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SECOND TRIMESTER UTERINE ARTERY COLOUR DOPPLER SONOGRAPHY IN PREDICTING PREECLAMPSIA AND INTRAUTERINE GROWTH RESTRICTION: A PROSPECTIVE OBSERVATIONAL STUDY

Radio-Diagnosis

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ABSTRACT

Background: Preeclampsia and fetal growth restriction (FGR) are major causes of maternal and perinatal morbidity and mortality, primarily resulting from impaired placentation and increased uteroplacental vascular resistance. Second trimester uterine artery colour Doppler sonography has emerged as a valuable non-invasive tool for early identification of pregnancies at risk of these adverse outcomes. **Objectives:** To evaluate the diagnostic performance of second trimester uterine artery colour Doppler, using mean pulsatility index (PI) and early diastolic notching, in predicting preeclampsia and intrauterine growth restriction. **Materials and Methods:** A prospective longitudinal observational study was conducted in the Departments of Radiodiagnosis and Obstetrics & Gynaecology at Bankura Sammilani Medical College and Hospital. A total of 110 singleton pregnancies underwent uterine artery Doppler examination between 18 and 24 weeks of gestation. Five patients were excluded due to incomplete follow-up, leaving 105 pregnancies for final analysis. Mean uterine artery PI and early diastolic notching were recorded, and pregnancy outcomes were followed until delivery. Diagnostic accuracy was assessed using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR), and negative likelihood ratio (NLR). **Results:** Mean uterine artery PI demonstrated a sensitivity of 88.89% and specificity of 88.54% for predicting preeclampsia, while early diastolic notching showed a specificity of 93.75%. For prediction of IUGR, mean PI showed a sensitivity of 64.71% and specificity of 90.91%, whereas early diastolic notching demonstrated a specificity of 96.59%. Both parameters exhibited high negative predictive values. **Conclusion:** Second trimester uterine artery colour Doppler is a reliable, non-invasive screening modality for predicting preeclampsia and FGR. Incorporation of uterine artery Doppler into routine anomaly scans may facilitate early risk stratification, closer antenatal surveillance, and timely intervention, thereby improving maternal and fetal outcomes.

KEYWORDS

Uterine Artery Doppler; Preeclampsia; Fetal Growth Restriction; Pulsatility Index; Colour Doppler; Pregnancy.

INTRODUCTION

Hypertensive disorders of pregnancy remain among the leading causes of maternal and perinatal morbidity and mortality worldwide, complicating approximately 5–10% of all pregnancies.[1] Along with obstetric haemorrhage and sepsis, preeclampsia constitutes one of the major contributors to maternal mortality, particularly in developing countries.[1,2] In addition to maternal complications, preeclampsia is associated with adverse fetal outcomes including fetal growth restriction (FGR), preterm delivery, placental abruption, fetal distress, and increased perinatal mortality.[2,3]

The pathogenesis of preeclampsia and fetal growth restriction is closely related to abnormal placentation. During normal pregnancy, cytotrophoblastic invasion of the maternal spiral arteries transforms these vessels from high-resistance, low-capacitance arteries into low-resistance channels capable of meeting the increasing metabolic demands of the developing fetus. Failure of this physiological transformation results in persistent high-resistance uteroplacental circulation, placental hypoperfusion, endothelial dysfunction, and subsequent development of hypertensive disorders of pregnancy and fetal growth restriction.[3-5]

Colour Doppler ultrasonography has emerged as an important non-invasive imaging modality for evaluating uteroplacental circulation. Doppler assessment of the uterine arteries reflects downstream placental vascular resistance and allows early identification of pregnancies at increased risk for adverse obstetric outcomes.[6] The principal Doppler parameters used in clinical practice include the pulsatility index (PI), resistive index (RI), systolic-to-diastolic (S/D) ratio, and the presence or absence of an early diastolic notch.[6,7] Among these indices, the mean uterine artery PI and persistence of an early diastolic notch during the second trimester have consistently demonstrated significant predictive value for the subsequent development of preeclampsia and IUGR.[7-9]

