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### Research Article

### Section: Radiodiagnosis

## Role of First-Trimester Ophthalmic Artery Doppler in Predicting Eclampsia: A Prospective Observational Study

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### HIGHLIGHTS

- First-trimester Doppler predicted eclampsia
- Eclampsia showed reduced RI
- PI was lower in eclampsia
- P2/P1 ratio was elevated
- Doppler aided early risk-stratification

### Key Words:

Ophthalmic artery Doppler  
Eclampsia  
Preeclampsia  
Pulsatility index  
Resistance index  
PSV ratio

### ABSTRACT

**Introduction:** Eclampsia is a severe complication of hypertensive disorders of pregnancy associated with substantial maternal and fetal morbidity. Ophthalmic artery Doppler provides a non-invasive assessment of maternal cerebrovascular hemodynamics and may facilitate early identification of women at risk. **Aim & Objective:** To evaluate first-trimester ophthalmic artery Doppler parameters and their association with subsequent development of eclampsia. **Materials & Methods:** This prospective observational study included 10 pregnant women who underwent ophthalmic artery Doppler ultrasonography at 11 weeks to 13 weeks and 6 days of gestation and were subsequently followed for development of eclampsia. Resistance index (RI), pulsatility index (PI), peak systolic velocity ratio (P2/P1), and second peak systolic velocity (PSV2) were evaluated. Doppler parameters were compared between women who developed eclampsia and those who did not. **Results:** Seven (70%) women developed eclampsia. Compared with women without eclampsia, those who developed eclampsia had significantly lower RI (0.573 vs 0.627;  $p=0.033$ ) and PI (1.05 vs 1.37;  $p=0.039$ ) and a significantly higher P2/P1 ratio (0.779 vs 0.653;  $p=0.033$ ). PSV2 was higher in the eclampsia group (46.43 vs 41.97 cm/s), although the difference was not statistically significant ( $p=0.067$ ). A P2/P1 ratio  $>0.65$  demonstrated 100% sensitivity, 66.7% specificity, 87.5% positive predictive value, and 100% negative predictive value. **Conclusion:** First-trimester ophthalmic artery Doppler demonstrates promising hemodynamic alterations associated with subsequent eclampsia. Reduced RI and PI and an increased P2/P1 ratio may aid early risk stratification; however, larger prospective studies are required to validate these preliminary findings.



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## INTRODUCTION

Preeclampsia is a pregnancy-specific multisystem hypertensive disorder and remains a major contributor to maternal and perinatal morbidity and mortality worldwide [1,2]. It complicates approximately 2–8% of pregnancies and is characterized by new-onset hypertension after 20 weeks of gestation, accompanied by proteinuria and/or maternal organ dysfunction [1,3]. Eclampsia, defined by the occurrence of new-onset generalized seizures in a woman with preeclampsia without an alternative neurological cause, represents one of its most severe complications [2,4]. Despite improvements in antenatal surveillance, early recognition of women likely to develop severe disease remains an important clinical challenge [5].

The pathogenesis of preeclampsia involves abnormal placentation, incomplete spiral artery remodeling, placental ischemia, systemic endothelial dysfunction, oxidative stress, and an exaggerated inflammatory response [6,7]. These processes produce widespread alterations in maternal vascular resistance and organ perfusion [8]. Cerebral involvement is particularly important in severe preeclampsia and eclampsia, where impaired autoregulation, endothelial dysfunction, cerebral hyperperfusion, vasogenic edema, and posterior reversible encephalopathy may contribute to neurological manifestations and seizures [9,10]. Direct evaluation of the maternal cerebral circulation during pregnancy is difficult. The ophthalmic artery, however, is a branch of the internal carotid artery and shares important anatomical and physiological characteristics with the intracranial circulation [11]. Doppler assessment of this vessel therefore provides a non-invasive means of indirectly evaluating maternal cerebral hemodynamics. Previous studies have demonstrated characteristic ophthalmic artery Doppler alterations in preeclampsia, suggesting reduced vascular impedance and increased

orbital blood flow compared with normotensive pregnancies [12,13]. Several Doppler indices have been investigated, including the resistance index (RI), pulsatility index (PI), second peak systolic velocity (PSV2 or P2), and peak systolic velocity ratio (P2/P1) [14,15]. Reduced RI and PI indicate decreased downstream vascular resistance, whereas increased P2 and P2/P1 ratio may reflect increased flow and altered vascular autoregulation [14,16]. A recent meta-analysis demonstrated that peak ratio and P2 had particularly good diagnostic performance for preeclampsia [17].

