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Role of uterine artery Doppler sonography in prediction and management of preeclampsia: a systematic review analysis of the recent 10-year evidence

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Abstract

Introduction: Preeclampsia (PE) is a leading cause of maternal and perinatal morbidity worldwide, and early identification of at-risk pregnancies remains a clinical priority. This systematic review synthesizes evidence from the past decade to evaluate the diagnostic performance and clinical utility of uterine artery Doppler (UAD) sonography in predicting and guiding management of PE.
Materials and Methods: We systematically searched PubMed, Embase, Scopus, Web of Science, Cochrane Library, and Google Scholar for English-language original studies published between 2016 and 2025 that evaluated UAD parameters for predicting PE. Two reviewers independently extracted data on study design, gestational timing, Doppler findings, and diagnostic accuracy using a standardized form.
Results: In this review of 18 observational and cohort studies published over the past decade, UAD sonography demonstrated moderate to high diagnostic accuracy for predicting PE, with parameters such as pulsatility index (PI), resistive index (RI), and the presence of a diastolic notch, alone or in combination, yielding sensitivities ranging from ~60% to 91% and specificities up to 99%. First-trimester assessments showed particular promise, especially when Doppler indices were combined with biochemical markers, and second-trimester measurements maintained predictive value for both early- and late-onset disease.
Conclusion: These findings pose UAD sonography as a noninvasive, cost-effective tool for early risk stratification of PE and support its incorporation into routine antenatal screening.
Registration: This study has been compiled based on the PRISMA checklist, and its protocol was registered on the PROSPERO (ID: CRD420251173030 and the Research Registry (UIN: reviewregistry2054) websites.

Introduction

Preeclampsia (PE) is a multisystem hypertensive disorder of pregnancy characterized by new-onset hypertension and proteinuria or end-organ dysfunction after 20 weeks of gestation (1,2). It complicates approximately 5–10% of pregnancies worldwide and is a leading cause of maternal and perinatal morbidity and mortality (1,3,4). The pathogenesis involves abnormal remodeling of the uteroplacental spiral arteries, leading to impaired placental perfusion, oxidative stress, and systemic endothelial dysfunction (4). Early identification of women at risk for PE is critical to allow timely intervention to reduce the incidence of PE and associated adverse neonatal outcomes (5)

Uterine artery Doppler (UAD) sonography non-invasively assesses uteroplacental blood flow by measuring indices such as the pulsatility index (PI), resistive index (RI), and the presence of early diastolic notching (6,7). These parameters reflect downstream vascular resistance within the uterine circulation and correlate with the adequacy of spiral artery remodeling (8). When trophoblast invasion is deficient, elevated PI and RI values and persistent notching are observed, indicating increased impedance to blood flow (6,9). Doppler waveform analysis

Key point

The findings from this systematic review endorse the routine use of uterine artery Doppler (UAD) sonography as a noninvasive, cost-effective screening tool in antenatal care to identify pregnancies at risk for preeclampsia (PE) early, enabling timely monitoring and intervention. Implementing UAD in routine prenatal screening, especially in low-resource settings, could improve maternal and fetal outcomes by facilitating early risk stratification. Future clinical focus should target standardizing Doppler indices cutoffs, integrating Doppler with multimodal screening approaches, and evaluating the effects of Doppler-guided management on complications related to PE to optimize care pathways and reduce perinatal morbidity and mortality.

between the first and second trimesters provides insight into placental development and has been extensively studied as a surrogate marker of placental insufficiency (9).

The UAD sonography plays a pivotal role in both predicting and managing PE by non-invasively evaluating uteroplacental blood flow impedance through indices such as the PI, RI, and the presence of early diastolic notching (10). Elevated Doppler indices in the first and mid-trimester correlate with impaired spiral artery remodeling and identify women at high risk for early-onset PE, enabling initiation of prophylactic measures such as low-dose aspirin and increased surveillance (9). When integrated into multivariable risk models alongside maternal history and biochemical markers, Doppler sonography improves prediction sensitivity for early-onset disease, facilitating tailored antenatal care and timely delivery planning to optimize maternal and fetal outcomes (10).

Objectives

The objective of this systematic review is to systematically evaluate and synthesize the evidence from the past decade regarding the role of UAD sonography in the prediction and management of PE. Specifically, the review aims to assess the diagnostic accuracy, sensitivity, specificity, and clinical utility of various UAD parameters, such as PI, RI, systolic/diastolic (S/D) ratio, and diastolic notch, across different gestational stages and populations, to determine their effectiveness as non-invasive screening tools for early detection and risk stratification of PE.

Materials and Methods

Study design

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (11). A PRISMA flow diagram was used to illustrate the study selection process, including identification, screening, eligibility, and inclusion stages. This systematic review examined all types of original research studies that evaluated and synthesized the evidence from the past decade regarding the role of UAD sonography in the prediction and management of PE published between January 2016 and October 2025.

