SSR Institute of International Journal of Life Sciences
ISSN (O): 2581-8740 | ISSN (P): 2581-8732
Shukla *et al*., 2026
doi: 10.21276/SSR-IIJLS.2026.12.3.23

Original Article

open access

Prediction of Preeclampsia using Uterine Artery Doppler Indices and Placental Parameters

Rakesh Kumar Shukla[1], Vikesh Kumar Dubey[2], Archana Mishra[3], Nitesh Agarwal[4]*

[1]Associate Professor & HOD, Dept of Anatomy, Autonomous State Medical College, Kaushambi, UP, India
[2]Assistant Professor, Dept of Pediatrics, Autonomous State Medical College, Kaushambi, UP, India
[3]Associate Professor, Dept of Biochemistry, MLN Medical College, Prayagraj, UP, India
[4]Ex-Assistant Professor, Dept of Radio-diagnosis, Autonomous State Medical College, Kaushambi, UP, India

***Address for Correspondence:** Dr. Nitesh Agarwal, Ex-Assistant Professor, Dept of Radio-diagnosis, Autonomous State Medical College, Kaushambi, UP, India
E-mail: niteshagar92@gmail.com

Received: 04 Jan 2026/ Revised: 08 Mar 2026/ Accepted: 21 Apr 2026

ABSTRACT

Background: Uterine artery Doppler indices and placental morphometric parameters have emerged as useful tools for assessing abnormal placentation and impaired uteroplacental circulation. This study evaluates the diagnostic performance of uterine artery Doppler indices, placental quotient, and diastolic notch, individually and in combination, for predicting preeclampsia.

Methods: This is a hospital-based prospective study. A total of 100 pregnant women underwent transabdominal ultrasonography with uterine artery Doppler evaluation between 18–22 weeks of gestation. Mean pulsatility index (PI), resistance index (RI), placental volume, placental quotient, and presence of diastolic notch were assessed. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated using SPSS version 15.0.

Results: Out of 100 participants, 14 developed preeclampsia. PI demonstrated sensitivity of 41.20% and specificity of 95.25%, whereas RI showed sensitivity of 35.15% and specificity of 91.50%. The placental quotient demonstrated improved sensitivity (45.55%) with a specificity of 95.00%. The diastolic notch showed the highest specificity (97.66%) and PPV (81.75%), but low sensitivity (35.30%). The combined assessment of PI and placental quotient demonstrated the highest sensitivity (75.44%), specificity (90.54%), and NPV (94.45%), indicating superior screening performance compared to individual parameters.

Conclusion: The combination of pulsatility index and placental quotient significantly improves sensitivity while maintaining a high negative predictive value. A multimodal approach incorporating functional Doppler indices and structural placental parameters appears to be a more effective strategy for early prediction of preeclampsia in routine antenatal care.

Key-words: Preeclampsia; Uterine artery Doppler; Pulsatility index; Placental quotient; Diastolic notch

INTRODUCTION

Preeclampsia is a multisystem hypertensive disorder of pregnancy characterized by new-onset hypertension with proteinuria or end-organ dysfunction occurring after 20 weeks of gestation. It complicates approximately 5–8% of pregnancies worldwide.

How to cite this article
Shukla RK, Dubey VK, Mishra A, Agarwal N. Prediction of Preeclampsia using Uterine Artery Doppler Indices and Placental Parameters. SSR Inst Int J Life Sci., 2026; 12(3): 9846-9852.

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It remains a major cause of maternal and perinatal morbidity and mortality, particularly in low- and middle-income countries [1,2]. Despite advances in antenatal surveillance, early identification of women at risk for preeclampsia continues to be a significant clinical challenge.

The pathophysiology of preeclampsia is complex and multifactorial; however, abnormal placentation and impaired trophoblastic invasion of the maternal spiral arteries are widely accepted as central mechanisms [3]. Failure of physiological spiral artery remodeling results in increased uteroplacental vascular resistance, reduced placental perfusion, and subsequent placental ischemia. These changes precede the clinical manifestations of

doi: 10.21276/SSR-IIJLS.2026.12.3.23

preeclampsia by several weeks, providing a window for early prediction and intervention.