More recently, interest has shifted toward the potential application of ophthalmic artery Doppler during the first trimester, before clinical manifestations of preeclampsia become apparent. Gana et al. demonstrated that the ophthalmic artery PSV ratio measured at 11–13 weeks was increased in pregnancies subsequently complicated by preeclampsia and could improve prediction of preterm disease when incorporated with established maternal and biophysical markers [15]. However, systematic reviews have emphasized heterogeneity among available studies and the need for further prospective validation before ophthalmic artery Doppler can be incorporated routinely into prediction models [17,18]. **Figure 1.** Role of first-trimester ophthalmic artery Doppler in predicting eclampsia through assessment of maternal vascular and cerebral hemodynamic changes.

The present study therefore aimed to evaluate ophthalmic artery Doppler parameters during early pregnancy and assess their potential role in predicting subsequent eclampsia, with particular emphasis on RI, PI, P2/P1 ratio, and PSV2.

## MATERIALS & METHODS

This prospective observational study included 10 pregnant women enrolled as part of an ongoing study who underwent

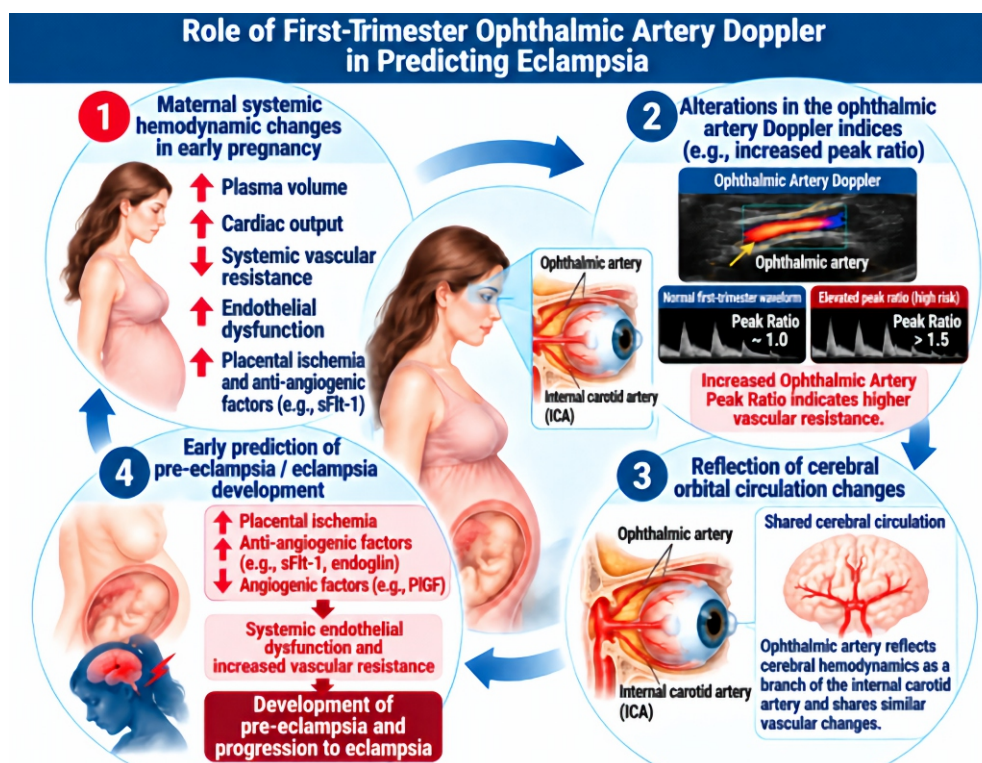


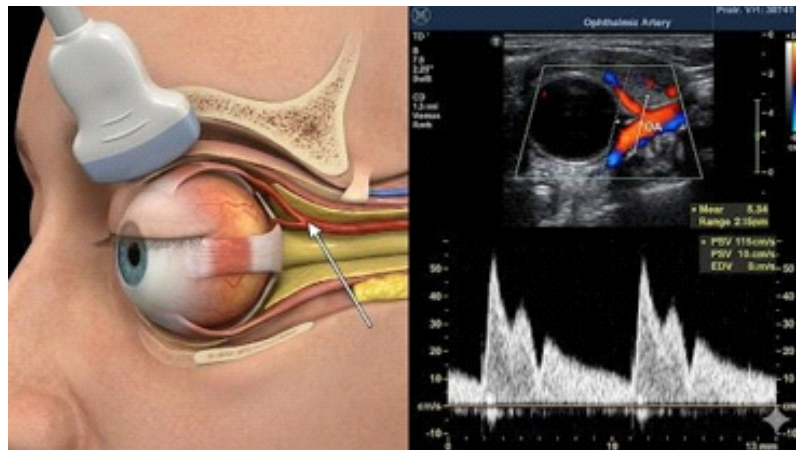
Figure 1: First-trimester ophthalmic artery Doppler for eclampsia prediction.

ophthalmic artery Doppler ultrasonography at 11 weeks to 13 weeks and 6 days of gestation. Participants were subsequently followed for the development of eclampsia.

