ORIGINAL RESEARCH ARTICLE

Role of uterine artery doppler at 14–22 weeks of gestation in predicting preeclampsia and intrauterine growth restriction

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Abstract

Hypertensive disorders, particularly pre-eclampsia, are major contributors to maternal mortality worldwide. Uterine artery Doppler ultrasonography, which measures indices such as the pulsatility index (PI) and resistance index (RI), has proven to be an effective tool for the early prediction of pre-eclampsia and intrauterine growth restriction (IUGR). This study aimed to evaluate the predictive value of uterine artery Doppler indices between 14–22 weeks of gestation for these adverse pregnancy outcomes.This study included 480 pregnant women between 14–22 weeks of gestation. Uterine artery Doppler measurements, including PI, RI, and the presence of diastolic notching, were recorded. Participants were followed up for the development of pre-eclampsia and IUGR. The sensitivity, specificity, and predictive values of the Doppler indices were calculated.Pre-eclampsia was observed in 6.9% (n = 33) of participants, while IUGR occurred in 5% (n = 24). Pre-eclamptic women exhibited significantly higher uterine artery PI (1.0 ± 0.15) and RI (0.75 ± 0.07) compared to normotensive women ($p < 0.001$). The sensitivity and specificity of uterine artery PI in predicting pre-eclampsia were 52% and 83.3%, respectively. Uterine artery notching demonstrated a sensitivity of 58.3% and a specificity of 90% in predicting IUGR. Uterine artery Doppler ultrasonography is a valuable tool for predicting pre-eclampsia and IUGR. *(Afr J Reprod Health 2026; 30 [11]: 63-71).*

Keywords: Pre-eclampsia, Doppler ultrasonography, Intrauterine growth restriction, Pulsatility index, Resistance index

Résumé

Les troubles hypertensifs, en particulier la prééclampsie, contribuent fortement à la mortalité maternelle dans le monde. L'échographie Doppler des artères utérines, qui mesure des indices tels que l'indice de pulsatilité (IP) et l'indice de résistance (IR), s'est révélée un outil efficace pour le dépistage précoce de la prééclampsie et du retard de croissance intra-utérin (RCIU). Cette étude visait à évaluer la valeur prédictive des indices Doppler des artères utérines entre 14 et 22 semaines d'aménorrhée pour ces complications de la grossesse. L'étude a inclus 480 femmes enceintes entre 14 et 22 semaines d'aménorrhée. Les mesures Doppler des artères utérines, incluant l'IP, l'IR et la présence d'une encoche diastolique, ont été enregistrées. Les participantes ont été suivies afin de détecter l'apparition d'une prééclampsie et d'un RCIU. La sensibilité, la spécificité et les valeurs prédictives des indices Doppler ont été calculées. Une prééclampsie a été observée chez 6,9 % (n = 33) des participantes, tandis qu'un retard de croissance intra-utérin (RCIU) est survenu chez 5 % d'entre elles (n = 24). Les femmes prééclamptiques présentaient un indice de pulsatilité (IP) (1,0 ± 0,15) et un indice de résistance (IR) (0,75 ± 0,07) de l'artère utérine significativement plus élevés que les femmes normotendues ($p < 0,001$). La sensibilité et la spécificité de l'IP de l'artère utérine pour prédire la prééclampsie étaient respectivement de 52 % et 83,3 %. L'encoche de l'artère utérine a démontré une sensibilité de 58,3 % et une spécificité de 90 % pour prédire le RCIU. L'échographie Doppler de l'artère utérine est un outil précieux pour prédire la prééclampsie et le RCIU. *(Afr J Reprod Health 2026; 30 [11]:63-71).*

Mots-clés: Prééclampsie, échographie Doppler, retard de croissance intra-utérin, indice de pulsatilité, indice de résistance

