Out of the total cohort, 24 participants (19.8%) developed one or more adverse pregnancy outcomes. The individual outcome rates were as follows:

- Pre-eclampsia (PE): 15 cases (12.4%)
- Fetal Growth Restriction (FGR): 8 cases (6.6%)
- Low Birth Weight (LBW <2.5 kg): 16 cases (13.2%)
- Preterm Delivery (<37 weeks): 15 cases (12.4%)
- Oligohydramnios: 10 cases (8.3%)

The distribution of these outcomes is illustrated in Figure 1 and listed in Table 3.
Association Between Doppler Indices and Outcomes

Elevated PI values were significantly associated with various adverse outcomes:

- Pre-eclampsia: PI > 2.59 yielded a sensitivity of 60% and specificity of 85.8%

- FGR: PI > 2.22 showed 100% sensitivity and 63.7% specificity
- LBW: PI > 2.22 demonstrated 75% sensitivity and 64.8% specificity
- Preterm Delivery: PI > 2.51 was predictive with 60% sensitivity and 82.1% specificity
- Oligohydramnios: PI > 2.51 had an AUROC of 0.778, indicating moderate discriminative ability

These associations are detailed in Table 4.
In addition, the presence of an early diastolic notch was statistically correlated with increased incidence of FGR, LBW, preterm birth, and oligohydramnios, although no significant association was found with pre-eclampsia in this study population.
Further analysis evaluated the predictive performance of uterine artery Doppler parameters using additional metrics including Positive Predictive Value (PPV), Negative Predictive Value (NPV), Likelihood Ratios (LR+ and LR−), and Youden Index. The strongest performance was observed for fetal growth restriction, with a Youden Index of 0.64 and 100% NPV. Pre-eclampsia, preterm delivery, and oligohydramnios also demonstrated moderate diagnostic value (Youden Index > 0.4). Table 5 presents a summary of the enhanced diagnostic performance measures.

Table 1. Baseline Characteristics of Participants

Characteristic	Frequency (%)
Age Group (25–29 years)	43.8
Vaginal Delivery	80.2
Gestational Age at Screening (11–13+6 weeks)	100.0

Table 2. Uterine Artery Doppler Findings

Doppler Finding	Frequency (%)
Normal PI (<2.4)	73.6
Abnormal PI (>2.4)	26.4
Early Diastolic Notch Present	2.5

Table 3. Incidence of Adverse Pregnancy Outcomes

Outcome	Frequency (%)
Pre-eclampsia (PE)	12.4
Fetal Growth Restriction (FGR)	6.6
Low Birth Weight (LBW <2.5 kg)	13.2
Preterm Delivery (<37 weeks)	12.4
Oligohydramnios	8.3
At least one adverse outcome	19.8

Table 4. Diagnostic Performance of PI and Notch for Adverse Outcomes

Outcome	PI Cut-off	Sensitivity (%)	Specificity (%)	AUROC
Pre-eclampsia (PE)	2.59	60	85.8	—
Fetal Growth Restriction	2.22	100	63.7	—
Low Birth Weight (LBW)	2.22	75	64.8	—
Preterm Delivery	2.51	60	82.1	—
Oligohydramnios	2.51	70	—	0.778