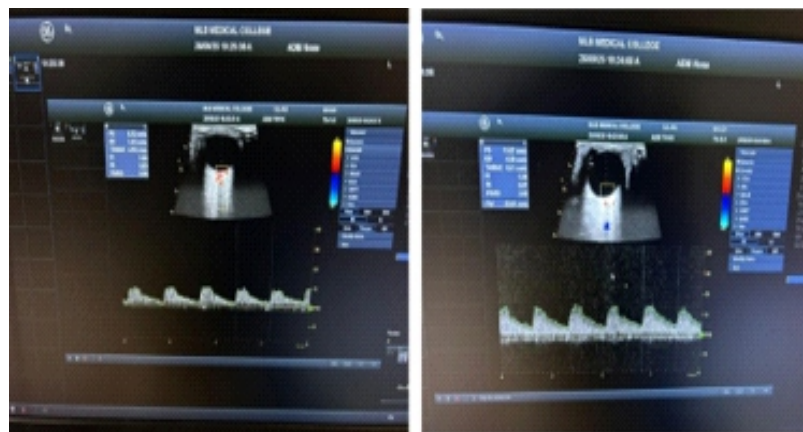
Ophthalmic artery Doppler was performed with the participant in a semi-recumbent position using a 7.5–12 MHz high-frequency linear transducer. With the eyelid closed and minimal pressure over the eye, the ophthalmic artery was identified using color Doppler. Pulsed-wave Doppler was then applied with the sample volume positioned centrally within the vessel, and at least three consecutive consistent cardiac waveforms were recorded. The measured parameters were resistance index (RI), pulsatility

index (PI), peak systolic velocity ratio (P2/P1), and second peak systolic velocity (PSV2). Predefined abnormal values were RI <0.60, PI <1.20, PSV ratio >0.65, and PSV2  $\geq$ 43.75 cm/s.

Continuous variables were expressed as mean  $\pm$  standard deviation, and categorical variables as frequency and percentage. Doppler parameters were compared between women who developed eclampsia and those who did not using the Mann–Whitney U test. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated for the predefined Doppler cut-offs. A p-value <0.05 was considered statistically significant (Figure 2-3).



**Figure 2. Ophthalmic artery Doppler examination technique and waveform acquisition.** Left: transorbital probe positioning and anatomical course of the ophthalmic artery. Right: color Doppler identification of the ophthalmic artery with spectral Doppler waveform used for measurement of ophthalmic artery flow parameters.