Introduction

Despite significant advancements in obstetrics, maternal morbidity and mortality remain high in India, largely due to hypertensive disorders such as pre-eclampsia. Hypertensive disorders affect approximately 6–8% of pregnancies, and pre-eclampsia, a condition that can escalate to eclampsia, remains a leading cause of maternal mortality globally. The World Health Organization

estimates that 16% of maternal deaths are related to complications arising from hypertensive disorders, particularly pre-eclampsia. Pre-eclampsia is a multifactorial disorder defined by hypertension (blood pressure ≥140/90 mmHg) and proteinuria (≥300 mg in 24 hours) occurring after 20 weeks of gestation in previously normotensive women. If untreated, pre-eclampsia can progress to eclampsia, a condition characterized by seizures and potentially life-threatening outcomes for both the mother and the fetus. In India, hospital-based studies report a pre-eclampsia incidence of 5–15%, with eclampsia affecting approximately 1.5% of pregnancies. The pathophysiology of pre-eclampsia is associated with abnormal placentation, leading to impaired uteroplacental blood flow. This results in placental hypoxia and oxidative stress, with the release of anti-angiogenic factors that disrupt endothelial function. Such endothelial damage contributes to hypertension and multi-organ injury, which are hallmark features of pre-eclampsia.

Pre-eclampsia has both immediate and long-term health consequences. Women with a history of pre-eclampsia have a significantly higher risk of developing cardiovascular and cerebrovascular diseases later in life. Furthermore, pre-eclampsia is closely linked to intrauterine growth restriction (IUGR). Therefore, it is important to utilize effective tools and techniques to predict conditions such as pre-eclampsia in pregnant women.

Efforts to predict and manage pre-eclampsia have led to the use of uterine artery Doppler assessments in early pregnancy, which can detect abnormal blood flow patterns associated with this condition.

Doppler ultrasonography measures indices such as the pulsatility index (PI) and resistance index (RI), which reflect vascular resistance within the uteroplacental circulation. Elevated PI and RI values, along with persistent notching in the uterine arteries, have been identified as predictive markers of pre-eclampsia and IUGR. In this context, the present study aims to evaluate the role of uterine artery Doppler indices measured between 14–22 weeks of gestation in predicting the development of pre-eclampsia and IUGR. Early identification of at-risk pregnancies can facilitate timely interventions, such as increased surveillance and preventive strategies, potentially improving both maternal and fetal outcomes.

Methods

Study design

This study was a prospective observational study conducted at the Department of Radiodiagnosis in collaboration with the Department of Obstetrics and Gynecology at a tertiary care hospital. The study spanned 22 months, from August 2022 to May 2024, and was designed to evaluate the predictive utility of uterine artery Doppler ultrasonography performed between 14–22 weeks of gestation for the development of pre-eclampsia and intrauterine growth restriction (IUGR).

Inclusion criteria

Pregnant women aged 18 years or older Singleton pregnancies with a vertex presentation.Gestational age confirmed between 14 and 22 weeks using ultrasound

Exclusion criteria

Pregnancies complicated by chronic hypertension, congenital uterine anomalies, or systemic illnesses such as rheumatoid arthritis, systemic lupus erythematosus (SLE), and antiphospholipid antibody syndrome (APLA)

Multifetal pregnancies

Congenital fetal anomalies detected on ultrasound
Pregnancies conceived through assisted reproductive technologies

Protocol for USG

Eligible participants were recruited during their antenatal visits after meeting the inclusion and exclusion criteria. Comprehensive obstetric and medical histories were recorded, and clinical examinations were performed. Participants underwent Doppler ultrasonography using a GE LOGIQ P5 ultrasonography machine equipped with a 3.5 MHz curvilinear transducer.

Doppler examination

Uterine artery assessment

Uterine arteries were identified at the crossover point of the uterine and external iliac arteries. The

Doppler gate was placed 1 cm distal to this crossover point, ensuring that no branches were present. The pulsatility index (PI), resistance index (RI), and the presence of diastolic notching were recorded from both uterine arteries.The transducer was positioned in the iliac fossa with medial angulation, and the angle of insonation was maintained below 60° to obtain optimal waveforms.At least three consecutive waveforms were obtained, and indices were recorded automatically or manually from the frozen images.

