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Original Article

Obstetrics and Gynaecology Section

Comparison of Maternal Ophthalmic Artery Doppler Parameters in Gestational Hypertensive and Normotensive Pregnant Women: A Cross-sectional Study

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ABSTRACT

Introduction: Hypertensive disorders of pregnancy, including gestational hypertension and preeclampsia, significantly contribute to maternal and perinatal morbidity. Identifying early vascular changes through non invasive methods is crucial for improving risk stratification and clinical outcomes.

Aim: To compare the ophthalmic artery Doppler parameters in gestational hypertensive and normotensive pregnant women.

Materials and Methods: A cross-sectional study was conducted in the of Department of Obstetrics and Gynaecology at Dr. D.Y. Patil Medical College, Hospital, and Medical Research Centre, Pimpri, Pune, Maharashtra, India, from September 2023 to March 2025. A total of 450 primigravida and second-gravida women between 30 and 37 weeks of gestation, with confirmed gestational age based on first or early second-trimester ultrasonography, were included in both the gestational hypertension (n=80) and normotensive groups (n=370). Doppler ultrasound assessed key ophthalmic artery parameters, including the first and second Peak Systolic Velocities (PSV), the Peak Ratio (PR), and the Pulsatility Index (PI). Statistical analysis was performed to compare Doppler indices between the groups using appropriate statistical tests.

Results: The mean maternal age was 29.4±5.7 years. The first and second PSVs were significantly elevated in hypertensive pregnancies ($p<0.001$). The PR was also significantly higher in hypertensive pregnancies ($p<0.001$), suggesting altered arterial compliance. While one PI parameter (PI-C) was significantly elevated ($p<0.001$), other PI values did not show significant differences.

Conclusion: Ophthalmic artery Doppler parameters, mainly first and second PSVs and PR, serve as promising non invasive markers for hypertensive disorders in pregnancy.

Keywords: Hypertensive disorders of pregnancy, Ophthlamic artery doppler, Pulsatility index, Resistance index

INTRODUCTION

Gestational hypertension and preeclampsia are significant contributors to maternal and foetal morbidity, necessitating reliable tools for early prediction and monitoring. Among various diagnostic methods, ophthalmic artery Doppler ultrasound has emerged as a promising non invasive tool for assessing the risk of these hypertensive disorders, potentially enabling timely intervention and improved outcomes [1]. The ophthalmic artery, a branch of the internal carotid artery, shares haemodynamic characteristics with systemic circulation. Pregnancy-related hypertensive disorders, characterised by endothelial dysfunction, vasoconstriction, and impaired placental perfusion, lead to systemic vascular changes that can be reflected in ophthalmic artery Doppler parameters [1]. Elevated Resistance Index (RI) and PI in the ophthalmic artery have been linked to increased vascular resistance, serving as early indicators of gestational hypertension and preeclampsia [2,3]. Research suggests that abnormal Doppler flow patterns in the ophthalmic artery may precede the clinical onset of preeclampsia by several weeks, offering a valuable opportunity for early risk stratification and closer surveillance. Compared to invasive tests, Doppler ultrasound is a safe, accessible, and cost-effective method for monitoring vascular changes in pregnancy [3]. Additionally, its utility extends beyond prediction, providing insights into the underlying pathophysiology of preeclampsia, including systemic vasoconstriction and endothelial dysfunction [4,5]. A study has demonstrated a strong association between ophthalmic artery Doppler indices and the likelihood of developing gestational hypertension and preeclampsia [1]. This technique's predictive value is enhanced when combined with maternal history, serum biomarkers, and blood pressure measurements, allowing for comprehensive risk assessment [5,6]. Early identification of at-risk pregnancies enables proactive management strategies, including closer monitoring, antihypertensive therapy, and timely delivery planning to prevent complications such as foetal growth restriction and preterm birth [7]. The present study aimed to compare the ophthalmic artery Doppler parameters in gestational hypertensive and normotensive pregnant women.