Uterine artery Doppler ultrasonography is a non-invasive method that allows functional assessment of uteroplacental circulation. Doppler indices such as the pulsatility index (PI) and resistance index (RI) reflect downstream placental resistance and have been extensively studied as predictors of preeclampsia [4]. Additionally, the presence of a persistent diastolic notch in the uterine artery waveform beyond mid-gestation is considered a qualitative marker of increased vascular resistance and defective placentation [5].

While Doppler indices provide functional information, placental morphometric parameters offer insight into the structural development of the placenta. Placental volume and placental quotient, derived by normalizing placental volume to gestational age, have been shown to correlate with placental insufficiency, fetal growth restriction, and hypertensive disorders of pregnancy [6]. A reduced placental quotient reflects inadequate placental growth and impaired fetomaternal exchange capacity.

Previous studies suggest that single-parameter screening tests have limited sensitivity for early prediction of preeclampsia, despite demonstrating high specificity [7]. Consequently, recent research has focused on combining functional Doppler parameters with placental morphometric indices to improve predictive accuracy [8]. The present study was undertaken to evaluate the diagnostic performance of uterine artery Doppler indices, placental quotient, and diastolic notch—both individually and in combination—for predicting preeclampsia.

MATERIALS AND METHODS

Research Design- The present study is a hospital-based prospective study conducted in the Department of Obstetrics and Gynecology in collaboration with the Department of Pathology at Rama Medical College and Hospital, Kanpur, Uttar Pradesh, India. The study was conducted over 21 months**,** from April 2016 to December 2017**.** The institution is a tertiary care teaching hospital catering to both urban and rural populations, with a high volume of antenatal and intrapartum cases, thereby providing an adequate and diverse study population.

Methodology- All pregnant women admitted to the labor ward or obstetric units of Rama Medical College and Hospital during the study period who fulfilled the inclusion criteria and subsequently delivered either by vaginal route or caesarean section were considered eligible for inclusion. A total of 100 pregnant women were enrolled in the study after applying the inclusion and exclusion criteria.

Inclusion Criteria- Pregnant women diagnosed with pre-eclampsia, eclampsia, or pre-eclampsia/eclampsia superimposed on previously undiagnosed chronic hypertension were included in the study. Only women who delivered vaginally or by caesarean section within the institution were enrolled to ensure complete outcome data.

Exclusion Criteria- Pregnant women with gestational diabetes mellitus, pre-existing diabetes mellitus, chronic or essential hypertension, chronic renal disease, coarctation of the aorta, pheochromocytoma, thyrotoxicosis, systemic lupus erythematosus or other connective tissue disorders, and multiple pregnancies were excluded from the study.

Procedure- The patient was put in supine position and then a detailed trans-abdominal ultrasonographic examination at 18 to 22 weeks to confirm the gestational age, presentation, liquor was done. Ultrasound machine (GE VOLUSON-730 EXPERT SERIES and PHILIPS HD 7XE) with a convex probe of 1-7 MHz with a high pass filter was used. Doppler mode was then switched on. With the transducer in the longitudinal plane, the external iliac artery was visualized at pelvic side wall with colour and spectral Doppler. The transducer was then angled medially towards the uterine artery, where it crosses the external iliac artery. Flow velocity waveforms of the right and left uterine arteries were recorded. When 3 or 4 waves of equal height were observed, the image was frozen and measurements were taken by the trace method/manually/automatic trace. Then Doppler indices were obtained directly from the machine. Parameters of Mean placental volume, Mean PI, Mean RI and presence or absence of diastolic notch in bilateral uterine arteries were analyzed, whereas Placental quotient was analyzed using the formula:

Placental Quotient= Placental Volume / Gestational Age

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Data Collection- Total of 100 pregnant women, 14 patients developed pre-eclampsia, thus a prevalence of 14% was noted. Out of 14 patients who developed pre-eclampsia, majority were primigravid women, which constituted 57.2% of the pre-eclampsia population. Placental quotient was calculated by normalizing placental volume to gestational age. Mean PI, Mean RI, and the presence or absence of a diastolic notch in bilateral uterine arteries were analyzed. Participants were followed until delivery for the development of preeclampsia and intrauterine growth restriction. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated.