Umbilical and middle cerebral artery (MCA) assessment

The umbilical artery was assessed from a free-floating segment of the umbilical cord. Indices such as PI, RI, and the systolic-to-diastolic (S/D) ratio were recorded.
The MCA was identified on an axial view of the fetal head at the level of the sphenoid bone using color Doppler. The Doppler gate was placed at the proximal third of the MCA, ensuring an insonation angle of less than 30°.

Follow-up

Participants were followed throughout their pregnancies.

Pre-eclampsia

Blood pressure readings were taken on two separate occasions at least **six hours apart** to confirm new-onset hypertension (≥140/90 mmHg) after 20 weeks of gestation. Proteinuria was diagnosed using either a 24-hour urine protein test or a spot urine protein-to-creatinine ratio (≥0.3).IUGR: Diagnosed based on fetal biometry, including abdominal circumference and estimated fetal weight (EFW) below the 10th percentile, or abnormal Doppler findings in the umbilical artery and MCA.

Outcome measures

Primary outcomes

Incidence of pre-eclampsia and IUGR Predictive value of uterine artery Doppler indices (PI, RI, and diastolic notching)

Secondary outcomes

Diagnostic accuracy of umbilical artery and MCA Doppler indices
Relationship between cerebroplacental ratio (CPR) and adverse pregnancy outcomes

Sample size calculation

The sample size was calculated using the following formula:

$$N = \frac{Z_{1-\alpha/2}^2 \cdot p \cdot (1-p)}{d^2}$$

Where, represents the standard normal variate at a 95% confidence level (1.96).$p$denotes the estimated proportion of the outcome (incidence of pre-eclampsia), which was taken as 12.5% based on previous studies by Rashid et al. $d$represents the allowable error, set at 3%.The minimum sample size calculated was 467. To account for potential dropouts, the sample size was rounded off to 480 participants.

Statistical analysis

All collected data were entered into Microsoft Excel and analyzed using SPSS version 25. Descriptive statistics were used to summarize sociodemographic characteristics and Doppler findings. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were expressed as frequencies and percentages.

Key statistical methods

Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV)

These metrics were calculated to evaluate the diagnostic accuracy of Doppler indices in predicting pre-eclampsia and IUGR.

Receiver operating characteristic (ROC) curve analysis

Used to determine the optimal cut-off values for PI and RI in predicting adverse outcomes.

Chi-square test

Applied to assess associations between categorical variables.

Independent t-test

Used to compare continuous variables between groups (e.g., pre-eclamptic vs. normotensive women).A p-value < 0.05 was considered statistically significant.

Ethical considerations

The study protocol was approved by the Institutional Scientific and Ethical Committee, Sher-i-Kashmir Institute of Medical Sciences (clearance number: #138/2023). Informed written consent was obtained from all participants prior to recruitment. Data confidentiality was maintained by storing participant information in a password-protected database, ensuring anonymity throughout the study

Results

Table 1: Sociodemographic characteristics of participants (n=480)

Parameter	Frequency (n)	Percentage (%)
Age (years)		
<20	12	2.5
20-24	135	28.1
25-29	183	38.1
30-34	132	27.5
≥35	18	3.8
Parity		
Nulligravida	219	45.6
1	123	25.6
2	81	16.9
>2	57	11.9
Education		
Illiterate/Non-formal	12	2.5
Primary	69	14.4
Middle	103	21.3
Secondary	189	39.4
Higher Secondary	93	19.4
Graduate and Above	14	3.0
Socioeconomic Status		
Upper	57	11.9
Upper Middle	282	58.8
Middle	140	29.3

Table 2: Incidence of Pre-eclampsia and IUGR (n=480)

Condition	Frequency (n)	Percentage (%)
Normotensive	447	93.1
Pre-eclampsia	33	6.9
Normal Growth	456	95.0
IUGR	24	5.0

Table 3: Comparison of doppler indices at 14–22 weeks between pre-eclampsia and normotensive groups.