MATERIALS AND METHODS

The present cross-sectional study was conducted in the Department of Obstetrics and Gynaecology at Dr. D. Y. Patil Medical College, Hospital, and Medical Research Centre, Pimpri, Pune, Maharashtra, India, from September 2023 to March 2025. The Institutional Ethics Subcommittee (IESC/322/2023) approved the study.

Sample size calculation: The sample size was calculated using WinPepi software.

Inclusion and Exclusion criteria: Primigravida and second-gravida women between 30 and 37 weeks of gestation, with confirmed gestational age based on first or early second-trimester ultrasonography, were included in both the gestational hypertension

(n=80) and normotensive groups (n=370). Chronic hypertension, other pre-existing conditions such as pre-gestational diabetes mellitus, and any ophthalmic diseases that could interfere with ocular Doppler assessments were excluded, as these factors may independently influence ophthalmic artery findings and potentially affect study outcomes.

Study Procedure

Patients were selected continuously based on these criteria, and informed written consent was obtained from all participants. A comprehensive history was recorded. Each patient underwent a thorough general, systemic, and obstetric examination and was categorised as either normotensive or gestational hypertensive (preeclampsia defined by two readings of Blood Pressure (BP)>140/90 mmHg, taken four hours apart). Routine antenatal investigations were reviewed, and any missing tests were conducted as required.

All participants underwent an ophthalmic artery Doppler study, which was performed by a dedicated sonologist from the Radiology Department. Those who developed gestational hypertension during the study period or whose mild hypertension progressed to severe disease underwent a second ophthalmic artery Doppler evaluation 3-4 weeks after their first Doppler evaluation.

The ophthalmic artery Doppler examination was conducted with the patient in a supine position. After applying conduction gel, a 7.5 MHz linear transducer was placed transversely over the closed upper eyelid. Colour flow Doppler was used to identify the ophthalmic artery, which lies superior and medial to the optic nerve. Pulsed-wave Doppler was then used to record waveforms while maintaining an insonation angle of less than 20°. Measurements were taken sequentially from the right and left eyes, with two readings from each eye. The average values for the first PSV, second PSV, PI, and PSV ratio (second to first PSV) were recorded. While the machine automatically displayed the first PSV and PI, the second PSV was measured manually, and the PSV ratio was subsequently calculated [1].

STATISTICAL ANALYSIS

Statistical analysis was conducted using MS Excel (Microsoft 365) and IBM Statistical Package of Social Sciences (SPSS) Statistics for Windows, version 27.0 (IBM Corp. Released 2020; Armonk, NY: IBM Corp.). Data were presented using means and standard deviations for continuous variables. Normality was checked using the Shapiro-Wilk normality test. Differences between the hypertensive and normotensive groups were analysed using the Mann's-Whitney U test since the data did not follow a normal distribution. For all tests, a p-value of <0.05 (two-tailed) was considered statistically significant.

RESULTS

The mean maternal age was similar between hypertensive (n=80) and normotensive pregnancies (n=370) (31.23±4.50 vs. 31.70±5.33 years, p=0.316). The mean maternal age was also reported as 29.4±5.7 years. The overall average of the first peak velocities was 36.08±4.07 cm/s in hypertensive pregnancies, significantly greater than the 34.86±6.59 cm/s observed in normotensive pregnancies (p<0.001) [Table/Fig-1]. The ratio of the second to the first peak (PR) was significantly higher in hypertensive pregnancies (0.77±0.11) compared to normotensive pregnancies (0.52±0.11, p<0.001), suggesting altered systolic dynamics [Table/Fig-2].

The PI values exhibited some differences, with PI-C in the left eye being significantly higher in hypertensive pregnancies; however, the overall average PI was nearly identical between the groups (1.73±0.27 in hypertensive vs. 1.74±0.19 in normotensive, p=0.452) [Table/Fig-3].

