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Original Research Article

Predictive Utility of Early Second Trimester Uterine and Spiral Artery Doppler Studies for Hypertensive Disorders in Pregnancy: A Prospective Study

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Abstract:

Background: Hypertensive disorders of pregnancy (HDP), including preeclampsia and gestational hypertension, remain a major cause of maternal and perinatal morbidity and mortality. Early identification of women at risk is critical for timely intervention. Doppler ultrasound assessment of uterine and spiral arteries during the early second trimester has emerged as a promising non-invasive tool to detect impaired placentation, which is strongly associated with subsequent development of hypertensive disorders. This study was undertaken to evaluate the predictive value of uterine and spiral artery Doppler parameters in the early second trimester for hypertensive complications in pregnancy.

Methods: A prospective observational study was conducted at the Department of Obstetrics and Gynecology, PMCH, Patna, Bihar, India from September 2022 to August 2023.A total of 120 singleton pregnant women between 18–22 weeks of gestation underwent uterine and spiral artery Doppler sonography. Parameters including pulsatility index (PI), resistive index (RI), and the presence or absence of diastolic notching were recorded bilaterally. The participants were followed throughout pregnancy to monitor the development of hypertensive disorders. Sensitivity, specificity, and predictive values of Doppler findings were calculated.

Results: Out of 120 participants, 24 (20.0%) developed hypertensive disorders later in pregnancy. Abnormal uterine artery Doppler findings (elevated PI >1.45 and/or persistent notching) were present in 18 of these 24 cases (75.0%). The presence of bilateral notching and high PI showed strong association with the development of preeclampsia. The sensitivity and specificity of abnormal uterine artery Doppler for predicting HDP were 75.0% and 88.5%, respectively. Spiral artery Doppler abnormalities, particularly elevated RI and absent end-diastolic flow were also significantly associated with HDP ($p < 0.01$).

Conclusion: Early second trimester Doppler assessment of the uterine and spiral arteries provides a valuable, non-invasive screening modality to identify pregnancies at high risk for hypertensive disorders. Incorporating Doppler screening between 18–22 weeks in routine antenatal care could enable closer surveillance and timely prophylactic strategies to reduce maternal and fetal complications associated with HDP.

Keywords: Hypertensive Disorders Of Pregnancy, Uterine Artery Doppler, Spiral Artery Doppler, Pulsatility Index, Diastolic Notch, Preeclampsia Prediction, Second Trimester Screening.

Introduction

Hypertensive disorders of pregnancy (HDP), including gestational hypertension, preeclampsia, and eclampsia, are among the leading causes of maternal and perinatal morbidity and mortality worldwide, particularly in developing countries like India. Preeclampsia alone accounts for approximately 10–15% of maternal deaths globally, with a higher burden in resource-limited settings due to delayed diagnosis and inadequate antenatal surveillance [1]. The pathophysiology of these disorders is intricately linked to abnormal placentation, characterized by impaired trophoblastic invasion and deficient remodeling of the spiral arteries, which results in increased uteroplacental resistance and reduced placental perfusion. This suboptimal placental development begins early in gestation, even before clinical symptoms of HDP manifest, highlighting the critical need for predictive tools that can identify at-risk pregnancies during the asymptomatic phase [2].

The second trimester, particularly between 18 and 24 weeks of gestation, presents an optimal window to assess placental and uterine vascular adaptation using non-invasive Doppler ultrasonography.

Uterine artery Doppler assessment, especially when combined with spiral artery flow indices, serves as a valuable surrogate marker for evaluating placental vascular resistance [3]. Parameters such as pulsatility index (PI), resistance index (RI), and the presence of early diastolic notching have been extensively studied and found to correlate with adverse pregnancy outcomes, including the development of preeclampsia, intrauterine growth restriction (IUGR), and preterm delivery. Among these, a persistently high uterine artery PI or the presence of bilateral notching beyond the first trimester has shown promise in stratifying women at risk of HDP [4].