Search strategy

For the systematic review, the search strategy included querying databases such as PubMed, Embase, Scopus, Web of Science, Cochrane Library, and Google Scholar for publications from 2016 to 2025. This search strategy combined relevant keywords and controlled vocabulary related to pregnancy and its complications, including pregnancy, pregnancy complications, pregnancy-induced hypertension, and preeclampsia, alongside terms specific to the diagnostic tool, such as uterine artery, Doppler ultrasonography, pulsatility index, resistive index, diastolic notch, and prenatal diagnosis. The terms were combined using Boolean operators like AND and OR.

The PubMed search protocol is described as follows:

(((((((((Pregnancy) OR (Pregnancy complications)) OR (Pregnancy-induced hypertension)) AND (Preeclampsia)) AND (Uterine artery)) OR (Doppler ultrasonography)) OR (Pulsatility index)) OR (Resistive index)) OR (Diastolic notch)) OR (Prenatal diagnosis).

PICO component

- Population (P): Pregnant women across various gestational ages (first to third trimester), including both low-risk and high-risk groups.
- Intervention /Exposure (I/E): The UAD sonography parameters, including assessment of PI, RI, S/D ratio, and diastolic notch.
- Comparison (C): Normal Doppler findings or alternative biomarkers (e.g., serum ß-hCG).
- Outcome (O): Prediction and early diagnosis of PE, including sensitivity, specificity, and diagnostic accuracy.

Eligibility criteria

Inclusion criteria

- Original research articles published in peer-reviewed journals between 2016 and 2025.
- Observational, case-control, cohort, randomized controlled trials, cross-sectional, or longitudinal designs.
- Use of UAD sonography for predicting or managing PE.
- Reported outcomes, including sensitivity, specificity, or diagnostic accuracy.
- Full-text available in English.

Exclusion criteria

- Case reports, editorials, reviews, or conference abstracts
- Studies not involving Doppler sonography or not focused on PE
- Non-human studies
- Low-quality studies

Quality assessment

The quality assessment of the included studies was conducted using the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guideline (12), which provides a checklist of essential items for evaluating observational research. This assessment guideline comprises 22 items, each scored up to 2 points, culminating in a total score that signifies the overall quality of the study. Based on this total, studies are classified into three categories: those with a score below 15 are considered of poor quality, scores between 16 and 30 indicate moderate quality, and scores exceeding 30 denote high-quality research. Each study was reviewed for clarity in reporting objectives, study design, setting, participant selection, variables, data sources, bias, statistical methods, and outcome measures. Particular attention was given to the transparency of Doppler measurement protocols, gestational timing, and diagnostic criteria for PE. Overall, all included studies demonstrated moderate to high adherence to STROBE criteria.

Data extraction

Data were independently extracted by two reviewers using a standardized form. Extracted information included:

- First author and publication year
- Study design and location
- Sample size and population characteristics
- Gestational age at assessment
- Sonographic parameters used (PI, RI, S/D ratio, diastolic notch)
- Study objectives and outcomes
- Sensitivity, specificity, and predictive values
- Conclusions drawn by the authors

Discrepancies between reviewers were resolved through discussion or consultation with a third reviewer.

Results

Following the PRISMA framework, our database search initially identified 1,178 records. After removing 614 duplicates, 564 unique records were screened by title and abstract, leading to the exclusion of 406 studies. Full texts were retrieved for 158 articles, of which 97 were unavailable, leaving 61 studies for eligibility assessment. Of these, 43 were excluded due to non-original design, focus on alternative diagnostic methods, non-relevant outcome data, or poor reporting quality. Ultimately, 18 studies satisfied all inclusion criteria and were incorporated into the systematic review (Figure 1).

