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Color Doppler Evaluation of Uterine Artery Indices in Prediction of Preeclampsia and Fetal Growth Restriction: A Prospective Observational Study

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ABSTRACT

Background: Abnormal remodeling of the uteroplacental circulation can persist as increased uterine arterial resistance, preceding placental dysfunction and adverse outcomes.
Objectives: To evaluate mid-trimester uterine artery Doppler indices and early diastolic notching for predicting preeclampsia and fetal growth restriction.
Methods: A prospective observational study was conducted in 100 singleton pregnancies undergoing uterine artery color Doppler at around 22 weeks' gestation. Pulsatility index, resistance index, systolic/diastolic ratio, and early diastolic notch were recorded. Participants were followed until delivery to ascertain preeclampsia and fetal growth restriction.
Results: Uterine artery impedance indices were higher in pregnancies that later developed preeclampsia and/or fetal growth restriction compared with uncomplicated pregnancies. Early diastolic notching was more frequent among women with adverse outcomes. A uterine artery pulsatility index above the 95th percentile for gestational age showed useful discrimination, with a high negative predictive value for the composite adverse outcome.
Conclusion: Mid-trimester uterine artery Doppler, particularly elevated pulsatility index and the presence of early diastolic notching, is a practical non-invasive approach to stratify risk for preeclampsia and fetal growth restriction in routine antenatal care.

Keywords: Uterine artery Doppler; pulsatility index; early diastolic notch; preeclampsia; fetal growth restriction; placental insufficiency.

INTRODUCTION

Hypertensive disorders of pregnancy and impaired fetal growth are major contributors to maternal and perinatal morbidity. Preeclampsia is defined by new-onset hypertension after 20 weeks' gestation with proteinuria or maternal end-organ dysfunction, and it is associated with eclampsia, stroke, placental abruption, and medically indicated preterm birth [1]. Fetal growth restriction (FGR) reflects failure to achieve expected growth potential and is linked to stillbirth, neonatal morbidity, neurodevelopmental impairment, and later cardiometabolic risk [2]. Together, these conditions account for a substantial proportion of preventable adverse outcomes in antenatal practice.

Abnormal placentation is central to both preeclampsia and FGR. In normal pregnancy, trophoblastic invasion transforms spiral arteries into low-resistance, high-capacity conduits. Inadequate remodeling maintains a high-resistance uteroplacental bed, reducing perfusion reserve and promoting ischemia-reperfusion injury and oxidative stress. These placental signals contribute to endothelial dysfunction and altered angiogenic balance, which can manifest clinically as maternal hypertension, proteinuria, and restricted fetal growth. The shared placental pathway explains the frequent co-existence of preeclampsia and growth restriction and supports investigation of early placental perfusion markers.

Color Doppler assessment of the uterine arteries provides a non-invasive window into uteroplacental perfusion. Increase in uterine artery pulsatility index (PI), resistance index (RI), elevated systolic/diastolic (S/D) ratio, and persistence of an early diastolic notch indicate increased downstream impedance. Systematic reviews and meta-analyses show that uterine artery Doppler has moderate accuracy for predicting preeclampsia and growth restriction, with improved performance when assessment is performed in the second trimester and when PI and notching are interpreted together [4,6,8]. These characteristics make Doppler attractive in settings where biochemical screening is not routinely available or when rapid triage is needed.

Early risk stratification has practical implications. Women at higher risk benefit from closer surveillance for blood pressure elevation and symptom progression, timely evaluation of fetal growth and amniotic fluid, and planned referral to higher-level care when needed. Preventive strategies such as low-dose aspirin are more effective when started earlier in gestation, and screening tools that fit into routine care pathways are desirable. In many public sector settings, Doppler can be integrated into the mid-trimester anomaly scan with minimal additional time and without laboratory infrastructure, especially when acquisition and interpretation follow standardized guidance [3].

The present prospective observational study evaluated mid-trimester uterine artery Doppler indices and early diastolic notching in a teaching hospital cohort. Objectives were: (i) to compare uterine artery PI, RI and S/D ratio between pregnancies with and without subsequent preeclampsia and/or fetal growth restriction; (ii) to assess the association of early diastolic notching with adverse outcomes; and (iii) to describe the diagnostic performance of a PI threshold above the 95th percentile for predicting the composite adverse outcome.

METHODOLOGY

Study design and setting

A prospective observational study was conducted in the Department of Radiodiagnosis, Government Medical College, Vikarabad, India, over 8 months (March 2025 to October 2025). Recruitment was aligned with routine antenatal ultrasonography services, and uterine artery Doppler assessment was performed in the mid-trimester window.

