

Role of First-Trimester Ophthalmic Artery Doppler in Predicting Preeclampsia and Progression to Eclampsia: A Case Series

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ABSTRACT:

Background: Preeclampsia is a leading cause of maternal and perinatal morbidity, and its cerebral complication, eclampsia, contributes substantially to adverse outcomes. The ophthalmic artery offers an accessible window into the cerebral circulation, but first-trimester data remain limited. We evaluated first-trimester ophthalmic artery Doppler for early prediction of preeclampsia and eclampsia.

Case presentation: In this prospective observational case series, ten pregnant women aged 28–36 years underwent ophthalmic artery Doppler at 11⁺⁰–13⁺⁶ weeks. Resistance index (RI), pulsatility index (PI), the second-to-first peak systolic velocity ratio (PSV ratio, P2/P1) and second peak systolic velocity (PSV2) was recorded, and participants were followed for disease development. Given the small sample, findings are reported descriptively.

Results: Seven women subsequently developed eclampsia and three remained normotensive. Those who progressed consistently showed reduced RI (mostly <0.60) and PI (≤ 1.1) with an elevated PSV ratio (>0.65) and PSV2 (≥ 43.75 cm/s, reaching 50.5 cm/s), whereas unaffected women retained higher impedance and lower velocities. The PSV ratio was the most discriminating index, exceeding 0.65 in every affected woman.

Conclusion: A first-trimester ophthalmic artery Doppler signature of low orbital vascular impedance and high systolic velocity preceded eclampsia in this series. Although limited by sample size, these findings suggest early orbital Doppler merits further evaluation as a simple, non-invasive screening tool for preeclampsia and eclampsia.

Keywords: ophthalmic artery Doppler; preeclampsia; eclampsia; first-trimester screening; peak systolic velocity ratio



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INTRODUCTION:

Preeclampsia is a pregnancy-specific, multisystem disorder characterised by new-onset hypertension after 20 weeks of gestation and remains a leading cause of maternal and perinatal morbidity and mortality worldwide ^[1]. Its pathophysiology involves defective trophoblastic invasion and impaired placentation, which trigger release of anti-angiogenic factors and widespread maternal endothelial dysfunction, producing generalised vasoconstriction, raised vascular resistance and multi-organ hypoperfusion^[1]. Because cerebral complications such as eclampsia contribute substantially to adverse outcomes, early identification of women destined to develop the disease is a global health priority, enabling timely surveillance and prophylaxis^[1].

Current first-trimester screening combines maternal risk factors with mean arterial pressure, uterine artery Doppler and biochemical markers; nonetheless, the search continues for simple, reproducible tools that reflect the cerebral haemodynamic changes central to the disorder ^[1]. The ophthalmic artery, a branch of the internal carotid artery, is an easily accessible vessel that provides an indirect window into the otherwise inaccessible intracranial circulation, making it an attractive target for Doppler interrogation in pregnancy^[2].

In women with preeclampsia, ophthalmic artery waveforms demonstrate reduced impedance to flow and increased velocities compared with normotensive pregnancies, reflecting cerebral overperfusion and disturbed autoregulation^[2]. The waveform is characteristically biphasic, and the ratio of the second to first peak systolic velocity (PSV ratio) has emerged as the most informative index, alongside a reduced pulsatility index^[2,3]. Sarno et al. showed that ophthalmic artery Doppler at 35–37 weeks could predict subsequent preeclampsia, particularly disease developing within three weeks of assessment, with the PSV ratio outperforming other single indices ^[3]. Comparable value has been reported earlier in pregnancy, including multiparametric models incorporating ophthalmic Doppler at 28–32 weeks that achieved high sensitivity and specificity when combined with uterine artery Doppler and biochemical markers ^[4], and second-trimester assessments in which an elevated PSV ratio identified a substantial proportion of affected women ^[5].

This evidence has been reinforced by systematic reviews. A meta-analysis by de Melo et al. confirmed that ophthalmic artery Doppler parameters differ significantly between preeclamptic and normotensive women, supporting a role in complementary diagnosis^[6], while a more recent synthesis demonstrated that adding ophthalmic indices to established biophysical markers improves predictive performance for both preterm and term preeclampsia^[7]. Correlational studies have further linked ophthalmic Doppler indices, particularly pulsatility index and end-diastolic velocity, with maternal

blood pressure, underscoring their potential as reliable, low-cost markers^[8].

Compared with existing modalities, ophthalmic artery Doppler is non-invasive, inexpensive, rapid and requires neither contrast nor specialised biochemical assays, making it well suited to low-resource settings ^[6, 8]. Yet reference ranges and optimal cut-offs remain to be standardised across gestational ages and populations. The present study therefore evaluates ophthalmic artery Doppler indices—resistance index, pulsatility index, PSV ratio and second peak systolic velocity—measured in the first trimester (11–13⁺6 weeks) for early prediction of preeclampsia and eclampsia.