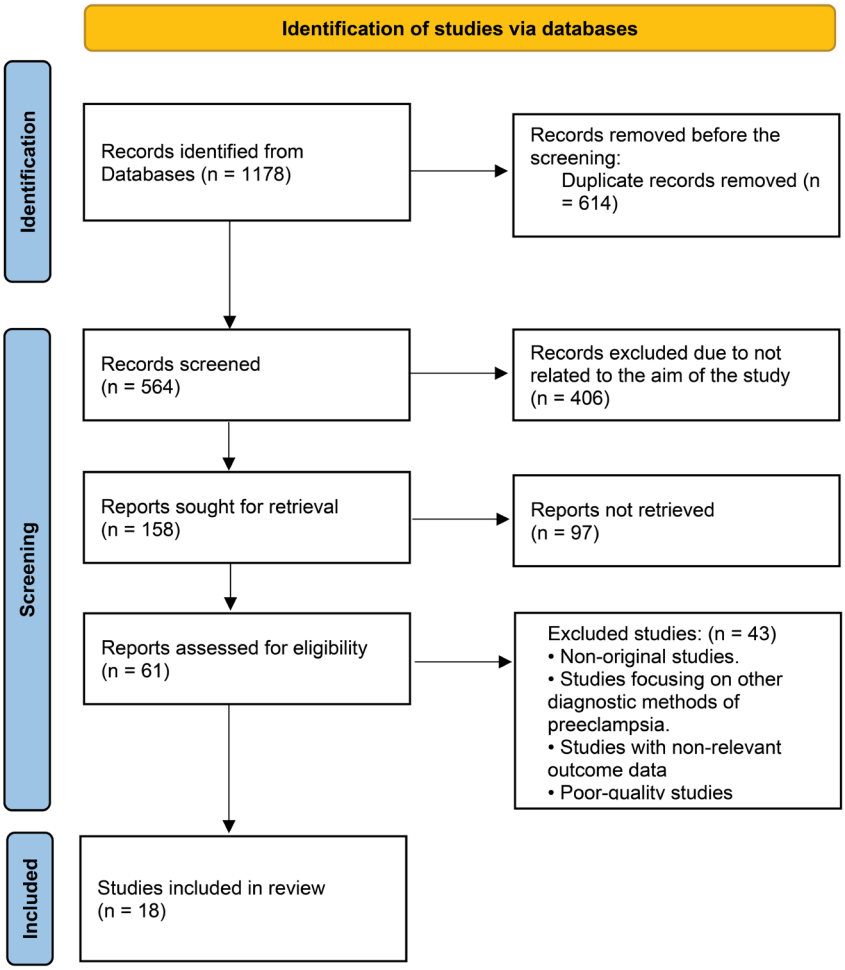

Figure 1. The PRISMA flowchart of study selection.

Eighteen observational, cross-sectional, and cohort studies published between 2017 and 2025 evaluated UAD sonography in over 3,500 pregnant women at gestational ages ranging from 11 to 32 weeks. Across these studies, key Doppler parameters, including PI, RI, S/D ratio, diastolic notch (unilateral and bilateral), and notch depth index, were measured, often alongside serum β-hCG. The primary aim was early prediction and screening of PE in both high- and low-risk populations. Elevated PI and RI values, persistent notching, and combined Doppler indices consistently correlated with later development of PE, demonstrating sensitivities of approximately 60–91% and specificities up to 99%; first-trimester PI thresholds (≥1.5–≥1.91) achieved area under the curve (AUC) values up to 0.896. These findings uniformly support UAD as a reliable, noninvasive, and cost-effective tool for early risk stratification of PE, particularly when integrated into multimodal screening strategies (Table 1).

Discusion

The findings from this systematic review indicated that UAD sonography has an acceptable diagnostic accuracy for the diagnosis and prediction of pre-eclampsia in pregnant women. Recent evidence from systematic reviews and meta-analyses in line with our findings supports this idea that UAD sonography, particularly the measurement of the PI, offers acceptable diagnostic accuracy for predicting PE in pregnant women. Our findings are well-aligned with foundational studies such as the meta-analysis by Cnossen et al, which established that increased uterine artery PI, alone or in combination with diastolic notching, provides the highest predictive value for PE, particularly when measured in the second trimester (9). A large-scale review and pooled analyses have consistently found moderate sensitivity (0.58) and high specificity (0.87) for PI in predicting PE (31). In a meta-analysis study by Cao et al, the pooled RI showed a sensitivity of 0.73 and specificity of 0.90 (AUC 0.91), while the PI demonstrated a sensitivity of 0.65 and specificity of 0.88, confirming moderate-to-high predictive performance of these indices for PE (32). Subgroup analyses indicate that PI's diagnostic accuracy holds across both high- and low-risk populations, and between first and second trimester screenings; although the highest detection rates have generally been reported for early-onset and preterm PE, aligning with hypotheses that abnormal placentation underlies these cases (33-36). Meta-analysis studies focusing on placental-side Doppler revealed even greater accuracy: first-trimester PI cutoffs of 1.91 achieved 100% sensitivity and 96.3% specificity for early-onset PE (37). These findings corroborate our review, highlighting that both bilateral and placental-side Doppler measurements enhance early detection of PE.

In sum, contemporary evidence demonstrates that UAD sonography, specifically via PI assessment, achieves moderately high sensitivity and robust specificity for predicting PE, particularly early-onset and preterm disease, when applied in appropriately timed and standardized protocols. Its clinical value is maximized when incorporated into multifactorial algorithms alongside maternal risk factors and serum biomarkers, forming the foundation of current international guideline recommendations and leading screening models (33,36,38-40). While UAD alone may not suffice for broad, population-level screening, especially for late-onset or mild forms, it is a powerful adjunctive tool for stratifying risk, informing surveillance, and targeting preventive therapies such as low-dose aspirin, with scalable implementation possible even in resource-constrained settings (31,33,36,39). Reflecting methodological advances, recent studies stress the importance of protocol standardization, gestational age, specific normalization, and local population validation to reduce heterogeneity and broaden generalizability. Future research should be directed at refining risk thresholds, integrating novel biomarkers and machine learning for individualized early-pregnancy prediction, and evaluating cost-effectiveness and feasibility in diverse care environments. Ultimately, UAD, ideally as part of a comprehensive predictive framework, should be seen as a key component in the timely identification and management of PE risk, with a high potential for improving maternal and perinatal outcomes globally.