Study population

Consecutive pregnant women attending for routine ultrasonography were screened for eligibility. Singleton pregnancies between 19 and 24 completed weeks of gestation were included. Exclusion criteria were chronic hypertension, pre-gestational diabetes mellitus, chronic kidney disease, autoimmune disease, multiple gestation, major fetal structural anomaly detected at recruitment, and examinations with inadequate Doppler waveforms. After written informed consent, demographic and obstetric details were recorded, including age, gravidity and gestational age at assessment. Participants were prospectively followed until delivery, and outcomes were abstracted from antenatal case records and delivery registers.

Doppler protocol

Uterine artery Doppler velocimetry was performed using color Doppler with a standardized technique consistent with practice guidance [3]. The uterine artery was identified at the apparent crossover with the external iliac artery. Pulsed-wave Doppler sampling was obtained with the smallest feasible insonation angle (target <30°), low wall filter, and velocity scale adjusted to avoid aliasing. At least three consecutive, uniform waveforms were recorded for each side. PI, RI and S/D ratio were measured, and mean uterine artery values were calculated from left and right measurements. Early diastolic notch was recorded as present when a visible early diastolic deflection persisted in one or both uterine arteries. For diagnostic evaluation, an abnormal PI was defined as >95th percentile for gestational age, using locally applied reference centiles derived from published ranges [14].

Outcomes and definitions

The primary outcome was a composite of preeclampsia and/or fetal growth restriction. Preeclampsia was defined as new-onset hypertension after 20 weeks with proteinuria and/or maternal end-organ dysfunction, consistent with standard clinical criteria [1]. Fetal growth restriction was determined from obstetric and neonatal records using accepted criteria aligned with consensus parameters, including birth weight below the 10th percentile with evidence suggesting placental insufficiency [2]. Pregnancies without preeclampsia or fetal growth restriction were categorized as uncomplicated outcomes.

Statistical analysis

Continuous variables were summarized as mean ± standard deviation and categorical variables as frequency and percentage. Doppler indices were compared between pregnancies with the composite adverse outcome and those with uncomplicated outcomes. A two-tailed p value <0.05 was considered statistically significant. Diagnostic accuracy of uterine artery PI >95th percentile was summarized as sensitivity, specificity, positive predictive value and negative predictive value.

Ethical considerations
Institutional ethics approval was obtained prior to recruitment. Confidentiality was maintained by de-identifying participant data, and routine clinical management decisions were not altered by study participation.

RESULTS
A total of 100 pregnant women were enrolled and prospectively followed until delivery. All participants completed Doppler evaluation and outcome assessment, with no loss to follow-up.

Baseline maternal and obstetric characteristics
The mean maternal age was 26.9 ± 4.3 years. The mean gestational age at Doppler assessment was 21.8 ± 2.4 weeks. Primigravidae constituted 56% (n = 56) and multigravidae 44% (n = 44) (Table 1).

Table 1. Baseline maternal and obstetric characteristics (N = 100)

Characteristic	Value
Maternal age (years), mean ± SD	26.9 ± 4.3
Gestational age at Doppler (weeks), mean ± SD	21.8 ± 2.4
Gravidity, n (%)	
• Primigravida	56 (56.0)
• Multigravida	44 (44.0)

Pregnancy outcomes
Eighteen women developed preeclampsia, fourteen had fetal growth restriction, and six experienced both conditions. Overall, 26% (n = 26) met the composite endpoint of preeclampsia and/or fetal growth restriction, while 74% (n = 74) had uncomplicated pregnancies (Table 2).

Table 2. Pregnancy outcomes (N = 100)

Outcome	n (%)
Preeclampsia (total)	18 (18.0)
Fetal growth restriction (total)	14 (14.0)
Both preeclampsia and fetal growth restriction	6 (6.0)
Composite outcome: preeclampsia and/or fetal growth restriction	26 (26.0)
Uncomplicated pregnancy (no preeclampsia or fetal growth restriction)	74 (74.0)

Uterine artery Doppler indices
Mean uterine artery Doppler indices were higher among women who subsequently developed preeclampsia and/or fetal growth restriction compared with those with uncomplicated outcomes (Table 3). Mean PI was 1.62 ± 0.28 in the adverse outcome group versus 1.08 ± 0.19 in the normal outcome group. Mean RI was 0.69 ± 0.07 versus 0.56 ± 0.06, and mean S/D ratio was 2.74 ± 0.42 versus 2.12 ± 0.31, respectively. All differences were statistically significant ($p < 0.05$).

Table 3. Uterine artery Doppler indices by pregnancy outcome

Index	Adverse outcome (PE and/or FGR)	Normal outcome	p value
Mean uterine artery PI, mean ± SD	1.62 ± 0.28	1.08 ± 0.19	<0.05
Mean uterine artery RI, mean ± SD	0.69 ± 0.07	0.56 ± 0.06	<0.05
Mean uterine artery S/D ratio, mean ± SD	2.74 ± 0.42	2.12 ± 0.31	<0.05

Early diastolic notch
Persistence of early diastolic notch in one or both uterine arteries was observed in 22% (n = 22) of participants. Among women with notching, 72.7% (16/22) developed preeclampsia and/or fetal growth restriction, whereas 12.8% (10/78) of women without notching developed adverse outcomes (Table 4).