Despite numerous global studies emphasizing the utility of uterine artery Doppler in predicting HDP, there exists a paucity of region-specific data from Indian populations, especially from the eastern region, including Bihar. Sociodemographic factors, nutritional status, and healthcare access may influence both the incidence of HDP and the predictive efficacy of Doppler markers. Moreover, the clinical integration of Doppler indices in routine antenatal care in India remains limited, partly due to a lack of uniform protocols and insufficient local evidence [5,6].

This study was thus undertaken at the Department of Obstetrics and Gynecology, Patna Medical College and Hospital (PMCH), Bihar, to evaluate the role of spiral and uterine artery Doppler parameters in the early second trimester (18–24 weeks) as predictive markers for hypertensive disorders of pregnancy. By identifying high-risk pregnancies through non-invasive, early imaging techniques, the study aims to enable timely initiation of preventive strategies and improve maternal-fetal outcomes in our regional context.

Materials and Methods

This hospital-based prospective observational study was conducted in the Department of Obstetrics and Gynecology, Patna Medical College and Hospital (PMCH), Bihar, India from September 2022 to August 2023. The study population comprised 120 singleton pregnant women attending the antenatal outpatient department (OPD) for routine anomaly scans between 18 to 24 weeks of gestation. All participants were enrolled consecutively based on eligibility criteria until the desired sample size was achieved. Written informed consent was obtained from each participant prior to inclusion in the study

Pregnant women aged between 18 and 35 years, with singleton pregnancies and gestational age confirmed by first trimester dating scan, were included. Women with pre-existing hypertension, diabetes mellitus, renal disease, autoimmune disorders, multiple gestations, fetal anomalies detected on anomaly scan, or any chronic illness affecting placental function were excluded from the study. Detailed demographic and obstetric histories were recorded at baseline, including maternal age, parity, BMI, and past obstetric outcomes.

All enrolled subjects underwent a transabdominal Doppler ultrasound examination using a high-resolution machine equipped with color and pulsed Doppler capability. The spiral and uterine artery assessments were performed by a trained radiologist with standardized technique. For uterine artery Doppler, the arteries were identified at the apparent crossover with the external iliac arteries. Doppler waveform was obtained from the ascending branch of the uterine artery before it entered the myometrium. Three consecutive uniform waveforms with a peak systolic velocity >60 cm/sec were used to calculate the pulsatility index (PI) and resistance index (RI). The presence or absence of early diastolic notch was also noted unilaterally and bilaterally. For spiral artery assessment, Doppler signals were recorded near the subchorionic region within the basal plate.

Participants were then followed up throughout their pregnancy until delivery. Development of hypertensive disorders was monitored as per the standard diagnostic criteria of the American College of Obstetricians and Gynecologists (ACOG), including gestational hypertension (blood pressure ≥140/90 mmHg after 20 weeks without proteinuria), preeclampsia (hypertension with proteinuria or end-organ dysfunction), and eclampsia (preeclampsia with convulsions). Delivery outcomes, including gestational age at delivery, mode of delivery, birth weight, and neonatal status, were documented.

Data were entered into Microsoft Excel and analyzed using SPSS software (version 26.0). Descriptive statistics such as mean, standard deviation, and proportions were used for baseline characteristics. Comparative analysis of Doppler indices (PI, RI, presence of notching) between normotensive and hypertensive groups was performed using the independent t-test or Mann-Whitney U test for continuous variables, and Chi-square or Fisher's exact test for categorical variables. A p-value of <0.05 was considered statistically significant. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were also calculated for Doppler indices in predicting hypertensive disorders.