Several prospective studies have demonstrated that abnormal uterine artery Doppler findings during the second trimester are associated with an increased incidence of hypertensive disorders of pregnancy and impaired fetal growth.[9-12] Increased uterine artery PI above the 95th percentile and persistent bilateral early diastolic notching have been reported as reliable indicators of impaired trophoblastic invasion and abnormal placentation.[10,11] Furthermore, these Doppler abnormalities possess excellent negative predictive value, making them particularly useful for identifying women at low risk of developing severe obstetric complications.[12]

Early identification of pregnancies at increased risk permits closer antenatal surveillance, timely initiation of preventive measures such as low-dose aspirin in selected patients, optimization of maternal monitoring, and appropriate planning of delivery. Such interventions may reduce maternal morbidity, improve neonatal outcomes, and decrease healthcare burden associated with hypertensive disorders of pregnancy.[13,14]

Although numerous studies have evaluated uterine artery Doppler in different populations, regional data from eastern India remain limited.[15-17] Variations in maternal characteristics, nutritional status, socioeconomic conditions, and healthcare access necessitate validation of Doppler parameters in local populations before widespread clinical implementation.

Therefore, the present prospective observational study was undertaken to evaluate the role of second trimester uterine artery colour Doppler sonography in predicting preeclampsia and intrauterine growth restriction. The study also aimed to determine the diagnostic performance of mean uterine artery pulsatility index and early diastolic notching by calculating sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, and negative likelihood ratio, thereby assessing their usefulness as screening tools in routine antenatal practice.

MATERIALS AND METHODS

Study Design

A prospective longitudinal observational study

Study Setting

Departments of Radiodiagnosis and Obstetrics & Gynaecology, Bankura Sammilani Medical College and Hospital, Bankura, West Bengal, over a period of 18 months following approval from the Institutional Ethics Committee.

Study Population

Pregnant women attending the antenatal outpatient department and referred for routine anomaly scan between 18 and 24 weeks of gestation were screened for eligibility. Singleton pregnancies fulfilling

the inclusion criteria and providing written informed consent were enrolled consecutively.

Sample Size
A total of 110 singleton pregnancies were initially recruited. Five patients were excluded because of incomplete follow-up or missing pregnancy outcome data. Therefore, 105 pregnancies were included in the final statistical analysis.

Inclusion Criteria
- Singleton pregnancy.
- Gestational age between 18 and 24 weeks, confirmed by first trimester dating scan or reliable last menstrual period.
- Women willing to participate and provide written informed consent.

Exclusion Criteria
- Multiple gestation.
- Major fetal congenital anomalies.
- Known chromosomal abnormalities.
- Chronic hypertension diagnosed before pregnancy.
- Significant maternal renal, cardiac or autoimmune disease.
- Patients lost to follow-up or with incomplete pregnancy outcome data.

Doppler Examination
Ultrasonography and colour Doppler examination were performed using GE Logiq P9 and Esaote MyLab 7 ultrasound systems equipped with 1–5 MHz and 1–8 MHz curvilinear transducers, respectively.

After completion of the routine fetal anomaly scan, both uterine arteries were identified at the level of their crossover with the external iliac artery using colour Doppler imaging. Pulsed-wave Doppler interrogation was performed with an insonation angle of less than 30°, and at least three consecutive uniform waveforms were obtained before recording Doppler indices.[18],[19]

The following Doppler parameters were assessed:
- Mean uterine artery Pulsatility Index (PI)
- Presence or absence of early diastolic notch
- Laterality of notching (unilateral/bilateral)

An abnormal Doppler study was defined as:
- Mean uterine artery PI greater than the 95th percentile for gestational age, and/or
- Persistence of an early diastolic notch in one or both uterine arteries.[19]

Follow-up
All enrolled patients were followed prospectively until delivery through scheduled antenatal visits and telephonic follow-up. Maternal clinical records, blood pressure measurements, laboratory investigations and delivery records were reviewed to identify the occurrence of:
- Preeclampsia
- Intrauterine growth restriction (IUGR)
- Gestational age at delivery
- Birth weight
- Mode of delivery
- Perinatal outcome

Preeclampsia was diagnosed according to accepted obstetric criteria as new-onset hypertension after 20 weeks of gestation associated with proteinuria or evidence of maternal end-organ dysfunction.