Overall, our study concludes that UAD is a valuable non-invasive tool for early prediction of PE, with RI and PI demonstrating acceptable sensitivity and specificity across trimesters. Its greatest strength lies in second-trimester assessment and placental-side measurements, which yield the highest diagnostic accuracy. Integration of UAD into routine prenatal screening protocols, especially for high-risk populations, can facilitate timely identification of women at risk and implementation of preventive strategies.

Limitations of the study

Several limitations temper the conclusions of this review. The included studies varied widely in design, sample size, population risk profiles, gestational age at assessment, Doppler parameters, and cutoff values, which precluded quantitative synthesis and limited comparability. Most data derive from observational cohorts without randomized controls and few standardized protocols, raising concerns about selection bias, confounding, and measurement variability. Publication bias toward positive findings and restriction to English-language articles may have excluded relevant evidence. Finally, long-term maternal and neonatal outcomes following Doppler-guided interventions remain underreported, limiting assessment of clinical impact.

Conclusion

The results indicated that UAD sonography demonstrates moderate to high diagnostic accuracy in predicting PE, with combined indices such as PI, RI, and the presence of

Table 1. The overall information of the included studies in this systematic review

First author (Publication year)	Study design	Publication place	Sample size and population	Time of assessment	Sonographic parameter	Objective	Results	Overall outcomes
Reddy VPK (2018) (13)	Observational	India	100 antenatal women	16–24 weeks of gestation	PI, RI, and diastolic notch	Early prediction of PE using UAD.	19% had abnormal Doppler findings; among those, 84.2% developed PE. Sensitivity and specificity for PE were 84.2% and 83%.	UAD sonography is a good tool for early diagnosis of PE.
Mohammed O (2022) (14)	Cohort	Egypt	388 pregnant women	First trimester (11 to 14 weeks of gestation)	PI, RI, and diastolic notch	To evaluate the efficacy of maternal UAD versus serum β-hCG during the first trimester in predicting PE.	Women who developed PE had significantly higher uterine PI and RI and lower β-hCG levels. Uterine PI and RI showed higher specificity than β-hCG for predicting PE. Combined use of Doppler and β-hCG improved sensitivity (81% for PE) compared to individual tests.	UAD is a more specific screening tool than serum β-hCG for predicting PE. Combining both methods enhances predictive accuracy, especially in early pregnancy.
Dhakar V (2017) (15)	Prospective observational	India	100 high-risk pregnant women	26–32 weeks of gestation	S/D ratio, RI, and diastolic notch	Evaluate the predictive value of uterine and umbilical artery Doppler findings for PE and compare the efficacy of both Doppler modalities.	5% of participants developed PE. Abnormal UAD was more predictive than umbilical Doppler alone. Diastolic notch had the highest sensitivity (60%) among uterine indices. Combined abnormal uterine and umbilical Doppler had a 100% association with PE.	Doppler ultrasound, particularly the uterine artery notch and umbilical artery S/D ratio, is useful in predicting PE. Umbilical artery Doppler was found to be more predictive overall.
Arjmand A (2024) (16)	Cross-sectional	Pakistan	125 pregnant women	Second trimester	UAD notch	To determine the diagnostic accuracy of UAD for PE screening.	70% of preeclamptic patients had positive UAD findings. The UAD showed a significant association with PE, with a sensitivity of 75% and a specificity of 86%.	UAD sonography is a reliable and non-invasive tool for the early prediction of PE.
Pereira PM (2020) (17)	Prospective cohort	India	100 singleton pregnancies	18–22 weeks of gestation	PI, RI, and diastolic notch	To evaluate the role of UAD in predicting PE.	14% of participants developed PE. The sensitivity and specificity of PI, RI, and diastolic notch were (37.5%, 21.4%, 35.7%) and (90.6%, 91.8%, 98.8%), respectively.	UAD, especially the diastolic notch, is a useful non-invasive tool for predicting PE.
Oancea M (2020) (18)	Prospective longitudinal	Romania	120 pregnant women	First trimester (11–14 weeks of gestation)	PI and presence of bilateral diastolic notch	To evaluate the potential of first-trimester UAD ultrasonography for early prediction of PE in at-risk pregnant women, especially in low-resource settings.	PI alone predicted PE with 61.5% sensitivity and 63.8% specificity. Adding a bilateral notch slightly improved prediction to 65.4% sensitivity and 66% specificity.	UAD is a useful non-invasive screening tool for predicting PE in high-risk pregnancies, particularly in settings with limited access to advanced biomarker testing.
Patwa PA (2022) (19)	Prospective cross-sectional	India	195 pregnant women	During antenatal care, primarily in the second trimester	PI, RI, S/D ratio, and diastolic notch	To determine and compare the accuracy of UAD indices in predicting PE and adverse pregnancy outcomes among women with clinical suspicion of PE.	PE was observed in 34.9% of participants. PI >1.2 had the highest predictive validity, with a sensitivity of 64.71% and specificity of 71.65%. The S/D >2.85 also showed moderate predictive power.	Doppler findings, especially PI >1.2, are effective in predicting severe PE and adverse outcomes, making UAD a valuable screening tool in both high- and low-risk pregnancies.