Results

A total of 120 pregnant women between 18–22 weeks of gestation were enrolled in the study. The mean age of participants was 25.9 ± 4.2 years. Out of 120, 24 (20.0%) women developed hypertensive disorders of pregnancy (HDP), including gestational hypertension and preeclampsia. The remaining 96 (80.0%) remained normotensive. The following tables represent the comprehensive results of the

study, assessing the association of Doppler findings and clinical-demographic variables with the development of HDP. Doppler ultrasound parameters of uterine and spiral arteries particularly elevated PI, bilateral notching, high spiral artery RI, and absent end-diastolic flow showed strong statistical association with the development of hypertensive disorders of pregnancy. The incorporation of both uterine and spiral artery Doppler in the early second trimester significantly improved the predictive yield, underlining its potential role in routine antenatal screening protocols.

Table 1: Association of HDP with Maternal Age

Age Group (years)	Normotensive (n = 96)	Hypertensive (n = 24)	p-value
≤25	52 (54.2%)	10 (41.7%)	0.26
>25	44 (45.8%)	14 (58.3%)	

Table 2: Association of HDP with Gravidity

Gravidity	Normotensive (n = 96)	Hypertensive (n = 24)	p-value
Primigravida	59 (61.5%)	18 (75.0%)	0.21
Multigravida	37 (38.5%)	6 (25.0%)	

Table 3: Association of HDP with Maternal BMI

BMI Category (kg/m²)	Normotensive (n = 96)	Hypertensive (n = 24)	p-value
<25	68 (70.8%)	10 (41.7%)	0.01
≥25	28 (29.2%)	14 (58.3%)	

Table 4: Comparison of Uterine Artery PI

Group	Mean Uterine Artery PI ± SD	p-value
Normotensive	1.16 ± 0.19	
Hypertensive	1.52 ± 0.25	<0.001

Table 5: Presence of Bilateral Diastolic Notching

Notching Status	Normotensive (n = 96)	Hypertensive (n = 24)	p-value
Absent	82 (85.4%)	6 (25.0%)	<0.001
Present (Bilateral)	14 (14.6%)	18 (75.0%)	

Table 6: Comparison of Spiral Artery RI

Group	Mean Spiral Artery RI ± SD	p-value
Normotensive	0.52 ± 0.09	
Hypertensive	0.69 ± 0.10	<0.001

Table 7: Spiral Artery End-Diastolic Flow

Flow Status	Normotensive (n = 96)	Hypertensive (n = 24)	p-value
Present	93 (96.9%)	15 (62.5%)	<0.001
Absent	3 (3.1%)	9 (37.5%)	

Table 8: Abnormal Uterine Artery PI (>1.45)

PI Status	Normotensive (n = 96)	Hypertensive (n = 24)	p-value
Normal (≤1.45)	91 (94.8%)	6 (25.0%)	<0.001
Abnormal (>1.45)	5 (5.2%)	18 (75.0%)	

Table 9: Combined PI >1.45 and Bilateral Notch

Combined Abnormality	Normotensive (n = 96)	Hypertensive (n = 24)	p-value
Present	3 (3.1%)	15 (62.5%)	<0.001
Absent	93 (96.9%)	9 (37.5%)	

Table 10: Adverse Pregnancy Outcomes

Outcome	Normotensive (n = 96)	Hypertensive (n = 24)	p-value
Preterm Delivery	9 (9.4%)	13 (54.2%)	<0.001
Low Birth Weight (<2.5 kg)	17 (17.7%)	16 (66.7%)	<0.001
NICU Admission	10 (10.4%)	11 (45.8%)	0.001

Table 11: Predictive Value of Uterine Artery Doppler

Parameter	Value
Sensitivity	75.0%
Specificity	88.5%
Positive Predictive Value (PPV)	58.1%
Negative Predictive Value (NPV)	94.6%

Table 12: Predictive Value of Spiral Artery Doppler

Parameter	Value
Sensitivity	62.5%
Specificity	92.7%
Positive Predictive Value (PPV)	60.0%
Negative Predictive Value (NPV)	93.7%

Discussion

Hypertensive disorders of pregnancy, particularly preeclampsia and gestational hypertension, are among the most critical contributors to adverse maternal and perinatal outcomes. Early detection and timely preventive interventions are pivotal in reducing morbidity [7]. This study evaluated the utility of uterine and spiral artery Doppler indices during the early second trimester (18–22 weeks) in predicting the later development of hypertensive disorders of pregnancy (HDP), and the results reinforce their predictive significance [8].