Statistical Analysis- The collected information was summarized by using percentage for qualitative data. Sensitivity, Specificity, Positive predictive value, Negative predictive value was calculated using table. The statistical analysis was done using SPSS (Statistical Package for Social Sciences) version 15.0 statistical analysis software.

Ethical Considerations- The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Institutional ethical clearance was obtained from the Institutional Ethics Committee of Rama Medical College and Hospital, Kanpur, on 12.03.20216**,** before commencement of the study. Written informed consent was obtained from all participants before inclusion in the study. Confidentiality of patient information was strictly maintained throughout the study.

RESULTS

Out of the total 100 pregnant women included in the study, 14 women developed preeclampsia during follow-up. The diagnostic performance of uterine artery Doppler indices, placental quotient, and diastolic notch was evaluated using sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). The findings are presented in Table 1 and Fig. 1–2. As shown in Fig. 1, all individual Doppler parameters demonstrated high specificity but relatively low sensitivity for the prediction of preeclampsia. Among the individual parameters, placental quotient showed the highest sensitivity (45.55%), whereas diastolic notch demonstrated the highest specificity (97.66%). The combined assessment of pulsatility index (PI) and placental quotient showed a marked increase in sensitivity (75.44%) while maintaining high specificity (90.54%), indicating improved screening performance compared to individual parameters.

Fig. 1 demonstrates the comparative distribution of sensitivity and specificity among uterine artery Doppler parameters. The graphical analysis indicates that individual Doppler indices such as PI, RI, and diastolic notch have limited sensitivity despite high specificity. However, the combined PI and placental quotient approach substantially improved sensitivity, suggesting superior ability in identifying women at risk of developing preeclampsia.