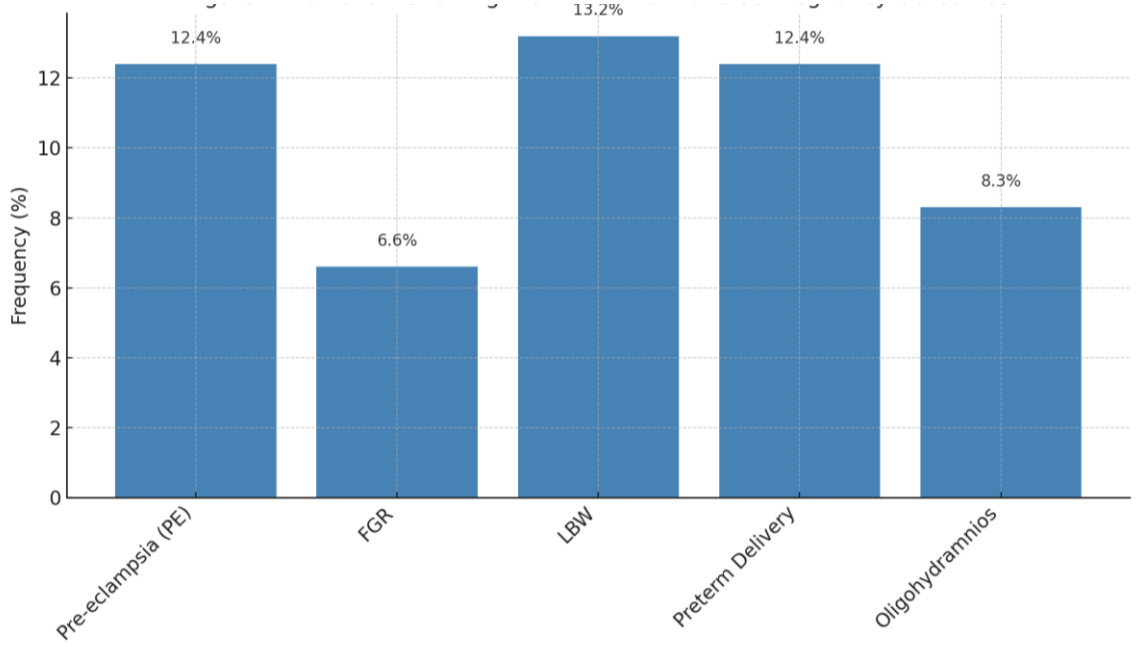

Figure 1 – Bar Chart Showing Distribution of Adverse Pregnancy Outcomes

Table 5. Predictive Performance of Uterine Artery PI for Adverse Outcomes

Outcome	PI Cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	LR+	Youden Index
Pre-eclampsia	2.59	60.0	85.8	45.0	92.2	4.23	0.46
FGR	2.22	100.0	63.7	22.2	100.0	2.75	0.64
LBW	2.22	75.0	64.8	28.6	93.1	2.13	0.40
Preterm Delivery	2.51	60.0	82.1	39.1	91.0	3.35	0.42
Oligohydramnios	2.51	70.0	81.1	33.3	95.0	3.70	0.51

DISCUSSION

This study evaluated the predictive role of **first-trimester uterine artery Doppler**—specifically **Pulsatility Index (PI)** and **early diastolic notch**—in identifying pregnancies at risk of adverse outcomes. The findings indicate that **elevated PI** values are significantly associated with **pre-eclampsia (PE), fetal growth restriction (FGR), low birth weight (LBW), preterm delivery**, and **oligohydramnios**.

A PI cut-off of **>2.59** demonstrated a specificity of **85.8%** and sensitivity of **60%** in predicting PE, with a **Youden Index of 0.46** and **positive likelihood ratio (LR+) of 4.23**, indicating moderate discriminatory power. Importantly, the **negative predictive value (NPV)** was particularly high across all adverse outcomes—**92.2% for PE** and **100% for FGR**—confirming the Doppler's value in ruling out complications in pregnancies with normal findings[11-12].

Although the **early diastolic notch** was identified in only 2.5% of cases, its presence correlated significantly with FGR, LBW, and preterm birth. This suggests that while infrequent, early notching may reflect impaired placentation and warrants close monitoring.

The **Youden Index** values further support the diagnostic relevance of PI thresholds in the first trimester, with the best performance observed for **FGR (0.64)** and **oligohydramnios (0.51)**.

These results are in alignment with previously published data. A meta-analysis by Velauthar et al. reported that **first-trimester uterine artery PI** is significantly higher in pregnancies that develop **PE and FGR**, supporting its use as a screening tool[1]. Similarly, Melchiorre et al. found that abnormal uterine artery flow in early pregnancy is associated with poor placentation and increased obstetric risk[13].

The diagnostic performance of PI > 2.22 for FGR (100% sensitivity, 63.7% specificity) in our study corresponds closely with the findings of prior studies, suggesting that this threshold may be clinically useful in predicting FGR[14].

Our observed AUROC value of 0.778 for predicting **oligohydramnios** is comparable to previous work indicating moderate accuracy of uterine artery Doppler in forecasting this condition[4]. Despite modest **PPV** values (e.g., 22.2% for FGR and 45.0% for PE), the high **NPV** underscores the role of uterine artery Doppler as a **strong rule-out tool**.

Poon et al. emphasized that combining uterine artery PI with **biochemical markers and maternal factors**—such as mean arterial pressure and PAPP-A—can significantly enhance predictive accuracy[16]. While such multimodal screening was not included in our protocol, future studies should explore integrated models to improve early detection.

Our results contribute population-specific evidence from a **tertiary care center in India**, reinforcing that **first-trimester uterine artery Doppler** is a practical and effective tool even in **resource-limited** settings where advanced screening methods may not be universally available

Limitations

This study, while informative, had certain limitations. The sample size was modest and drawn from a single tertiary care center, which may limit generalizability to broader populations. Doppler measurements were operator-dependent, although performed by trained personnel using standardized protocols. Additionally, the study did not integrate maternal biochemical markers (e.g., PAPP-A, PlGF) or demographic risk scores, which could have improved predictive performance. Lastly, we focused solely on uterine artery Doppler parameters and did not evaluate other vascular indices such as the resistance index or bilateral notch depth.

Recommendations

Given the findings, we recommend incorporating **first-trimester uterine artery Doppler screening**—particularly **Pulsatility Index**—into routine antenatal assessments for early risk stratification. Clinicians should consider combining Doppler results with maternal history and, where available, biochemical markers to improve predictive accuracy for adverse pregnancy outcomes. Additional training of sonographers and standardization of cut-off values will enhance reproducibility and diagnostic confidence.

Future Research Directions

Future studies should:

- Involve larger, multicentric cohorts to enhance external validity
- Evaluate integrated models combining uterine artery Doppler with biochemical markers and clinical variables
- Assess cost-effectiveness and feasibility of implementation in low-resource settings
- Examine longitudinal changes in Doppler indices beyond the first trimester for dynamic risk assessment
- Investigate intervention strategies (e.g., low-dose aspirin) in screen-positive patients to assess outcome modification

CONCLUSION

First-trimester uterine artery Doppler, particularly an elevated Pulsatility Index and the presence of an early diastolic notch, serves as a reliable non-invasive predictor of **pre-**eclampsia**,** fetal growth restriction**,** low birth weight**,** preterm delivery**, and** oligohydramnios. With high negative predictive value, it is particularly effective for **ruling out** high-risk pregnancies early in gestation. Integration of uterine artery Doppler into routine antenatal screening protocols may significantly improve pregnancy surveillance and outcome prediction, especially in resource-constrained settings.

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Conflict of Interest
The authors declare no conflict of interest.

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