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Doppler Ultrasonography And Preeclampsia: Predictive Value of Uterine Artery Hemodynamics (2021–2025 Review)

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Abstract: Early identification of women at risk of preeclampsia (PE) remains a major challenge in obstetrics. Among imaging modalities, uterine artery Doppler ultrasonography offers non-invasive insight into placental perfusion and uteroplacental vascular resistance.

Aim: This review assesses recent evidence (2023–2025) on uterine artery Doppler indices (pulsatility index [PI], resistance index [RI], notching) for early prediction of preeclampsia and related adverse outcomes.

Materials & Methods: A narrative review of the literature was conducted via PubMed, Scopus, and Web of Science for prospective and meta-analysis studies reporting Doppler uterine artery indices in pregnancies and their association with PE. Key metrics extracted included sensitivity, specificity, area under the ROC curve (AUC), gestational age at measurement, and impact on maternal-fetal outcomes.

Results: Meta-analyses suggest uterine artery PI and RI have moderate-to-high specificity (≈0.88–0.90) and lower sensitivity (≈0.58–0.65) in predicting PE. In prospective studies, mean PI cut-offs >2.2 at 11–14 weeks showed high accuracy (AUC ~0.98) in certain cohorts. Combining PI/RI with other markers (biochemical, maternal risk factors) further improved predictive performance (AUC >0.95).

Discussion: Uterine artery Doppler provides a valuable tool for risk stratification in early pregnancy; however, its sensitivity remains suboptimal when used alone, and heterogeneity in methodology, gestational age, and threshold values limit standardisation. Integration with biomarkers and clinical algorithms enhances utility.

Conclusion: Uterine artery Doppler indices have an important role in early prediction of preeclampsia, especially when used as part of a multimodal screening strategy. Further large-scale, multi-ethnic studies and standardised protocols are needed to implement it broadly in prenatal care.

Keywords: Preeclampsia; uterine artery Doppler; pulsatility index; resistance index; early prediction; screening; obstetric ultrasound

Introduction

Preeclampsia (PE) is a complex multisystem disorder unique to human pregnancy, typically defined by new-onset hypertension and proteinuria after 20 weeks of gestation [1]. It affects approximately 2–8% of all pregnancies globally and remains a significant contributor to maternal and perinatal mortality [2]. Despite advances in obstetric care, the condition continues to cause around 70,000 maternal deaths and 500,000 perinatal deaths annually [3].

The pathogenesis of preeclampsia is multifactorial, with the placenta playing a central role. One of the earliest events is defective trophoblastic invasion of the spiral arteries, leading to inadequate remodeling of uterine vessels and high-resistance blood flow [4]. This defective perfusion causes placental ischemia, oxidative stress, and the release of anti-angiogenic factors such as soluble fms-like tyrosine kinase-1 (sFlt-1) and soluble endoglin (sEng), which result in endothelial dysfunction, hypertension, and proteinuria [5,6].

Early identification of women at risk of developing preeclampsia is therefore a cornerstone of modern prenatal care. Conventional clinical indicators such as blood pressure and proteinuria appear late in the disease process, making them poor predictors of risk [7]. Hence, researchers have focused on biochemical and imaging biomarkers that can detect pathophysiologic changes before clinical manifestation [8].

Among imaging techniques, Doppler ultrasonography of uterine arteries is one of the most promising non-invasive screening tools. It assesses the hemodynamic parameters of uteroplacental circulation, particularly the pulsatility index (PI) and resistance index (RI), which reflect downstream vascular resistance. Persistent notching or elevated PI and RI values are early indicators of impaired placental perfusion and increased risk of preeclampsia and intrauterine growth restriction (IUGR) [9,10].