Doppler Parameter	Pre-eclampsia (n=33)	Normotensive (n=447)	p-value
Mean Uterine Artery PI	1.0 ± 0.15	0.85 ± 0.10	<0.001*
Mean Uterine Artery RI	0.75 ± 0.07	0.50 ± 0.05	<0.001*
Mean Right Uterine Artery S/D	3.1 ± 0.4	2.5 ± 0.3	<0.001*
Mean Left Uterine Artery S/D	2.9 ± 0.3	2.4 ± 0.2	<0.001*
Combined Uterine Artery S/D	3.0 ± 0.3	2.45 ± 0.2	<0.001*

*Significant at $p < 0.05$.

Sociodemographic characteristics

A total of 480 pregnant women participated in the study. The majority (38.1%) were aged between 25-29 years, with a mean age of 27.1 ± 4.3 years. Most participants were nulligravida (45.6%) and had completed secondary education (39.4%). Socioeconomic status was predominantly upper-middle class (58.8%).

Incidence of Pre-eclampsia and IUGR

Doppler Indices at 14–22 Weeks

The study revealed significant differences in Doppler indices between pre-eclamptic and normotensive participants. Elevated pulsatility index (PI), resistance index (RI), and systolic/diastolic (S/D) ratios were observed in pre-eclamptic patients.

Diagnostic accuracy of doppler indices

Receiver operating characteristic (ROC) curve analyses determined the optimal cut-off values for PI and RI in predicting pre-eclampsia and IUGR.

Table 4: Doppler indices in the third trimester (n=480)

Doppler Parameter	Pre-eclampsia (n=33)	Normotensive (n=447)	p-value
Umbilical Artery PI	1.5 ± 0.2	0.9 ± 0.1	<0.001*
Umbilical Artery RI	0.7 ± 0.1	0.5 ± 0.1	<0.001*
Umbilical Artery S/D Ratio	4 ± 0.5	3 ± 0.3	<0.001*
MCA PI	1.2 ± 0.1	1.3 ± 0.2	0.058
MCA S/D Ratio	3.8 ± 0.4	4.5 ± 0.5	<0.001*
Cerebroplacental Ratio (CPR)	0.96 ± 0.1	1.61 ± 0.2	<0.001*

Table 5: Persistence of uterine artery notching after 22 Weeks

Condition	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Pre-eclampsia	60.6	85.0	23.0	96.7
IUGR	58.3	90.0	23.3	97.6

Table 6: Cut-off values for doppler parameters

Condition	Parameter	Cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Pre-eclampsia	PI	0.92	52	83.3	18.7	95.9
	RI	0.70	78.4	82.1	24.5	98.1
IUGR	PI	0.92	64.8	85.9	19.4	97.9
	RI	0.70	66.4	74.2	11.9	97.7