**Figure 3. Representative ophthalmic artery Doppler waveforms obtained during the study, demonstrating spectral Doppler assessment and measurement of vascular flow parameters.**

## RESULTS

A total of **10 pregnant women** undergoing ophthalmic artery Doppler assessment during early pregnancy were included in the preliminary analysis. The mean age of the participants was **33.6  $\pm$  2.4 years**, ranging from 28 to 36 years. During subsequent follow-up, **7 (70.0%) women developed eclampsia**, while **3 (30.0%) remained without eclampsia**. Ophthalmic artery Doppler assessment included resistance index (RI), pulsatility index (PI), peak systolic velocity ratio (P2/P1), and second peak systolic velocity (PSV2), as specified in the study protocol. Overall, the cohort demonstrated a mean RI of **0.589  $\pm$  0.037** and

mean PI of **1.15  $\pm$  0.20**. The mean PSV ratio was **0.741  $\pm$  0.079**, while mean PSV2 was **45.09  $\pm$  3.47 cm/s**. Seven of the ten women subsequently developed eclampsia, suggesting a high frequency of adverse hypertensive outcome within this small preliminary cohort (**Table 1**). As shown in **Table 2**, women who subsequently developed eclampsia demonstrated significantly lower ophthalmic artery vascular resistance. Mean RI was **0.573** compared with **0.627** among women without eclampsia ( $p=0.033$ ), while PI was similarly lower (**1.05 vs 1.37;  $p=0.039$** ). Conversely, the PSV ratio was significantly higher among women who developed eclampsia (**0.779 vs 0.653;  $p=0.033$** ).

PSV2 was also higher in the eclampsia group (**46.43 vs 41.97 cm/s**), although this difference did not reach conventional statistical significance ( $p=0.067$ ). These patterns correspond to the proposed Doppler alterations of reduced vascular impedance and increased flow described in the study protocol. **Figure 4.** Comparison of mean ophthalmic artery Doppler indices between women who developed eclampsia and those who did not. A grouped graphical presentation of RI, PI and PSV ratio would clearly demonstrate the lower RI and PI and higher PSV ratio observed among women who subsequently developed eclampsia. **Figure 5.** Second peak systolic velocity (PSV2) according to subsequent development of eclampsia. A dot/box plot of individual PSV2 values would demonstrate the tendency toward higher PSV2 among women who developed eclampsia, with mean values of **46.43 cm/s versus 41.97 cm/s** in women without eclampsia. Overall, the preliminary findings demonstrate a consistent ophthalmic artery Doppler pattern among women who subsequently developed eclampsia, characterized by **reduced RI and PI together with increased PSV ratio and PSV2**. RI, PI, and PSV ratio showed statistically significant differences between outcome groups, while PSV2 demonstrated a similar directional association. The high apparent diagnostic performance of several proposed thresholds is promising but should be regarded as exploratory because of the **very small**

**sample size (n=10)** and requires validation in the complete study cohort. The proposed abnormal Doppler thresholds showed clear separation between outcome groups (**Table 3**). Reduced RI and PI and elevated PSV2 were each present in **6 of 7 (85.7%)** women who developed eclampsia but in none of the three women without eclampsia. An elevated PSV ratio  $>0.65$  was observed in **all seven (100%)** women who developed eclampsia, compared with one of three women without eclampsia. The thresholds used were those specified in the study document.

**Table 4** summarizes the preliminary predictive performance of the individual Doppler indices. RI  $<0.60$ , PI  $<1.20$ , and PSV2  $\geq 43.75$  cm/s each yielded **85.7% sensitivity** and **100% specificity**, with a positive predictive value of 100%. The PSV ratio  $>0.65$  demonstrated the highest sensitivity (**100%**) and negative predictive value (**100%**), although its specificity was lower at **66.7%**. These diagnostic estimates should be interpreted cautiously because they are derived from only ten participants.

The individual observations presented in **Table 5** demonstrate the overall pattern underlying the group-level findings. Most women who developed eclampsia had relatively low RI and PI together with elevated PSV ratio and PSV2. In contrast, the three women without eclampsia generally showed higher RI and PI and lower PSV2 values. The individual measurements and outcomes were extracted directly from the patient-level dataset in the manuscript.