Table 1. Continued

First author (Publication year)	Study design	Publication place	Sample size and population	Time of assessment	Sonographic parameter	Objective	Results	Overall outcomes
Chilumula K (2021) (20)	Prospective observational study	India	60 women (30 early-onset and 30 late-onset severe preeclampsia)	During pregnancy	PI, RI, and diastolic notch	To assess the correlation of UAD findings with maternal and neonatal outcomes in early- and late-onset preeclampsia with severe features	Abnormal RI, PI, and diastolic notch were found in the early-onset group (63.3%, 30%, and 80%) and the late-onset group (50%, 33%, and 40%), respectively.	UAD can serve as a surrogate marker for risk stratification in severe preeclampsia, especially in early-onset cases.
Mallaiah PK (2022) (21)	Observational	India	120 antenatal women	16–24 weeks of gestation	PI, RI, and diastolic notch	Evaluate the sensitivity of UAD in the early detection of PE.	23 women (19.17%) had abnormal Doppler findings; among them, 82.6% developed PE. Sensitivity and specificity for PE were 83% and 85%.	UAD analysis, specifically elevated PI, RI, and persistent notching, is a useful non-invasive screening tool for early detection of PE.
Tarifi AO (2023) (22)	Prospective cohort	Saudi Arabia	138 pregnant women	11–14 weeks of gestation	PI, RI, and diastolic notch	To evaluate the efficacy of UAD ultrasound in predicting PE during the first trimester.	18% developed PE; 56% of these had abnormal Doppler findings. The sensitivity and specificity were 80% and 84%.	First-trimester UAD ultrasound is effective in early PE prediction.
Thakur M (2019) (23)	Prospective observational	India	100 pregnant women	Second trimester (18–24 weeks of gestation)	PI, RI, S/D ratio, and diastolic notch	To assess the role of UAD waveform analysis in the second trimester for predicting PE in high-risk pregnancies.	Elevated RI in the second trimester was significantly associated with later development of PE. Sensitivity and specificity of UAD were 84% and 55%, respectively.	UAD findings in the second trimester can serve as a moderately strong predictor for PE in high-risk pregnancies.
Jayson J (2021) (24)	Prospective cohort	India	280 pregnant women	First trimester (11–14 weeks of gestation)	PI	Assessing first-trimester UAD in predicting adverse pregnancy outcomes.	25% had abnormal PI (≥1.5); 40% of these developed complications. Significant associations were found between PI and PE.	First-trimester UAD is a valuable, non-invasive tool for predicting adverse pregnancy outcomes, especially PE.
Shahid N (2021) (25)	Retrospective observational	Pakistan	75 high-risk pregnant women	20–26 weeks of gestation	RI and diastolic notch	To determine the role of UAD ultrasound in predicting PE.	Out of 75 women, 56 (76.7%) developed PE. Abnormal RI was observed in 72% and Uterine artery notching was present in 56%. The sensitivity and specificity of UAD ultrasound for predicting PE were 71.4% and 26.3%, respectively. Notching had a higher specificity (89%) than RI alone.	UAD ultrasound, particularly uterine artery notching, is a useful screening tool for predicting PE in high-risk women.
Panda S (2023) (26)	Prospective cohort	India	360 low-risk pregnant women	14–20 and 20–28 weeks of gestation	PI, RI, NDI, and diastolic notch	Assessing the prognostic value of UAD indices for predicting PE in low-risk pregnancies.	15.5% of participants developed PE. Bilateral notching and NDI > 0.14 were the most predictive markers. PI showed moderate sensitivity and high specificity, while RI had low sensitivity but high specificity. Combined indices (PI + RI + Notch) yielded the highest diagnostic accuracy (95%) and relative risk of 13.72.	UAD indices, especially PI, bilateral notching, and NDI > 0.14, are effective predictors of PE in low-risk pregnancies, particularly during the 14–20 week period.