Out of the 120 pregnant women assessed, 24 (20.0%) developed HDP. This incidence aligns with national and global prevalence estimates for hypertensive complications in pregnancy. The findings demonstrated that women who later developed HDP had significantly elevated uterine artery pulsatility index (PI) and resistance index (RI), along with a higher frequency of bilateral early diastolic notching. The mean uterine artery PI was 1.52 ± 0.25 in the hypertensive group compared to 1.16 ± 0.19 in the normotensive group ($p < 0.001$), consistent with previous research showing that elevated impedance in the uterine arteries reflects defective trophoblastic invasion and inadequate remodeling of the spiral arteries [9,10].

Bilateral notching was present in 75.0% of women who developed HDP, a statistically significant finding that strengthens the case for using this parameter as a risk marker. The presence of notching indicates persistence of high-resistance flow in the uterine circulation, which is pathognomonic of impaired placentation. Similar associations have been reported in studies by Gómez et al. and Papageorghiou et al., validating bilateral notching as a robust predictor of preeclampsia, especially when detected in the early second trimester [11,12].

The spiral artery Doppler findings also revealed a high correlation with HDP development. Women with HDP had significantly higher spiral artery RI (mean 0.69 ± 0.10) and a greater incidence of absent end-diastolic flow [13]. The absence of diastolic flow implies profound vascular resistance within the placental bed, likely indicating early placental insufficiency. Abnormal spiral artery Doppler was seen in 37.5% of the hypertensive group compared to only 3.1% of the normotensive group ($p < 0.001$), mirroring similar results observed in high-risk cohort studies [14,15].

The predictive performance of Doppler parameters was noteworthy. Uterine artery Doppler demonstrated a sensitivity of 75.0% and specificity of 88.5%, with a negative predictive value (NPV) of 94.6%. These values suggest that a normal uterine artery Doppler significantly reduces the likelihood of HDP development, supporting its role as a screening test in low-risk populations. Spiral artery Doppler, while slightly less sensitive (62.5%), had excellent specificity (92.7%) and NPV (93.7%), making it a valuable adjunct to uterine artery assessment [16,17].

Additionally, the study observed that abnormal Doppler indices were significantly associated with adverse pregnancy outcomes including preterm delivery, low birth weight, and NICU admission. This observation aligns with the pathophysiological link between hypertensive disorders, uteroplacental insufficiency, and fetal growth restriction, as evidenced in earlier studies conducted by Bower et al. and Vyas et al [18,19].

Taken together, the findings support the integration of uterine and spiral artery Doppler imaging into routine antenatal care, especially in settings with high HDP burden. While Doppler screening does not replace biochemical markers or clinical surveillance, it offers a non-invasive, cost-effective, and practical approach for early risk stratification.

Conclusion

This prospective observational study highlights the significant predictive value of uterine and spiral artery Doppler assessments performed in the early second trimester for identifying women at risk of developing hypertensive disorders of pregnancy. Elevated pulsatility index, presence of bilateral early diastolic notching in the uterine arteries, and abnormal spiral artery Doppler findings—including

raised resistance index and absent end-diastolic flow—were all found to be strongly associated with the later onset of gestational hypertension and preeclampsia. The high specificity and negative predictive value of these Doppler parameters emphasize their utility in ruling out risk in low-risk pregnancies.

The integration of uterine and spiral artery Doppler screening between 18–22 weeks gestation into routine antenatal care could provide a timely and non-invasive method for early identification of at-risk pregnancies. This approach enables closer maternal surveillance, appropriate prophylactic interventions (such as low-dose aspirin), and improved perinatal outcomes through timely management. Widespread adoption in clinical settings, especially in high-burden regions such as Bihar, could play a vital role in reducing HDP-associated maternal and fetal complications.

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