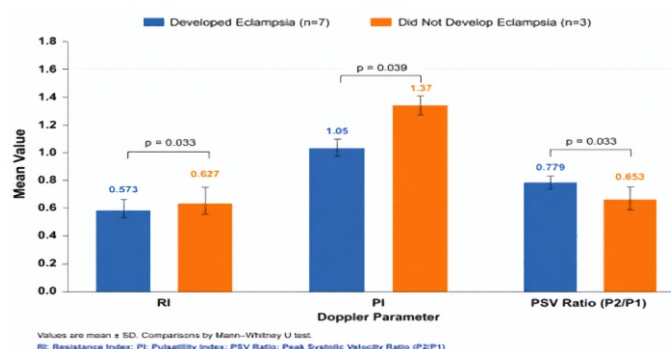
**Table 1. Baseline characteristics and overall ophthalmic artery Doppler parameters**

| Parameter                        | Overall (n=10)    |
|----------------------------------|-------------------|
| Age (years), mean $\pm$ SD       | 33.6 $\pm$ 2.4    |
| Age range (years)                | 28–36             |
| RI, mean $\pm$ SD                | 0.589 $\pm$ 0.037 |
| PI, mean $\pm$ SD                | 1.15 $\pm$ 0.20   |
| PSV ratio (P2/P1), mean $\pm$ SD | 0.741 $\pm$ 0.079 |
| PSV2 (cm/s), mean $\pm$ SD       | 45.09 $\pm$ 3.47  |
| Developed eclampsia              | 7 (70.0%)         |
| Did not develop eclampsia        | 3 (30.0%)         |

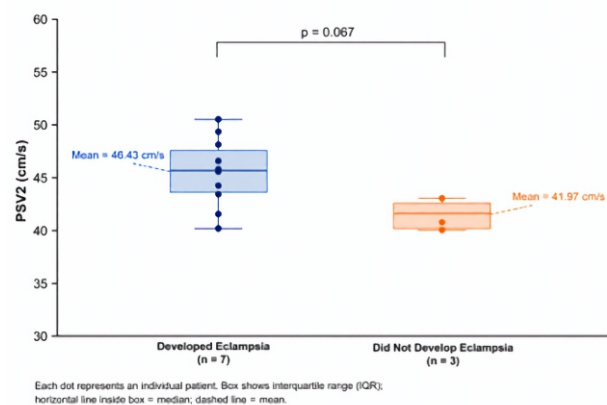
**Table 1. Baseline characteristics and overall ophthalmic artery Doppler parameters**

| Doppler parameter | Developed eclampsia (n=7) | No eclampsia (n=3) | p-value*     |
|-------------------|---------------------------|--------------------|--------------|
| RI                | 0.573 $\pm$ 0.027         | 0.627 $\pm$ 0.025  | <b>0.033</b> |
| PI                | 1.05 $\pm$ 0.13           | 1.37 $\pm$ 0.15    | <b>0.039</b> |
| PSV ratio (P2/P1) | 0.779 $\pm$ 0.055         | 0.653 $\pm$ 0.042  | <b>0.033</b> |
| PSV2 (cm/s)       | 46.43 $\pm$ 3.03          | 41.97 $\pm$ 1.62   | 0.067        |

\*Comparison by Mann–Whitney U test because of the very small group sizes.



**Figure 4. Comparison of mean ophthalmic artery Doppler indices between women who developed eclampsia and those who did not.**



**Figure 5. Second peak systolic velocity (PSV2) according to subsequent development of eclampsia.**

**Table 3. Distribution of abnormal Doppler parameters and subsequent eclampsia**

| Doppler criterion      | Eclampsia (n=7), n (%) | No eclampsia (n=3), n (%) |
|------------------------|------------------------|---------------------------|
| RI <0.60               | 6 (85.7)               | 0 (0.0)                   |
| PI <1.20               | 6 (85.7)               | 0 (0.0)                   |
| PSV ratio >0.65        | 7 (100.0)              | 1 (33.3)                  |
| PSV2 $\geq$ 43.75 cm/s | 6 (85.7)               | 0 (0.0)                   |