FGR was diagnosed based on ultrasonographic fetal biometry together with Doppler findings and confirmed by birth weight below the expected gestational age percentile according to institutional protocol.

Outcome Measures
Primary Outcomes
- Development of preeclampsia.
- Development of fetal growth restriction.

Secondary Outcomes
- Gestational age at delivery.
- Birth weight.
- Mode of delivery.
- Perinatal outcome.

Statistical Analysis
Collected data were entered into Microsoft Excel and analysed using SPSS software (Version 26.0).

Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were presented as frequencies and percentages.

Diagnostic performance of uterine artery Doppler indices was evaluated by calculating:
- Sensitivity
- Specificity
- Positive Predictive Value (PPV)
- Negative Predictive Value (NPV)
- Positive Likelihood Ratio (PLR)
- Negative Likelihood Ratio (NLR)

Associations between Doppler findings and pregnancy outcomes were assessed using the Chi-square test or Fisher's exact test, as appropriate. A p-value <0.05 was considered statistically significant.

Ethical Considerations
The study protocol was approved by the Institutional Ethics Committee of Bankura Sammilani Medical College and Hospital before commencement of the study. Written informed consent was obtained from all participants prior to enrolment, and the study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

RESULTS
A total of 110 pregnant women were initially enrolled in the study. Five participants were excluded because of incomplete follow-up, leaving 105 women for final analysis.

Baseline Characteristics
The majority of women belonged to the 20–24 years age group (47.62%), while 10.47% were of <20 years age group, 28.57% from 25-29 years age group, 11.43% were of 30-34 years age group, and only 1.90% were of >35 years of age group.

Primigravidae constituted 35.24%, while second gravidae accounted for 34.29% , 3rd gravidae were 24.76%, 4th gravidae were 5.71% of the study population.

Most participants (58%) had a normal body mass index, 7.6% were underweight, 18.1% were overweight, 11.42% were pre obese, 4.7% obese.

The mean maternal systolic blood pressure was 118.17 ± 10.77 mmHg, while the mean diastolic blood pressure was 75.50 ± 6.71 mmHg.

Table 1. Baseline Characteristics Of The Study Population

Variable	Result
Total patients	105
Mean maternal age	24.8 ± 3.9 years
Primigravida	37 (35.2%)
Second gravida	36 (34.3%)
Normal BMI	61 (58.1%)
Mean SBP	118.17 ± 10.77 mmHg
Mean DBP	75.50 ± 6.71 mmHg

Table 9. Distribution of Various Risk Factors

Risk Factors	Frequency	Percentage
Age <20	11	10.47%
Age>35	2	1.90%
h/o diabetes	1	0.95%
h/o chronic renal disease	0	0.00%
h/o SLE	1	0.95%
Past h/o preeclampsia, Abruption, FGR, IUFD	10	9.52%
Total	25	23.8%

Total 23.8% had various risk factors.

Pregnancy Outcome
Among the 105 pregnancies, 85 (80.95%) delivered at term, whereas 15 (14.28%) had preterm delivery and 5 (4.76%) delivered post-term.

The commonest mode of delivery was normal vaginal delivery

(55.2%), followed by emergency caesarean section (33.3%), 7.6% with assisted delivery, 3.8% by elective caesarean section.

Low birth weight (<2500 g) was observed in 28 neonates (26.7%), while 77 had normal weight > 2500g 73.33%.