CASE PRESENTATIONS:

This prospective observational case series was conducted at [institution] after approval by the Institutional Ethics Committee and with written informed consent from all participants, in accordance with the Declaration of Helsinki. Ten pregnant women attending for first-trimester assessment between 11⁺0 and 13⁺6 weeks of gestation were included consecutively from an ongoing study.

Each woman was examined in a semi-recumbent position with the head slightly extended and the eyes gently closed. A thin layer of coupling gel was applied to the upper eyelid and a high-frequency linear transducer (7.5–12 MHz) was placed over the closed eyelid with minimal pressure, angled medially toward the orbital apex. Colour Doppler was used to identify the ophthalmic artery adjacent to the optic nerve, after which pulsed-wave Doppler was applied with the sample volume within the vessel lumen and a low insonation angle. At least three consecutive uniform waveforms were recorded, and the RI, PI, PSV ratio (P2/P1) and second peak systolic velocity (PSV2) were obtained. The reference ranges and proposed cut-offs used to classify indices as normal or abnormal are shown in Table 1.

Women were followed through pregnancy for the development of preeclampsia and eclampsia. Given the descriptive nature and small size of this series, results are summarised as counts and simple descriptive statistics; no formal test of statistical significance was applied.

All ten participants were women aged 32–36 years. Their first-trimester ophthalmic artery Doppler indices and outcomes are presented in Table 2. Seven women subsequently developed eclampsia and three did not.

The seven women who progressed to eclampsia consistently showed an ophthalmic artery pattern of reduced RI (mostly below 0.60) and reduced PI (1.1 or lower), together with an elevated PSV ratio (above 0.65) and an elevated PSV2 (at or above 43.75 cm/s), the last reaching 50.5 cm/s in the most

severely affected case. In contrast, the three women who remained unaffected had higher RI values (0.60–0.65), PI within the normotensive range (1.2–1.5) and PSV2 values below the proposed threshold. The overall pattern was of

lower orbital vascular impedance and higher second-peak velocity in the women who were destined to develop eclampsia.

Table 1. Ophthalmic artery Doppler parameters: normotensive reference ranges and proposed preeclampsia cut-offs.

Doppler parameter	Normotensive range	Preeclampsia pattern / proposed cut-off	Interpretation of altered pattern
Resistance index (RI)	0.60–0.70	Reduced (<0.60; <0.58 for high risk)	Decreased downstream impedance and orbital vasodilatation, suggesting cerebral hyperperfusion.
Pulsatility index (PI)	1.2–1.5	Reduced (<1.2)	Lower impedance to flow in the cerebral circulation.
PSV ratio (P2/P1)	<0.60	Elevated (>0.65–0.75)	Loss of vascular tone and autoregulation, producing a high-flow state.
Second peak systolic velocity (PSV2)	Lower absolute velocity	Elevated (≥ 43.75 cm/s)	Increased systolic velocity, correlating with raised cerebral perfusion pressure.

RI, resistance index; PI, pulsatility index; PSV, peak systolic velocity; P1, first peak; P2, second peak; PSV2, second peak systolic velocity.

Table 2. Maternal age, first-trimester ophthalmic artery Doppler indices and outcome (n = 10).

Case	Age (y)	RI	PI	PSV ratio (P2/P1)	PSV2 (cm/s)	Developed eclampsia
1	28	0.58	1.1	0.75	45.2	Yes
2	35	0.62	1.3	0.68	41.5	Yes
3	35	0.55	1	0.78	47.1	Yes
4	34	0.6	1.2	0.64	42.8	No
5	32	0.59	1.1	0.77	44.5	Yes
6	35	0.57	1	0.8	46.9	Yes
7	36	0.63	1.4	0.7	43	No
8	34	0.56	0.95	0.82	49.3	Yes
9	35	0.54	0.9	0.85	50.5	Yes
10	32	0.65	1.5	0.62	40.1	No

All participants were female. RI, resistance index; PI, pulsatility index; PSV ratio, ratio of second to first peak systolic velocity (P2/P1); PSV2, second peak systolic velocity. Patient names and hospital numbers have been removed to preserve confidentiality.

DISCUSSION:

In this first-trimester case series, the seven women who later progressed to eclampsia consistently showed an orbital Doppler signature of low vascular impedance and high systolic velocity – a reduced resistance index and pulsatility index accompanied by an elevated second-to-first peak systolic velocity ratio and a raised second peak systolic velocity – whereas the three women who remained normotensive retained higher impedance and lower velocities. This pattern is concordant with the accepted pathophysiological model in which defective placentation and generalised endothelial dysfunction produce a hyperdynamic, low-resistance cerebral circulation with impaired autoregulation, of which the ophthalmic artery provides an accessible external window^[1, 2].