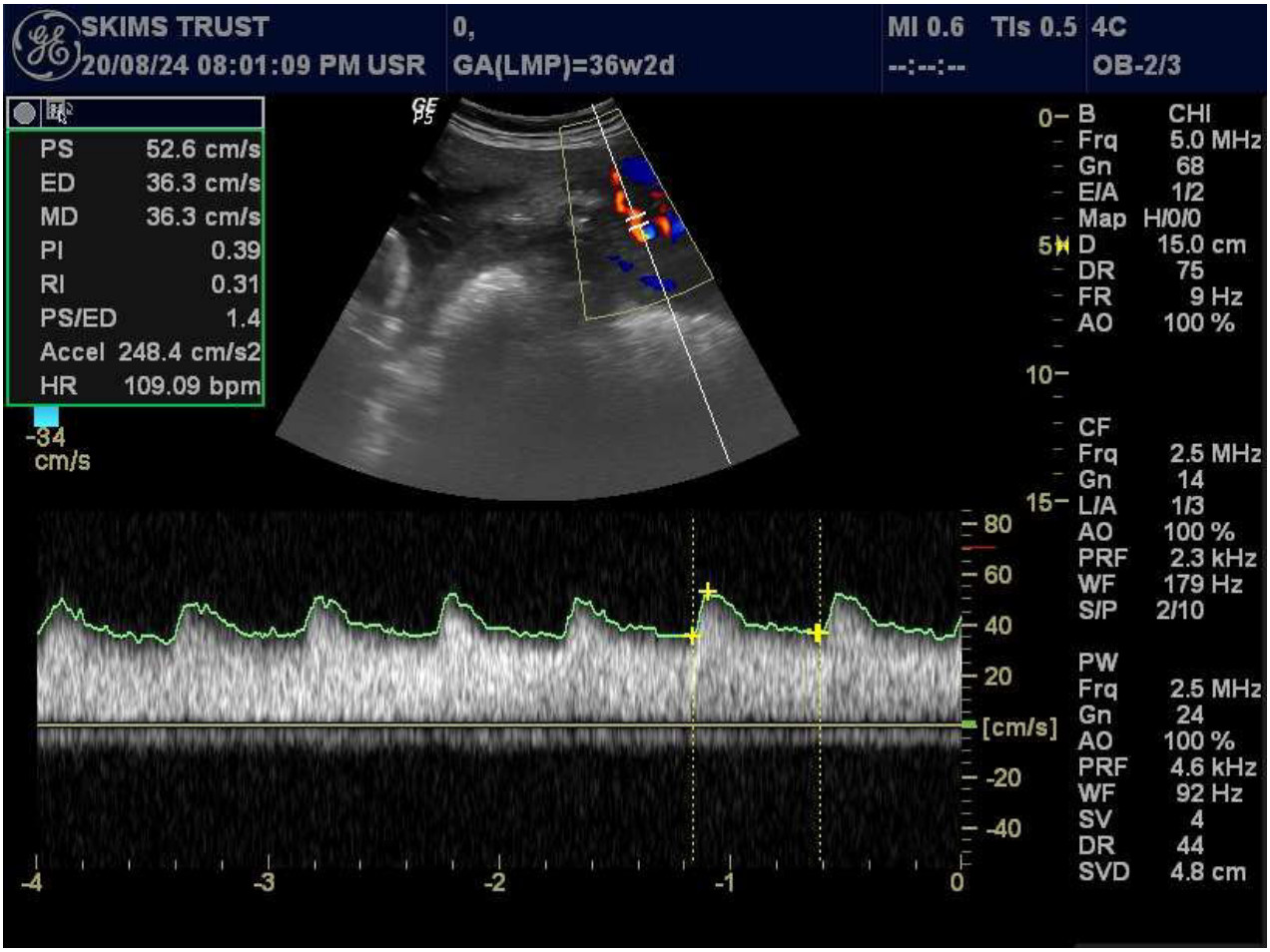

Figure 1: Uterine artery doppler waveform showing a normal low-resistance flow pattern.