DISCUSSION

By evaluating key Doppler indices, the present study aimed to determine whether these non invasive assessments could effectively

Doppler parameters	Hypertensive 80 (17.8%)	Normotensive 370 (82.2%)	Total N=450	p-value
1st Peak-A right eye	38.10±6.80	36.94±7.90	37.15±7.73	<0.001*
1st Peak-B right eye	33.77±4.70	32.01±8.34	32.32±7.84	<0.001*
1st Peak-C left eye	37.89±2.88	35.91±7.90	36.26±7.30	<0.001*
1st Peak-D left eye	34.69±4.11	34.58±5.63	34.60±5.39	0.339
Average of 1st peak	36.08±4.07	34.86±6.59	35.08±6.23	<0.001*

[Table/Fig-1]: Comparison of 1st peak velocity of right and left eye between hypertensive and normotensive patients.
Mann's-Whitney U test; Values presented as mean±Standard Deviation (SD)

Doppler parameters	Hypertensive 80 (17.8%)	Normotensive 370 (82.2%)	Total N=450	p-value
2nd Peak-A right eye	29.98±6.96	19.30±6.09	21.20±7.46	<0.001*
2nd Peak-B right eye	24.86±4.45	16.55±6.87	18.03±7.24	<0.001*
2nd Peak-C left eye	30.96±5.20	18.55±4.79	20.76±6.79	<0.001*
2nd Peak-D left eye	25.15±5.85	17.91±4.35	19.19±5.41	<0.001*
Average of 2nd peak	27.74±4.79	18.08±4.87	19.80±6.10	<0.001*
Ratio of 2nd to 1st Peak	0.77±0.11	0.52±0.11	0.57±0.14	<0.001*

[Table/Fig-2]: Comparison of 2nd peak velocity and Peak Ratio (PR) of right and left eye between hypertensive and normotensive patients.
Mann's-Whitney U test; Values presented as mean±Standard Deviation (SD)

Doppler parameters	Hypertensive 80 (17.8%)	Normotensive 370 (82.2%)	Total N=450	p-value
Pulsality index-A right eye	1.66±0.30	1.75±0.38	1.73±0.37	0.14
Pulsality index-B right eye	1.67±0.42	1.70±0.26	1.69±0.30	0.126
Pulsality index-C left eye	1.83±0.42	1.77±0.33	1.78±0.35	<0.001*
Pulsality index-D left eye	1.78±0.32	1.73±0.31	1.74±0.31	0.424
Average of pulsality index	1.73±0.27	1.74±0.19	1.74±0.21	0.452

[Table/Fig-3]: Comparison of right and left eye Pulsatility Index (PI) between hypertensive and normotensive patients.
Mann's-Whitney U test; Values presented as mean±Standard Deviation (SD)

detect early haemodynamic alterations linked to hypertensive conditions. The relevance of the present research lies in its potential to introduce a simple, cost-effective, and easily accessible screening method into routine obstetric care, thereby facilitating the early identification of high-risk pregnancies.

The first PSV of the ophthalmic artery provided critical insights into haemodynamic alterations associated with hypertensive pregnancies. In this study, the overall average first peak was notably higher in the hypertensive group, suggesting early endothelial dysfunction and increased arterial stiffness due to hypertensive stress. These results align with findings by Alves JA et al., who demonstrated that Doppler waveform alterations in high-risk pregnancies indicate an elevated risk of preeclampsia, although their focus was primarily on uterine artery parameters [8]. Similarly, Oliveira CA et al., (2012) reported increased ocular blood flow velocities in hypertensive pregnancies, likely reflecting a compensatory response to heightened vascular resistance [9]. Matias D et al., (2012) also emphasised that early systolic changes in ophthalmic artery Doppler assessments could serve as indicators of vascular stress in hypertensive pregnancies [10]. These findings highlight the clinical value of first peak measurements in the early detection and risk assessment of hypertensive pregnancy disorders.