**Table 4. Preliminary diagnostic performance of individual ophthalmic artery Doppler parameters for subsequent eclampsia**

| Doppler criterion      | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%)      |
|------------------------|-----------------|-----------------|---------|--------------|
| RI <0.60               | 85.7            | 100.0           | 100.0   | 75.0         |
| PI <1.20               | 85.7            | 100.0           | 100.0   | 75.0         |
| PSV ratio >0.65        | <b>100.0</b>    | 66.7            | 87.5    | <b>100.0</b> |
| PSV2 $\geq$ 43.75 cm/s | 85.7            | 100.0           | 100.0   | 75.0         |

**Table 5. Individual patient Doppler profile and clinical outcome**

| Patient | Age (years) | RI   | PI   | P2/P1 | PSV2 (cm/s) | Eclampsia |
|---------|-------------|------|------|-------|-------------|-----------|
| 1       | 28          | 0.58 | 1.10 | 0.75  | 45.2        | Yes       |
| 2       | 35          | 0.62 | 1.30 | 0.68  | 41.5        | Yes       |
| 3       | 35          | 0.55 | 1.00 | 0.78  | 47.1        | Yes       |
| 4       | 34          | 0.60 | 1.20 | 0.64  | 42.8        | No        |
| 5       | 32          | 0.59 | 1.10 | 0.77  | 44.5        | Yes       |
| 6       | 35          | 0.57 | 1.00 | 0.80  | 46.9        | Yes       |
| 7       | 36          | 0.63 | 1.40 | 0.70  | 43.0        | No        |
| 8       | 34          | 0.56 | 0.95 | 0.82  | 49.3        | Yes       |
| 9       | 35          | 0.54 | 0.90 | 0.85  | 50.5        | Yes       |
| 10      | 32          | 0.65 | 1.50 | 0.62  | 40.1        | No        |

## DISCUSSION

The present preliminary study evaluated first-trimester ophthalmic artery Doppler parameters as potential predictors of subsequent eclampsia. Women who developed eclampsia demonstrated a consistent hemodynamic pattern characterized by significantly lower RI and PI and a higher P2/P1 ratio, suggesting reduced vascular impedance and increased orbital blood flow. Mean RI was 0.573 versus 0.627 ( $p=0.033$ ), PI was 1.05 versus 1.37 ( $p=0.039$ ), and P2/P1 ratio was 0.779 versus 0.653 ( $p=0.033$ ) in women with & without subsequent eclampsia, respectively. PSV2 was also higher (46.43 vs 41.97 cm/s), although the difference did not attain statistical significance ( $p=0.067$ ).

These findings are biologically plausible considering the cerebral hemodynamic alterations associated with severe hypertensive disorders of pregnancy. Belfort et al. [12] described altered orbital and cerebral circulation in preeclampsia, while Diniz et al. [11] demonstrated the usefulness of ophthalmic artery Doppler in

assessing severe preeclampsia. Reduced vascular impedance may represent vasodilatation and cerebral hyperperfusion resulting from impaired autoregulation. This mechanism is particularly relevant to eclampsia, where disruption of cerebral autoregulation, endothelial injury and vasogenic edema may contribute to seizure development [9,10].

The direction of Doppler changes in the present study is also consistent with Matias et al. [13,14], who reported altered ophthalmic artery velocimetry in preeclamptic pregnancies and demonstrated its potential predictive value. Takata et al. [16] similarly observed altered ophthalmic arterial blood flow in women with preeclampsia. Collectively, these findings support the concept that reduced RI and PI accompanied by increased systolic flow characteristics may serve as markers of abnormal maternal cerebral circulation.

An important finding was the performance of the P2/P1 ratio  $>0.65$ , which demonstrated 100% sensitivity and 100% negative predictive value, although specificity was 66.7%. RI  $<0.60$ , PI

<1.20 and PSV2  $\geq 43.75$  cm/s each demonstrated 85.7% sensitivity and 100% specificity in this preliminary cohort. These observations agree with the systematic review and meta-analysis by de Melo et al. [17], which identified peak ratio and second peak systolic velocity as particularly promising ophthalmic artery Doppler parameters for assessment of preeclampsia.