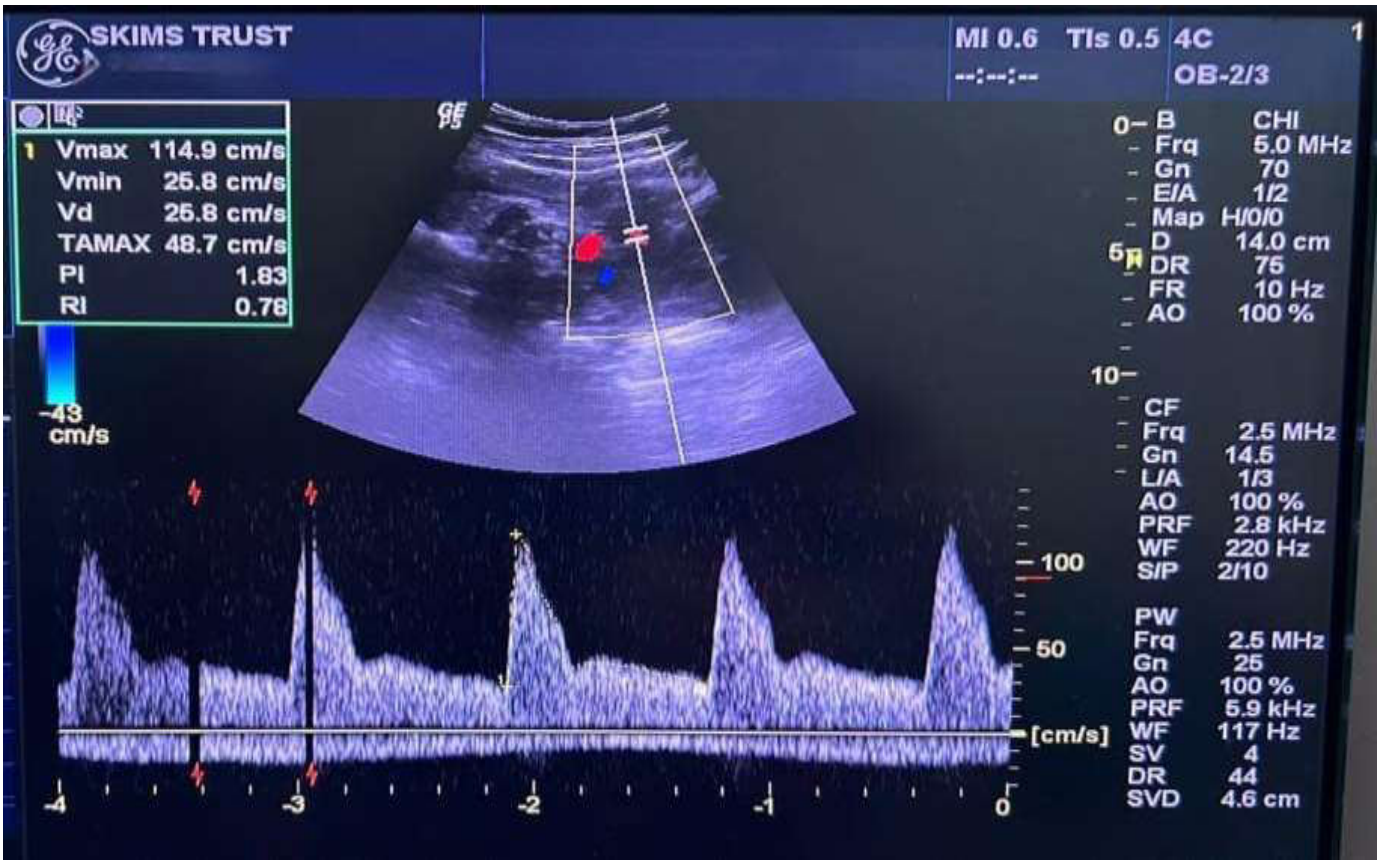

Figure 2: Uterine artery Doppler waveform showing a high-resistance flow pattern with markedly elevated PI and RI values of 1.83 and 0.78, respectively.

Discussion

The primary aim of the present study was to utilize Doppler parameters for the prediction of the development of pre-eclampsia and IUGR.In our study, the incidence of pre-eclampsia was **6.9%**, while **5%** of cases involved intrauterine growth restriction (IUGR). IUGR cases had significantly lower cerebroplacental ratios compared to non-IUGR cases. This finding aligns with Rizzo *et al*. (2020), who reported that lower cerebroplacental ratios and higher uterine artery pulsatility indices were linked to adverse perinatal outcomes in pregnancies complicated by IUGR. Additionally, the sensitivity and specificity of uterine artery pulsatility index (PI) and resistance index (RI) for predicting IUGR in our cohort were comparable to those observed by Abdelaziz et al. (2022), who demonstrated that Doppler ultrasonography, particularly in the first and second trimesters, effectively predicts IUGR with high sensitivity and specificity.