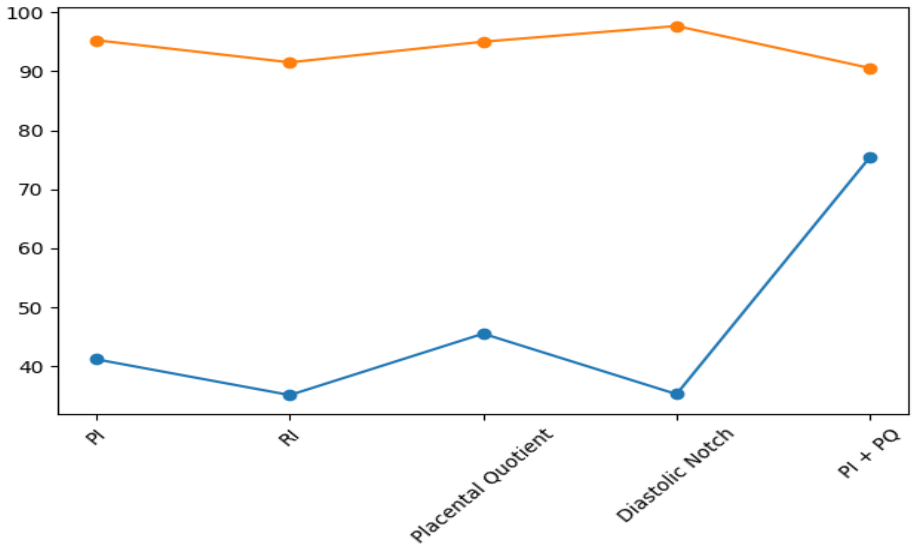

Fig. 1: Sensitivity (Blue line) and Specificity (Orange line) Comparison

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Table 1 presents the diagnostic accuracy of uterine artery Doppler parameters for the prediction of preeclampsia. Uterine artery pulsatility index (PI) demonstrated a sensitivity of 41.20% and specificity of 95.25%, with PPV and NPV of 44.50% and 94.35%, respectively. The resistance index (RI) showed sensitivity of 35.15% and a specificity of 91.50%, with PPV of 41.78% and an NPV of 92.81%. Placental quotient demonstrated comparatively better sensitivity (45.55%) along with high specificity (95.00%). The PPV and NPV for placental quotient were 50.17% and 95.85%, respectively. Diastolic notch showed the highest specificity (97.66%) and PPV (81.75%) among all parameters, although sensitivity remained low (35.33%). The combined assessment of pulsatility index and placental quotient demonstrated the highest sensitivity (75.44%) among all evaluated parameters, with specificity of 90.54%, PPV of 31.55%, and NPV of 94.45%. These findings indicate that combining functional Doppler indices with placental morphometric assessment improves the overall predictive performance for preeclampsia.

Table 1: Diagnostic Accuracy of Uterine Artery Doppler Parameters: Sensitivity, Specificity, PPV, and NPV

Parameters	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Pulsatility Index (PI)	41.20%	95.25%	44.50%	94.35%
Resistance Index (RI)	35.15%	91.50%	41.78%	92.81%
Placental Quotient	45.55%	95.00%	50.17%	95.85%
Diastolic Notch	35.33%	97.66%	81.75%	92.35%
Pulsatility Index + Placental Quotient	75.44%	90.54%	31.55%	94.45%

Table 1 clearly shows that the combined PI and placental quotient approach had the highest sensitivity, whereas the diastolic notch had the highest specificity and PPV. The high NPV observed across all parameters suggests good utility in excluding the development of preeclampsia in low-risk women.

Fig. 2 compares the positive predictive value (PPV) and negative predictive value (NPV) of all evaluated uterine artery Doppler parameters. The graph demonstrates that the diastolic notch had the highest PPV, indicating better confirmatory ability for predicting adverse pregnancy outcomes. Placental quotient and combined PI with placental quotient also demonstrated high NPV values, suggesting reliable exclusion of disease among test-negative women.

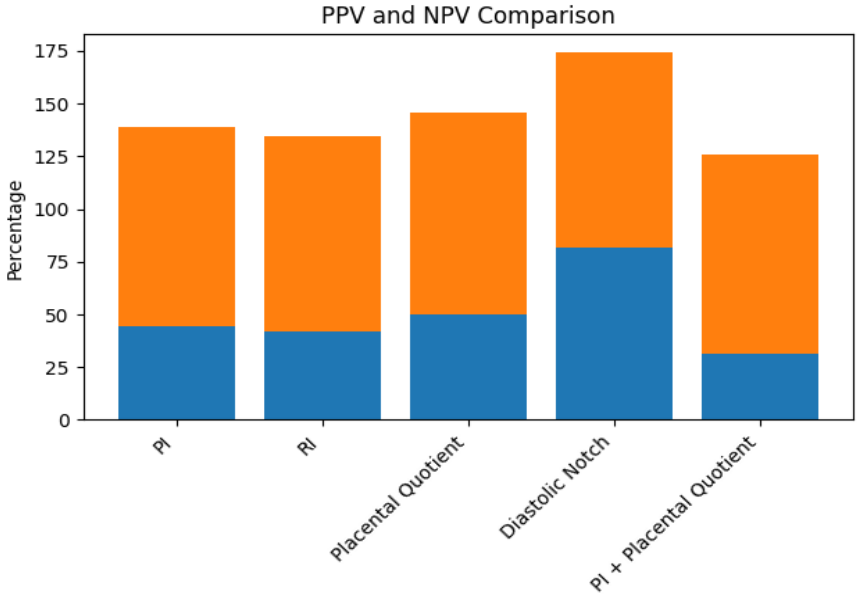

Fig. 2: Comparison of Positive and Negative Predictive Values of Uterine Artery Doppler Parameters

doi: 10.21276/SSR-IIJLS.2026.12.3.23

DISCUSSION

The present study evaluated the predictive performance of uterine artery Doppler indices, placental quotient, and diastolic notch for preeclampsia. The findings demonstrate that individual Doppler parameters, including pulsatility index and resistance index, exhibit high specificity but relatively low sensitivity. In contrast, the combined assessment of pulsatility index and placental quotient significantly improves sensitivity and maintains a high negative predictive value.