In the present study, the second peak values in both eyes were significantly higher in hypertensive cases ($p<0.001$), indicating a compensatory hyperdynamic response to maintain cerebral perfusion despite increased vascular resistance. Matias D et al., (2020) identified the second systolic peak as an independent predictor of hypertensive disorders, establishing a clear cut-off value for distinguishing abnormal cases [11]. Chaves MTP et al., (2017) similarly observed a correlation between increased second peak velocities and severe maternal vascular compromise, reinforcing the findings of present study [12]. Hikima M et al., (2023) further confirmed significantly elevated PSV values in pre-eclamptic patients, supporting the reliability of second peak measurements in detecting vascular changes [13]. The consistency of these findings across multiple studies highlights the second peak's potential as a dependable marker for hypertensive pregnancies, justifying its inclusion in clinical screening protocols.

The ratio of the second to the first peak (PR) is a key parameter reflecting the redistribution of systolic flow. The present study found significantly elevated PR values in hypertensive pregnancies ($p<0.001$), indicating increased downstream vascular resistance and altered arterial compliance. Nicolaides K et al., (2021) demonstrated that PR is a superior predictor of both early- and late-onset preeclampsia compared to conventional markers such as the uterine artery PI [1]. Gonser M et al., (2021) linked elevated PR values to increased pulse wave reflections, a hallmark of hypertensive pathophysiology [14]. Similarly, Selima ER et al., (2022) found higher PR values to be associated with severe preeclampsia and adverse maternal outcomes [15]. Clinically, incorporating PR measurements into routine ophthalmic Doppler evaluations could enhance risk stratification and facilitate timely interventions in hypertensive pregnancies.

The PI, which indirectly measures vascular resistance, yielded mixed results in this study. While PI-C was significantly elevated in hypertensive pregnancies ($p<0.001$), other PI values did not show statistically significant differences. This suggests that localised vascular changes may occur in hypertensive pregnancies, whereas global impedance, as measured by PI, may not be uniformly affected. Kumari N et al., (2023) reported an inverse correlation between PI and mean arterial pressure, particularly in severe preeclampsia, which contrasts with this study's findings [16]. Matias D et al., (2012) acknowledged the value of PI in assessing vascular impedance but highlighted its limitations as a standalone predictor [11]. Satish S et al., (2019) recommended combining PI with other Doppler indices and maternal biomarkers to improve predictive accuracy for hypertensive disorders [17].

Future studies should adopt longitudinal designs with serial Doppler assessments across different gestational stages to better understand the trajectory of vascular changes. Expanding the range of Doppler parameters and incorporating biochemical and clinical risk factors could enhance predictive accuracy for hypertensive disorders. Additionally, validation in more diverse populations and investigation of long-term maternal and neonatal outcomes linked to early Doppler findings would be essential to enhance clinical applicability and refine prenatal screening strategies.

Limitation(s)

One key limitation is the operator dependency of Doppler ultrasound, which may introduce inter-observer variability even when standardised protocols are followed. Additionally, the cross-sectional study design limits the ability to capture the dynamic, evolving nature of vascular changes throughout pregnancy. By relying on a single time-point measurement, the study may overlook important temporal trends or fluctuations in haemodynamic parameters that could provide early warnings or track disease progression more effectively. The relatively small number of hypertensive cases may also restrict the statistical power to detect associations with less common outcomes or complications. Furthermore, while the study focused on specific Doppler indices, other potentially informative haemodynamic markers-such as end-diastolic velocities and resistivity indices-were not examined, possibly limiting the scope of vascular assessment.

CONCLUSION(S)

These findings highlight the potential of ophthalmic artery Doppler parameters as valuable tools for assessing haemodynamic alterations in hypertensive pregnancies. The observed elevations in PSVs and the second-to-first PR suggest significant changes in vascular dynamics, likely reflecting increased resistance and reduced arterial compliance. While the PI showed no overall significant difference, regional variations indicate that localised vascular responses warrant closer examination. These results support the integration of ophthalmic artery Doppler assessment into routine prenatal care, particularly for identifying and monitoring high-risk pregnancies.

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