Table 1. Continued

First author (Publication year)	Study design	Publication place	Sample size and population	Time of assessment	Sonographic parameter	Objective	Results	Overall outcomes
Mohamed HME (2021) (27)	Prospective observational	Egypt	109 pregnant women	First trimester (11–14 weeks of gestation)	PI	To assess the relationship between first-trimester uterine artery PI and the development of early-onset PE in high-risk pregnant women.	11% of participants developed early-onset PE. Mean PI was significantly higher in the PE group (2.01) vs. the control (1.71). Best cutoff for PI was ≥ 2.03, with sensitivity 75%, specificity 79%, and accuracy 79%.	First-trimester UAD is a reliable, noninvasive screening tool for predicting early-onset PE in high-risk pregnancies.
Sharma N (2018) (28)	Cohort	India	697 pregnancies followed (743 waveforms obtained)	Second trimester (20–23 weeks of gestation)	PI	To study maternal risk factors and UAD waveform in mid-trimester singleton pregnancies to predict PIH.	PIH occurred in 8.18% of pregnancies (57 cases: 25 early-onset, 32 late-onset). High PI (>1.55) was significantly associated with PIH (Sensitivity: 91.23%, Specificity: 99.06%).	UAD sonography can detect PIH in its preclinical stage, especially early-onset cases.
Medjedovic E (2021) (29)	Retrospective and prospective observational	Bosnia and Herzegovina	80 pregnant women	Second trimester (after 22 weeks of gestation)	Presence of notch sign	To investigate risk factors for PE from history, laboratory, and Doppler ultrasound findings.	The presence of the notch sign was an independent predictor for PE and had a sensitivity of 88.89% and specificity of 47.62%.	Doppler sonography in the second trimester is a valuable tool for early prediction of PE, and the notch sign, especially when bilateral, is a strong predictor.
Parry AH (2025) (30)	Observational	India	342 pregnant women	First trimester (11–14 weeks gestation)	PI, RI, and diastolic notch	To assess the role of UAD in screening for PE during the first trimester of pregnancy.	12.28% of participants developed PE. Mean PI was significantly higher in the PE group (1.9455) versus the control (1.474). Best PI cutoff: ≥ 1.622 had sensitivity 75%, specificity 86%, accuracy 80.5%, and AUC 0.896. RI also showed strong predictive value (AUC 0.920). Bilateral notching was present in 88% of PE cases versus 16% in controls.	First-trimester UAD is a reliable, noninvasive tool for early prediction of PE.

PI: Pulsatility index; RI: Resistive index; UAD: Uterine artery Doppler; PE: Pre-eclampsia; NDI: Notch depth index; S/D: Systolic/Diastolic; PIH: Pregnancy-induced hypertension; AUC: Area under the curve; ROC: Receiver operating characteristic.

a diastolic notch showing sensitivities from approximately 60% to 91% and specificities reaching up to 99%. These findings support the routine integration of UAD into antenatal screening programs as a noninvasive, cost-effective tool for early risk stratification. Future research should aim to establish standardized Doppler cutoff values, develop multimodal screening algorithms, and assess how Doppler-guided interventions influence maternal and fetal outcomes, thereby improving the management and prognosis of PE.

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Authors' contribution

Conceptualization: Hamideh Rahbarinezhad and Zeinab Zamanpour.
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Project management: Sina Salem Ahim and Zahra Hamidi Madani.
Supervision: All authors.
Visualization: Sadaf Rassouli and Zeinab Zamanpour.
Writing–original draft: All authors.
Writing–review and editing: All authors.

Conflicts of interest

The authors declared no conflict of interest.

Declaration of generative artificial intelligence (AI) and AI-assisted technologies in the writing process

During the preparation of this work, the authors utilized AI tools (Perplexity and Copilot) to refine grammar points and language style in writing. Subsequently, the authors thoroughly reviewed and edited the content as necessary, assuming full responsibility for the accuracy and content of the publication.

Ethical issues

This investigation has been compiled based on the PRISMA checklist, and its protocol was registered on the PROSPERO website with (ID: CRD420251173030) and Research Registry with Unique Identifying Number [UIN] of reviewregistry2054. Besides, the authors have observed ethical issues (including plagiarism, data fabrication, and double publication).