Table 2. Pregnancy Outcome

Variable	n (%)
Term delivery	85 (80.9)
Preterm delivery	15 (14.3)
Post-term delivery	5 (4.8)
Normal vaginal delivery	58 (55.2)
Assisted vaginal delivery	8 (7.6)
Emergency LSCS	35 (33.3)
Elective LSCS	4 (3.8)
Low birth weight	28 (26.7)

Uterine Artery Doppler Findings

Abnormal uterine artery Doppler was identified based on increased mean pulsatility index (>95th percentile) and/or persistence of early diastolic notching.

Women with abnormal Doppler findings demonstrated a significantly higher incidence of both preeclampsia and intrauterine fetal growth restriction compared with those having normal Doppler studies.

Diagnostic Performance for Prediction of Preeclampsia

The mean uterine artery pulsatility index demonstrated high sensitivity (88.9%) and high specificity (88.5%) for predicting preeclampsia, where 19 cases had (18.10%) had mean uterine artery PI of >95%.

Persistence of an early diastolic notch showed greater specificity (93.8%) but relatively lower sensitivity (66.7%), where notching was seen in 12 cases. (11.42%)

Table 3. Diagnostic Accuracy of Uterine Artery Doppler in Predicting Preeclampsia

Parameter	Mean PI	Early Diastolic Notch
Sensitivity	88.89%	66.67%
Specificity	88.54%	93.75%
PPV	42.11%	50.00%
NPV	98.84%	96.77%
PLR	7.76	10.67
NLR	0.13	0.36

Diagnostic Performance for Prediction of Intrauterine Fetal Growth Restriction

The diagnostic performance of uterine artery PI for prediction of FGR showed 64.7% sensitivity and 90.9% specificity.

Persistence of early diastolic notching demonstrated a specificity of 96.6%, indicating excellent ability to exclude disease in women with normal Doppler findings.

Table 4. Diagnostic Accuracy of Uterine Artery Doppler in Predicting FGR

Parameter	Mean PI	Early Diastolic Notch
Sensitivity	64.71%	52.94%
Specificity	90.91%	96.59%
PPV	57.89%	75.00%
NPV	93.02%	91.40%
PLR	7.12	15.53
NLR	0.39	0.49

Table 21 : Association of Mean Uterine Artery PI and Notching with Preeclampsia and IUGR

Association between	Sn	Sp	PPV	NPV	PLR	NLR	Accuracy	Kappa	P value
PI and Preeclampsia	88.89%	88.54%	42.11	98.84	7.76	0.13	88.57%	0.515	<0.0001
PI and IUGR	64.71%	90.91%	57.89	93.02	7.12	0.39	86.67%	0.531	<0.0001
Notching and Preeclampsia	66.67%	93.75%	50	96.77	10.67	0.36	91.43%	0.525	<0.0001
Notching and IUGR	52.94%	96.59%	75	91.40	15.53	0.49	89.52%	0.562	<0.0001

Overall Diagnostic Performance

Overall, an increased mean uterine artery pulsatility index demonstrated greater sensitivity, whereas persistence of an early diastolic notch demonstrated greater specificity for predicting both preeclampsia and intrauterine growth restriction.

Both Doppler parameters exhibited excellent negative predictive values (>90%), suggesting that a normal second trimester uterine artery Doppler examination effectively identifies women at low risk for developing these adverse pregnancy outcomes.

CONCLUSIONS

The present prospective observational study evaluated the role of second trimester uterine artery colour Doppler sonography in predicting preeclampsia and fetal growth restriction (FGR). The findings demonstrate that abnormal uterine artery Doppler parameters, particularly an elevated mean pulsatility index (PI) and persistence of an early diastolic notch, are significantly associated with adverse pregnancy outcomes. The high specificity and negative predictive value observed in the present study support the use of uterine artery Doppler as a valuable screening modality during routine second trimester obstetric ultrasonography.