Receiver operating characteristic (ROC) curve analyses in our study revealed that uterine artery PI and RI had moderate sensitivity and high specificity for predicting both pre-eclampsia and IUGR. These findings are in line with the study by Pedrosa et al. (2018), which highlighted the limitations of uterine artery Doppler indices alone in predicting adverse outcomes, but noted that combining these indices with other markers, such as maternal serum PlGF or β-hCG, improved predictive accuracy. Our study, which focused solely on Doppler indices, demonstrated good predictive value; however, future studies could consider integrating these indices with biochemical markers to further enhance sensitivity and specificity, as suggested by Pedrosa *et al*.[12]

Our results demonstrated that pre-eclamptic patients exhibited significantly higher uterine artery pulsatility index (PI) and resistance index (RI) compared to normotensive women. These findings are consistent with several studies reporting elevated PI and RI as significant markers

for pre-eclampsia and IUGR. Mittal *et al.* (2016) showed that uterine artery Doppler indices measured in the first trimester had high predictive value for both pre-eclampsia and IUGR.[13] The mean PI and RI in their cohort were significantly higher in patients who developed these complications, and our study extends this observation to second-trimester measurements, further validating the consistency of these Doppler indices in predicting adverse outcomes.

Furthermore, analysis of umbilical artery Doppler indices revealed significantly higher PI and RI in pre-eclamptic patients, along with a corresponding increase in the systolic-to-diastolic (S/D) ratio. This finding is consistent with Singh et al. (2016), who reported that abnormal umbilical artery Doppler results, particularly elevated PI and RI, were associated with adverse fetal outcomes, including low Apgar scores and prolonged NICU admissions. In our study, the elevated S/D ratio in pre-eclamptic patients serves as an additional marker of compromised fetal well-being, further reinforcing the utility of umbilical artery Doppler in predicting poor perinatal outcomes.

The middle cerebral artery (MCA) Doppler indices in our cohort, although not significantly different between pre-eclamptic and normotensive women in terms of PI, showed a marked decrease in the S/D ratio in pre-eclamptic patients. This observation reflects compensatory vasodilation of the fetal cerebral circulation in response to hypoxia. Raj et al. (2020) reported that abnormal MCA PI and reduced cerebroplacental ratio (CPR) were strong predictors of NICU admissions and adverse perinatal outcomes in pre-eclamptic pregnancies, a finding mirrored in our study by lower CPR values in pre-eclamptic patients.

The reduced CPR, indicative of fetal brain-sparing in response to placental insufficiency, underscores the importance of combining MCA and umbilical artery Doppler indices for a more comprehensive assessment of fetal well-being. The presence of uterine artery notching in pre-eclamptic patients was another significant finding, with a higher prevalence observed compared to normotensive women. Uterine artery notching has previously been identified as a strong predictor of pre-eclampsia and IUGR. Reddy et al. (2018) reported that uterine artery notching, along with elevated PI and RI, was associated with a higher incidence of pre-eclampsia and IUGR, particularly when notching persisted beyond the second trimester. Our findings align with these observations, supporting the notion that uterine artery notching, when combined with Doppler indices, can enhance predictive accuracy for pre-eclampsia and IUGR.

Additionally, the ROC analysis in our study showed that uterine artery PI and RI were better predictors of IUGR than pre-eclampsia, a finding consistent with Elhotkey et al. (2021), who reported that while both conditions could be predicted using uterine and umbilical artery Doppler indices, IUGR had a stronger association with these markers.[16] This distinction between the predictive capabilities of Doppler indices for pre-eclampsia and IUGR is important, as it highlights the need for tailored screening approaches based on the specific complications being monitored.