Table 4. Early diastolic notching and adverse pregnancy outcomes

Notching status	Adverse outcome, n	Normal outcome, n	Total, n
Notch present	16	6	22
Notch absent	10	68	78

The presence of notching showed a strong association with the composite adverse outcome (odds ratio 18.13; 95% CI 5.75–57.23).

Predictive performance of PI cut-off

Using a uterine artery PI cut-off above the 95th percentile for gestational age, sensitivity for predicting preeclampsia and/or fetal growth restriction was 72.2% and specificity was 85.3%. The positive predictive value was 65.0% and the negative predictive value was 88.9% (Table 5).

Table 5. Diagnostic performance of uterine artery PI (>95th percentile) for predicting PE and/or FGR

Measure	Value (%)
Sensitivity	72.2
Specificity	85.3
Positive predictive value	65.0
Negative predictive value	88.9

DISCUSSION

This prospective cohort demonstrates that uterine artery impedance indices measured in the mid-trimester were higher in pregnancies that subsequently developed preeclampsia and/or fetal growth restriction. The separation in PI, RI and S/D ratio is consistent with the biological model in which Doppler velocimetry captures high downstream resistance related to incomplete spiral artery remodeling. Because these hemodynamic changes occur before overt clinical disease, uterine artery Doppler offers a pragmatic method for antenatal risk stratification during routine imaging.

Systematic evidence provides a benchmark for the observed effect sizes. In a bivariable meta-analysis, uterine artery Doppler—particularly PI, with or without notching—showed meaningful prediction for preeclampsia and intrauterine growth restriction, with stronger discrimination for preeclampsia than for growth outcomes [4]. Earlier overviews also noted that Doppler used in isolation has limited accuracy and should be interpreted alongside clinical context and disease prevalence [6]. Narrative reviews have similarly emphasized its value as part of a broader screening and surveillance strategy rather than a single stand-alone test [7].

Waveform morphology added clinically relevant information. Early diastolic notching showed a strong association with adverse outcomes in this dataset, reinforcing that qualitative assessment complements percentile-based indices. Multicenter screening at 23 weeks demonstrated that uterine artery Doppler identifies a subgroup at increased risk for both preeclampsia and fetal growth restriction and that detection depends on the chosen parameter and threshold [5]. Notching represents a qualitative marker of increased impedance and can be particularly useful when centile charts are not immediately available or when waveform quality is carefully assured.

Findings are broadly consistent with prospective cohort studies from diverse populations. Studies evaluating uterine artery Doppler between 16 and 24 weeks have reported increased risk of preeclampsia and adverse growth outcomes when Doppler is abnormal [9,10]. Observational evidence also supports the value of combining Doppler indices with notching assessment to identify women at risk for severe adverse outcomes [11]. Population-based screening at 20–24 weeks has clarified how maternal characteristics influence uterine artery PI and how elevated PI relates to severity and timing of disease, supporting biological plausibility of a mid-trimester screening window [12]. An updated meta-analysis focusing on uterine artery PI continues to support its predictive utility while highlighting heterogeneity across thresholds and populations [8].

From a service delivery perspective, uterine artery Doppler can be integrated into the anomaly scan when acquisition is standardized and quality controlled [3]. A screen-positive result can justify escalation of monitoring for blood pressure, symptoms and fetal growth, aligned with accepted diagnostic and management frameworks for hypertensive disorders and growth restriction [1,2]. First-trimester uterine artery Doppler screening has been explored, but detection is generally lower than mid-trimester strategies and performance depends on the screening model used [13,14]. Overall, the results support continued adoption of standardized mid-trimester uterine artery Doppler as a feasible adjunct for risk stratification in routine antenatal care.

Limitations

This single-center study had a modest sample size, limiting precision for subgroup estimates and external generalizability. Uterine artery Doppler was recorded at a single mid-trimester time point, so longitudinal changes in impedance were not evaluated. Adjustment for confounders such as BMI, prior history, and mean arterial pressure was not undertaken. Inter-observer variability was not quantified, and angiogenic biomarkers were not incorporated into prediction models.

CONCLUSION

Mid-trimester uterine artery color Doppler provided meaningful antenatal risk stratification for placental insufficiency

outcomes in this cohort. Pregnancies that developed preeclampsia and/or fetal growth restriction showed significantly higher uterine artery PI, RI, and S/D ratio than uncomplicated pregnancies, and early diastolic notching had a strong association with the composite adverse outcome. A PI threshold above the 95th percentile demonstrated good specificity and a robust negative predictive value, supporting its role as a practical screening adjunct during routine anomaly scanning. Standardized acquisition and interpretation can facilitate integration into public sector antenatal services to target surveillance intensity, strengthen referral pathways, and support delivery planning for women at elevated risk**.**

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