The predictive potential of Doppler ultrasonography has been demonstrated in numerous studies. However, its diagnostic accuracy varies depending on gestational age, maternal risk factors, and technical methodology [11]. Some meta-analyses report moderate sensitivity (60–70%) but high specificity (85–90%) for predicting preeclampsia using uterine artery Doppler alone [12]. Combining Doppler parameters with biochemical markers (such as PAPP-A, PlGF, and sFlt-1) significantly improves predictive accuracy [13,14].

Recent literature (2021–2025) emphasizes the role of early first-trimester Doppler scanning (11–14 weeks) as part of a multimodal approach, enabling timely prophylaxis such as low-dose aspirin therapy to prevent disease progression [15,16]. Despite promising results, heterogeneity in methodology, equipment, and threshold values across studies poses challenges for standardization [17].

Therefore, this review aims to provide an updated synthesis of recent findings (2021–2025) on Doppler ultrasonographic assessment of uterine artery hemodynamics for early prediction of preeclampsia and to explore how these parameters can be integrated into routine antenatal screening programs.

Pupose of the work is to analyze and summarize recent evidence regarding the role of uterine artery Doppler ultrasonography and hemodynamic indices in the early prediction and prevention of preeclampsia.

Materials and Methods

A structured literature review was conducted in accordance with PRISMA guidelines. The PubMed, Scopus, and Web of Science databases were searched for studies from January 2021 to May 2025 using the “preeclampsia,” “uterine artery,” “Doppler ultrasound,” “pulsatility index,” “resistance index,” “notching,” “screening,” and “prediction”.

Inclusion criteria:

- Original research articles and meta-analyses;
- Studies assessing Doppler parameters (PI, RI, notching) in the prediction of preeclampsia;
- Published between 2021–2025;
- Human subjects only.

Data extracted included study design, sample size, gestational age at assessment, Doppler indices, cut-off values, and statistical parameters (sensitivity, specificity, AUC).

Results

A total of 38 studies meeting the inclusion criteria were analyzed.

Recent meta-analyses confirmed that elevated uterine artery PI and RI values during the first trimester are associated with a 4–7 fold increased risk of developing preeclampsia [18,19].

- **PI values** above 2.2 during 11–14 weeks had a predictive accuracy of 92–97% in high-risk populations [20].

- **Persistent bilateral notching** was strongly correlated with severe preeclampsia and IUGR [21].
- Combination of **uterine artery Doppler with PlGF and sFlt-1** increased AUC values to >0.95 in predicting PE onset before 34 weeks [22].
- Doppler indices obtained during the **second trimester (20–24 weeks)** maintained moderate sensitivity (~70%) and high specificity (>90%) [23].

Recent work also highlights novel composite ratios like the Cerebro-Placental-Uterine Ratio (CPUR) and Umbilical-Cerebral Ratio (UCR), which improve prognostic capability [24].

Discussions

The reviewed evidence consistently demonstrates the clinical utility of uterine artery Doppler ultrasonography for early detection of preeclampsia. However, Doppler alone cannot provide perfect predictive accuracy due to inter-patient and methodological variability [25].

When combined with biochemical markers and maternal history, predictive performance significantly increases [26]. The *Fetal Medicine Foundation (FMF)* model integrating PI, mean arterial pressure, PAPP-A, and PlGF achieves detection rates up to 95% for early-onset PE [27].

Doppler ultrasonography thus serves as both a diagnostic and monitoring tool, allowing obstetricians to identify high-risk women early and initiate preventive measures such as low-dose aspirin or closer surveillance [28].

Nevertheless, limitations include operator dependency, lack of standardized threshold values, and cost barriers in low-resource settings [29]. Standardized measurement protocols and training programs are necessary for widespread implementation [30].

Conclusion

Uterine artery Doppler ultrasonography is a powerful, non-invasive method to predict preeclampsia in its subclinical stage. Its integration into first-trimester screening protocols, especially when combined with biochemical markers, allows for early risk stratification and preventive therapy. Future studies should focus on refining Doppler-based predictive models, defining universal cut-offs, and validating them in diverse populations.

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