The timing of assessment is another relevant aspect of this study. Doppler examination was performed at 11–13 weeks and 6 days, substantially before the usual clinical onset of preeclampsia. Gana et al. [15] reported that the ophthalmic artery PSV ratio measured at 11–13 weeks was increased in pregnancies that subsequently developed preeclampsia and could contribute to first-trimester prediction. This supports the potential value of ophthalmic artery Doppler as an early, non-invasive vascular marker. Nevertheless, as emphasized in recent systematic evaluations [17,18], differences in Doppler methodology, thresholds and study populations currently limit routine clinical implementation.

The principal limitation of the present study is the very small sample size (n=10), resulting in imprecise estimates of diagnostic performance and limiting generalizability. Furthermore, the high proportion developing eclampsia suggests a selected high-risk population and prevents extrapolation of predictive values to an unselected obstetric population. The present results should therefore be regarded as preliminary. Larger prospective studies are required to validate the optimal Doppler thresholds and determine whether combining ophthalmic artery Doppler with established maternal, biochemical and uterine artery markers improves prediction of severe preeclampsia and eclampsia.

Overall, these preliminary findings suggest that reduced RI and PI together with increased P2/P1 ratio and PSV2 may identify early maternal cerebrovascular alterations associated with subsequent eclampsia. Ophthalmic artery Doppler may therefore represent a promising non-invasive adjunct for early risk stratification, provided that its predictive performance is confirmed in larger cohorts.

## CONCLUSION

First-trimester ophthalmic artery Doppler demonstrated distinct hemodynamic alterations in women who subsequently developed eclampsia, characterized by **reduced RI and PI and increased P2/P1 ratio and PSV2**. The P2/P1 ratio showed particularly promising predictive performance. Ophthalmic artery Doppler may therefore serve as a simple, non-invasive adjunct for early identification of women at increased risk of severe hypertensive complications. However, given the **small preliminary sample**, these findings require validation in larger prospective cohorts before routine clinical application.

## LIMITATIONS & FUTURE PERSPECTIVES

The study's limitations include a single-centre setting, a relatively small sample size, and a short study duration, which may limit the broader applicability of the results. Future studies should incorporate multi-centre designs with larger populations to enhance

validity, assess long-term outcomes, and investigate advanced diagnostic & management approaches. Such efforts will improve overall patient care & help minimize complications.

## CLINICAL SIGNIFICANCE

The clinical significance of this study lies in its potential to bridge the gap between research findings and practical health-care, diagnosis, and treatment outcomes. By highlighting real-care applications. It emphasizes the importance of translating scientific observations into meaningful improvements in patient world relevance, the study contributes to evidence based medical practice and supports informed clinical decision making. Ultimately, the findings aim to enhance patient quality of life, optimize therapeutic strategies, and promote better disease management in clinical settings.

## ABBREVIATIONS

**RI:** Resistance Index

**PI:** Pulsatility Index

**PSV:** Peak Systolic Velocity

**PSV2:** Second Peak Systolic Velocity

**P2/P1:** Second-to-First Peak Systolic Velocity Ratio

**OA:** Ophthalmic Artery

**Doppler USG:** Doppler Ultrasonography

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## AUTHOR CONTRIBUTIONS

All authors significantly contributed to the study conception and design, data acquisition, or data analysis and interpretation. They participated in drafting the manuscript or critically revising it for important intellectual content, consented to its submission to the current journal, provided final approval for the version to be published, and accepted responsibility for all aspects of the work. Additionally, all authors meet the authorship criteria outlined by the International Committee of Medical Journal Editors (ICMJE) guidelines.

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## CONFLICT OF INTEREST

Authors declared that there is no conflict of interest.

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None

## ETHICAL APPROVAL & CONSENT TO PARTICIPATE

All necessary consent & approval was obtained by authors.

## CONSENT FOR PUBLICATION

All necessary consent for publication was obtained by authors.

## DATA AVAILABILITY

All data generated and analyzed are included within this research article. The datasets utilized and/or analyzed in this study can be obtained from the corresponding author upon a reasonable request.

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