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References

1. Cushen SC, Goulopoulou S. New Models of Pregnancy-Associated Hypertension. Am J Hypertens. 2017;30:1053–62. doi: 10.1093/ajh/hpx063.
2. Anderson CM, Schmella MJ. CE: Preeclampsia: Current Approaches to Nursing Management. Am J Nurs. 2017;117:30–8. doi: 10.1097/01.NAJ.0000526722.26893.b5.
3. Hu XQ, Zhang L. Mitochondrial dysfunction in the pathogenesis of preeclampsia. Curr Hypertens Rep. 2022;24:157–72. doi: 10.1007/s11906-022-01184-7.
4. Lopez-Mendez MA, Martinez-Gaytan V, Cortes-Flores R, Ramos-Gonzalez RM, Ochoa-Torres MA, Garza-Veloz I, et al. Doppler ultrasound evaluation in preeclampsia. BMC Res Notes. 2013;6:477. doi: 10.1186/1756-0500-6-477.
5. Cheng X, Jiang Y, Chen X, Huang C, Li S. Early age at menarche is associated with an increased risk of preeclampsia and adverse neonatal outcomes: a 6-year retrospective study. Arch Gynecol Obstet. 2024;310:807–15. doi: 10.1007/s00404-023-07256-6.
6. Elmetwally M, Rohn K, Meinecke-Tillmann S. Noninvasive color Doppler sonography of uterine blood flow throughout pregnancy in sheep and goats. Theriogenology. 2016;85:1070–9.e1. doi: 10.1016/j.theriogenology.2015.11.018.
7. Kang X, Wang T, He L, Xu H, Liu Z, Zhao A. Effect of Low-Dose Aspirin on Midluteal Phase Uterine Artery Blood Flow in Patients With Recurrent Pregnancy Loss. J Ultrasound Med. 2016;35:2583–7. doi: 10.7863/ultra.16.01020.
8. Clark AR, James JL, Stevenson GN, Collins SL. Understanding abnormal uterine artery Doppler waveforms: A novel computational model to explore potential causes within the utero-placental vasculature. Placenta. 2018;66:74–81. doi: 10.1016/j.placenta.2018.05.001.
9. Cnossen JS, Morris RK, ter Riet G, Mol BW, van der Post JA, Coomarasamy A, et al. Use of uterine artery Doppler ultrasonography to predict pre-eclampsia and intrauterine growth restriction: a systematic review and bivariable meta-analysis. CMAJ. 2008;178:701–11. doi: 10.1503/cmaj.070430.
10. Rk K, Ramakrishnan KK, Gunasekaran D, Aram A, Natarajan P. Role of Uterine Artery Doppler Study Between 11 and 14 Weeks as a Predictor of Preeclampsia. Cureus. 2024;16:e63591. doi: 10.7759/cureus.63591.
11. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ. 2009;339:b2535. doi: 10.1136/bmj.b2535.
12. Von Elm E, Altman D, Egger M, Pocock S, Gøtzsche P, Vandenbroucke J, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. Int J Surg. 2014;12:1495–9. doi: 10.1016/j.ijsu.2014.07.013.
13. Reddy VPK, Manasvi V, Giri A. Role of uterine artery Doppler in early prediction of pre-eclampsia and intrauterine growth restriction at 16-24 weeks of gestation. India J Obstet Gynaecol Res. 2018;5:395–8. doi: 10.18231/2394-2754.2018.0091.
14. Mohammed O, Magdy A, Askalany A, Salem S, Abdel-Rasheed M, Ghobary H, et al. Role of maternal uterine artery doppler versus Serum β-hCG during the first trimester in the prediction of preeclampsia and IUGR. J Diagn Med Sonogr. 2022;38:111–8. doi: 10.1177/87564793211051986.
15. Dhakar V, Naz S. Role of uterine and umbilical artery doppler assessment of the uteroplacental circulation in predicting pre-eclampsia: comparison between different doppler parameters. Int J Reprod Contracept Obstet Gynecol. 2017;6:4314–8. doi: 10.18203/2320-1770.ijrcog20174134.
16. Arjmand A, Umer A, Imran S, Ghafoor R, Ubaid F, Butt K. The Uterine Artery Doppler's Diagnostic Accuracy in the Second Trimester for Preeclampsia Screening. Pak J Med Res. 2024;63:135–9.
17. Pereira PM, Lakshmi MM, Pereira VA. Role of uterine artery doppler at 18-22 weeks in the prediction of pre-eclampsia: a prospective study. Int J Reprod Contracept Obstet Gynecol. 2020;9:4131. doi: 10.18203/2320-1770.ijrcog20204300.
18. Oancea M, Grigore M, Ciortea R, Diculescu D, Bodean D, Bucuri C, et al. Uterine Artery Doppler Ultrasonography for First Trimester Prediction of Preeclampsia in Individuals at Risk from Low-Resource Settings. Medicina (Kaunas). 2020;56:428. doi: 10.3390/medicina56090428.
19. Patwa PA, Mishra GV, Singh RK, Manoj M, Dhande RP, Singh S, et al. Prediction of preeclampsia and adverse pregnancy