In terms of clinical application, the high negative predictive value (NPV) of uterine artery Doppler indices observed in our study suggests that Doppler ultrasonography can be an effective tool for ruling out pre-eclampsia and IUGR in low-risk pregnancies. This finding aligns with the conclusions of Mariana et al. (2020), who emphasized the role of uterine artery Doppler as a screening tool for identifying low-risk pregnancies, thereby allowing healthcare providers to focus resources on high-risk cases requiring more intensive monitoring and intervention.[17-19]

Uterine artery Doppler is a non-invasive, accessible, and reliable tool for the early detection of pre-eclampsia and IUGR. Its integration into antenatal screening protocols has the potential to improve obstetric care by enabling proactive management of high-risk pregnancies, ultimately reducing maternal and perinatal morbidity and mortality.

Limitations

The present study has certain limitations that merit consideration. The relatively broad gestational age window used for Doppler assessment may have influenced the predictive accuracy of the findings. Additionally, Doppler ultrasonography is inherently operator dependent, which may have introduced variability in measurements despite standardized protocols. Furthermore, the use of umbilical artery Doppler as an isolated screening tool demonstrated limited predictive value,

underscoring the need for its integration with other screening modalities.

Actionable clinical recommendations

Based on the findings of this study, several practical recommendations can be made to enhance clinical applicability. Uterine artery Doppler should be incorporated into a combined screening protocol rather than used in isolation. For optimal predictive performance, Doppler assessment is best performed between 20 and 22 weeks of gestation. Early identification of high-risk pregnancies should be followed by timely initiation of appropriate preventive and surveillance measures. In addition, standardization of Doppler acquisition techniques and reporting formats is essential to minimize inter-operator variability. The development of structured, risk-based follow-up protocols may further improve maternal and fetal outcomes.

Future directions

Future research should aim to strengthen predictive models by integrating Doppler parameters with biochemical markers. Narrowing the gestational age window for screening may enhance diagnostic precision. Large, multicenter studies involving diverse populations are needed to improve generalizability of the findings. Moreover, future studies should evaluate the effectiveness of targeted preventive interventions in high-risk groups to determine their impact on reducing the incidence of preeclampsia and intrauterine growth restriction.he limitations of the present study include a broad gestational age window, which may have influenced predictive accuracy; operator dependence, leading to variability in measurements; and the limited predictive value of umbilical artery Doppler when used in isolation.

Conclusion

This study highlights the significant role of uterine artery Doppler ultrasonography in predicting adverse pregnancy outcomes, specifically pre-eclampsia and intrauterine growth restriction (IUGR), when conducted between 14-22 weeks of gestation. Elevated Doppler indices, including pulsatility index (PI), resistance index (RI), and the presence of uterine artery notching, were found to be reliable indicators of impaired placental function and increased vascular resistance, which are hallmark features of these complications.

The present study emphasizes the need for routine Doppler assessments during the early stages of pregnancy to optimize antenatal care and reduce the incidence of severe complications. Implementing uterine artery Doppler assessments as part of routine prenatal care could facilitate early identification of patients who may benefit from additional surveillance or preventive interventions.

Key findings include:

Cut-off values for PI and RI: The study established threshold values of 0.92 for PI and 0.70 for RI, which demonstrated high specificity and negative predictive value (NPV). These cut-offs allow effective risk stratification and early identification of at-risk pregnancies.

Persistent uterine artery notching: Persistence of notching beyond 22 weeks was strongly associated with both pre-eclampsia and IUGR, providing an additional tool for early prediction.

Diagnostic utility: Uterine artery Doppler indices demonstrated moderate sensitivity but high specificity, making them valuable for ruling out adverse outcomes and targeting high-risk pregnancies for closer monitoring.

Third-trimester insights: Umbilical artery PI, RI, and cerebroplacental ratio (CPR) were critical in assessing fetal well-being during later stages of pregnancy, providing actionable information for timely intervention.

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