The majority of women in the present study belonged to the 20–24-year age group, reflecting the common reproductive age in our population. Similar age distribution has been reported in previous Indian studies evaluating uterine artery Doppler screening, indicating that maternal age alone was not an independent predictor of adverse pregnancy outcome.[20]

An abnormal mean uterine artery PI (>95th percentile) demonstrated a sensitivity of 88.89% and specificity of 88.54% for predicting preeclampsia. These findings are comparable with those reported by Prasanna Kumar Reddy et al., who observed a sensitivity of approximately 84.2% and specificity of 83% for predicting preeclampsia using second trimester uterine artery Doppler.[21] The slightly higher sensitivity observed in the present study may be attributable to differences in patient characteristics, Doppler cut-off values and study design.

Persistence of an early diastolic notch demonstrated comparatively lower sensitivity but higher specificity (93.75%) for predicting preeclampsia. This supports the concept that persistent high-resistance uteroplacental circulation resulting from defective trophoblastic invasion manifests as an early diastolic notch on Doppler examination. Similar findings were reported by Cnossen et al., whose systematic review concluded that combining increased uterine artery PI with persistent notching improves prediction of preeclampsia compared with either parameter alone.[22]

For prediction of IUGR, mean uterine artery PI demonstrated a sensitivity of 64.71% and specificity of 90.91%, whereas early diastolic notching demonstrated excellent specificity (96.59%). These findings closely resemble those reported by Desai et al., who concluded that uterine artery Doppler is a reliable non-invasive modality for identifying pregnancies at increased risk of fetal growth restriction and adverse perinatal outcome.[23]

One of the most important observations in the present study was the excellent negative predictive value of both Doppler parameters. A normal uterine artery Doppler examination during the second trimester reliably excluded subsequent development of preeclampsia and FGR in the majority of women. This has considerable clinical significance because it allows reassurance of low-risk women while enabling more intensive antenatal surveillance of those with abnormal Doppler findings. Similar conclusions have been reported in large systematic reviews evaluating uterine artery Doppler as a screening tool for placental insufficiency.[22]

The present study also demonstrated that mean PI exhibited greater sensitivity, whereas early diastolic notching demonstrated greater specificity for predicting adverse pregnancy outcomes. Therefore, combining both Doppler parameters appears to improve overall diagnostic performance. This observation is consistent with previous studies suggesting that a multiparametric Doppler approach provides superior risk stratification compared with a single Doppler parameter.[22-24]

The strengths of the present study include its prospective design,

standardized Doppler examination protocol and complete follow-up until delivery, allowing accurate assessment of maternal and fetal outcomes. However, the study has certain limitations. It was conducted at a single tertiary care centre with a relatively modest sample size, which may limit generalizability of the findings. Maternal biochemical markers and first trimester screening parameters were not incorporated into the predictive model. Current evidence suggests that combining uterine artery Doppler with maternal characteristics and biochemical markers may further improve prediction of placental-mediated disorders.[24,25]

Overall, the findings of the present study reinforce the growing evidence that second trimester uterine artery colour Doppler sonography is a valuable, inexpensive, reproducible and non-invasive screening tool for identifying pregnancies at increased risk of preeclampsia and fetal growth restriction. Early recognition of high-risk pregnancies facilitates closer antenatal surveillance, timely referral, appropriate preventive strategies where indicated, and better obstetric planning.

In conclusion, second trimester uterine artery Doppler demonstrated excellent diagnostic performance for predicting placental-mediated complications. Elevated mean uterine artery PI provided greater sensitivity, whereas persistent early diastolic notching demonstrated higher specificity. The excellent negative predictive value of both parameters indicates that a normal Doppler study reliably identifies women at low risk of developing preeclampsia and IUGR. Incorporation of uterine artery Doppler into routine anomaly scans between 18 and 24 weeks of gestation may improve early risk stratification and optimize maternal and fetal outcomes. Further multicentric studies involving larger populations and integration of maternal serum biomarkers with Doppler parameters are recommended to develop more robust predictive models for placental insufficiency-related disorders.[24,25]

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