outcome on the basis of uterine artery doppler. J Datta Meghe Inst Med Sci Univ. 2022;17:7–13. doi: 10.4103/jdmimsu.jdmimsu_36_22.
20. Chilumula K, Saha PK, Muthyala T, Saha SC, Sundaram V, Suri V. Prognostic role of uterine artery Doppler in early- and late-onset preeclampsia with severe features. J Ultrasound. 2021;24:303–10. doi: 10.1007/s40477-020-00524-0.
21. Mallaiah PK, Yeli RK, Sajjan S, Jeevangi B, Dhanya S, Pyadala N. Sensitivity of uterine artery Doppler in early detection of preeclampsia and fetal growth restriction. J Cardiovasc Dis Res. 2022;13:2068–74.
22. Tarifi AO, Akhtar N, Atito A, Ayman A. Early Prediction of Preeclampsia: The Role of Doppler Ultrasound in Improving Maternal and Fetal Outcomes. J Fatima Jinnah Med Univ. 2023;17:174–9. doi: 10.37018/JFJMU/TAO/4590.
23. Thakur M, Mehra R. Role of second trimester uterine artery doppler for the prediction of preeclampsia in high risk pregnancy. Int J Reprod Contracept Obstet Gynecol. 2019;8:906–12.
24. Jayson J, Mandrelle K, Dhar T, Singla S. First trimester uterine artery Doppler screening in the prediction of adverse pregnancy outcomes. Int J Reprod Contracept Obstet Gynecol. 2021;10:3934. doi: 10.18203/2320-1770.ijrcog20213864.
25. Shahid N, Masood M, Bano Z, Naz U, Hussain SF, Anwar A, et al. Role of Uterine Artery Doppler Ultrasound in Predicting Pre-Eclampsia in High-Risk Women. Cureus. 2021;13:e16276. doi: 10.7759/cureus.16276.
26. Panda S, Jante V, Das A, Shullai W, Sharma N, Basu R, et al. Unveiling Preeclampsia Prognosis: Uterine Artery Doppler Indices in Low-Risk Pregnancies. Cureus. 2023;15:e46060. doi: 10.7759/cureus.46060.
27. Mohamed HME, Badawy AMM, Ismail AG. Screening of High-Risk Patient by Uterine Artery Doppler Analysis in The 1st Trimester to Predict Early Onset Pre-Eclampsia. Egypt J Hosp Med. 2021;84:1852–7. doi: 10.21608/ejhm.2021.177620.
28. Sharma N, Jayashree K, Nadhamuni K. Maternal history and uterine artery wave form in the prediction of early-onset and late-onset preeclampsia: A cohort study. Int J Reprod Biomed. 2018;16:109–14.
29. Medjedovic E, Kurjak A. The Importance of Doppler Analysis of Uterine Circulation in Pregnancy for a Better Understanding of Preeclampsia. Med Arch. 2021;75:424–30. doi: 10.5455/medarh.2021.75.424-430.
30. Parry AH, Hassan I, Rehaman B, Bhat SA, Mir S, Khan NA, et al. Uterine artery Doppler at 11-14 weeks of gestation in the prediction of preeclampsia: An observational study. World J Radiol. 2025;17:112173. doi: 10.4329/wjr.v17.i9.112173.
31. Liu Y, Xie Z, Huang Y, Lu X, Yin F. Uterine arteries pulsatility index by Doppler ultrasound in the prediction of preeclampsia: an updated systematic review and meta-analysis. Arch Gynecol Obstet. 2024;309:427–37. doi: 10.1007/s00404-023-07044-2.
32. Cao L, He B, Zhou Y, Chen T, Gao Y, Yao B. Utility of uterine artery Doppler ultrasound imaging in predicting preeclampsia during pregnancy: a meta-analysis. Med Ultrason. 2024;26:197–204. doi: 10.11152/mu-4355.
33. Onwudiwe N, Yu CK, Poon LC, Spiliopoulos I, Nicolaides KH. Prediction of pre-eclampsia by a combination of maternal history, uterine artery Doppler and mean arterial pressure. Ultrasound Obstet Gynecol. 2008;32:877–83. doi: 10.1002/uog.6124.
34. Bucak M, Turan S, Turan OM. Stepwise risk stratification of early-onset preeclampsia: integrating mid-trimester uterine artery doppler and maternal comorbidities. BMC Pregnancy Childbirth. 2025;25:758. doi: 10.1186/s12884-025-07864-x.
35. Melchiorre K, Wormald B, Leslie K, Bhide A, Thilaganathan B. First-trimester uterine artery Doppler indices in term and preterm pre-eclampsia. Ultrasound Obstet Gynecol. 2008;32:133–7. doi: 10.1002/uog.5400.
36. Ronzoni S, Rashid S, Santoro A, Mei-Dan E, Barrett J, Okun N, et al. Preterm preeclampsia screening and prevention: a comprehensive approach to implementation in a real-world setting. BMC Pregnancy Childbirth. 2025;25:32. doi: 10.1186/s12884-025-07154-6.
37. Song WL, Zhao YH, Shi SJ, Liu XY, Zheng GY, Morosky C, et al. First trimester Doppler velocimetry of the uterine artery ipsilateral to the placenta improves ability to predict early-onset preeclampsia. Medicine (Baltimore). 2019;98:e15193. doi: 10.1097/md.0000000000015193.
38. Rode L, Ekelund CK, Riishede I, Rasmussen S, Lidegaard Ø, Tabor A. Prediction of preterm pre-eclampsia according to NICE and ACOG criteria: descriptive study of 597 492 Danish births from 2008 to 2017. Ultrasound Obstet Gynecol. 2021;58:561–7. doi: 10.1002/uog.23693.
39. Sotiriadis A, Hernandez-Andrade E, da Silva Costa F, Ghi T, Glanc P, Khalil A, et al. ISUOG Practice Guidelines: role of ultrasound in screening for and follow-up of pre-eclampsia. Ultrasound Obstet Gynecol. 2019;53:7–22. doi: 10.1002/uog.20105.
40. Chen G, Chen Y, Shi Y, Mao Z, Lou J, Ma J. A dynamic prediction model for preeclampsia using the sFlt-1/PLGF ratio combined with multiple factors. BMC Pregnancy Childbirth. 2024;24:443. doi: 10.1186/s12884-024-06627-4.