Uterine artery pulsatility index has been widely studied as a functional marker of uteroplacental resistance. In the present study, PI demonstrated high specificity but modest sensitivity, indicating its usefulness in confirming disease rather than serving as a standalone screening tool. Similar observations have been reported in previous studies, where elevated PI values were strongly associated with preeclampsia but failed to identify a substantial proportion of affected women when used alone [9,10]

The resistance index showed even lower sensitivity than PI, supporting earlier reports that RI is less robust at reflecting dynamic changes in uteroplacental circulation across the cardiac cycle [11]. This finding reinforces the preference for PI over RI in contemporary Doppler-based screening protocols.

The placental quotient demonstrated greater sensitivity and an excellent negative predictive value in the present study. This supports the concept that impaired placental growth is an early event in the pathogenesis of preeclampsia [12]. Structural placental parameters provide complementary information to Doppler indices by capturing placental developmental insufficiency rather than purely vascular resistance.

Diastolic notch exhibited the highest specificity and positive predictive value among all parameters studied. Persistent diastolic notch beyond mid-gestation reflects severe impairment of spiral artery remodeling and has been consistently associated with early-onset and severe preeclampsia [13]. However, its low sensitivity limits its role as a screening marker, a finding consistent with prior literature [14].

The most significant observation of this study is the substantial improvement in sensitivity achieved by combining pulsatility index with placental quotient. The combined parameter demonstrated the highest sensitivity and negative predictive value, indicating its superiority as a screening tool for preeclampsia. This multimodal approach aligns with recent evidence suggesting that integration of functional and structural placental markers enhances predictive performance [15,16].

High negative predictive value of the combined test is particularly valuable in clinical practice, as it allows reliable exclusion of disease in low-risk populations, thereby reducing unnecessary surveillance and anxiety. Similar benefits of combined screening strategies have been reported in first- and second-trimester prediction models [17].

The findings of this study support the evolving paradigm that preeclampsia prediction should not rely on a single marker. Instead, a combination of uteroplacental Doppler indices and placental morphometric assessment provides a more comprehensive evaluation of placental health and disease risk [18]. Future studies with larger sample sizes and integration of biochemical markers may further enhance predictive accuracy.

CONCLUSIONS

We conclude that the placental quotient showed greater sensitivity and a high negative predictive value, highlighting the importance of placental morphometric assessment in identifying women at risk of preeclampsia. The diastolic notch emerged as the most specific parameter with the highest positive predictive value, underscoring its usefulness as a confirmatory marker of impaired placentation; however, its low sensitivity limits its screening utility. Importantly, the combined assessment of uterine artery pulsatility index and placental quotient resulted in a marked improvement in sensitivity while maintaining high negative predictive value. This combined approach proved superior to individual parameters in identifying women at low risk of developing preeclampsia and may therefore serve as an effective screening strategy in routine antenatal care. Overall, the findings suggest that a multimodal approach incorporating both functional Doppler indices and structural placental parameters provides a more reliable and clinically meaningful method for early prediction of preeclampsia than single diagnostic markers.

ACKNOWLEDGMENTS

The authors express their acknowledgements to Dr R.K. Srivastava, Principal, Rama Medical College and Hospital,

doi: 10.21276/SSR-IIJLS.2026.12.3.23

Kanpur and all the concern faculty and staff for support and approval of this study.

CONTRIBUTION OF AUTHORS

Research Concept- Dr. Rakesh Kumar Shukla
Research design- Dr. Rakesh Kumar Shukla
Supervision- Dr. Rakesh Kumar Shukla
Materials- Dr. Rakesh Kumar Shukla
Data collection- Dr. Rakesh Kumar Shukla
Data analysis and interpretation- Dr. Rakesh Kumar Shukla
Literature search- Dr. Nitesh Agarwal
Writing article- Dr. Vikesh Kumar Dubey
Critical review- Dr. Archana Mishra
Article editing- Dr. Nitesh Agarwal
Final Approval- Rakesh Kumar Shukla[1], Vikesh Kumar Dubey[2], Archana Mishra[3], Nitesh Agarwal

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