Most published ophthalmic artery Doppler data derive from the second and third trimesters, yet our observations at 11–13⁺6 weeks echo the earliest first-trimester work. Gurgel Alves et al. were among the first to demonstrate that first-trimester ophthalmic artery indices differ in women who subsequently develop preeclampsia^[9], and this was later refined by Gana et al., who measured the peak systolic velocity ratio at 11–13 weeks and reported that it contributed to first-trimester prediction when combined with established biomarkers^[10]. Matias et al. similarly showed the predictive value of orbital velocimetry in relation to later disease^[11]. Our qualitative finding – that the abnormal pattern was already evident in the first trimester in the women destined to develop eclampsia – supports the biological plausibility of very early orbital Doppler screening described by these groups.

The second-to-first peak systolic velocity ratio was the most discriminating index in our series, exceeding 0.65 in every woman who progressed to eclampsia and remaining below this value in those who did not. This is consistent with Sarno et al., who found the peak systolic velocity ratio to be the single most informative index at 35–37 weeks and superior to other single measurements^[3], and with the meta-analysis of Kalafat et al., in which a peak ratio above 0.65 achieved diagnostic accuracy comparable with that of uterine artery Doppler for early-onset disease^[12]. The systematic reviews of de Melo et al.^[6] and Dai et al.^[13] likewise confirmed significant differences in peak systolic velocity, second systolic peak and peak ratio between preeclamptic and normotensive women, reinforcing the ratio as the most reproducible discriminator across gestational ages.

The reduction in resistance index and pulsatility index observed in our eclampsia group mirrors the low-impedance state described in correlational studies linking ophthalmic Doppler indices to maternal blood pressure^[8] and the diagnostic thresholds reported by Saleh et al. at 28–32 weeks

^[4]. It is worth noting, however, that the pulsatility index has been an inconsistent predictor in larger cohorts and pooled analyses, where it has frequently failed to reach clinically useful sensitivity or specificity^[12,13]. Our small series cannot resolve this discrepancy, but the clearer separation seen with the velocity-based indices (peak systolic velocity ratio and second peak systolic velocity) than with impedance indices alone is in keeping with that wider literature.

Contemporary screening increasingly favours multiparametric models, and the incremental value of adding ophthalmic Doppler to biophysical and biochemical markers has been demonstrated for both preterm and term disease^[7], including second-trimester combinations with uterine artery Doppler^[4,5]. Although our descriptive series did not construct a formal predictive model, the distinct separation between affected and unaffected women is consistent with the view that orbital Doppler carries information independent of established markers and could, in principle, strengthen existing first-trimester algorithms.

The principal strength of this series is the demonstration that a reproducible orbital Doppler pattern is detectable as early as 11–13⁺6 weeks using inexpensive, portable equipment that requires neither contrast nor specialised biochemical assays, a feature particularly relevant to low-resource settings^[6,8]. The limitations are, nonetheless, substantial. The sample of ten precludes any formal estimate of sensitivity, specificity or predictive value; the high rate of progression to eclampsia reflects a selected series rather than an unselected population and is likely to exaggerate the apparent separation between groups; single-centre, single-operator measurement introduces operator dependence; and reference ranges and optimal cut-offs for the first trimester remain unstandardised across populations. These findings should therefore be regarded as hypothesis-generating and require confirmation in adequately powered, prospective cohorts with blinded outcome assessment before first-trimester ophthalmic artery Doppler can be recommended for routine screening.

CONCLUSION:

First-trimester ophthalmic artery Doppler—in particular a reduced RI and PI with an elevated PSV ratio and PSV2—was associated with the later development of eclampsia in this case series. Although limited by its small size, the series suggests that early orbital Doppler merits further evaluation as a non-invasive screening tool for preeclampsia and eclampsia.

DECLARATIONS:

Ethical Approval: This prospective observational case series was conducted at [institution] after approval by the Institutional Ethics Committee and with written informed consent from all participants, in accordance with the

Declaration of Helsinki. Ref. 368/IEC/PG-8127/2026/SC-1, dated 22/05/2026

Informed Consent: Informed consent was obtained from all participants prior to their inclusion in the study. Participants were informed that their data would be kept confidential and used solely for research purposes.

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Data availability statement: The dataset presented in this study is available on request from the corresponding author.

AI Use Disclosure: No generative AI tools were used in the writing or data analysis. AI tools were limited to language assistance. The authors remain fully responsible for the content.

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