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Original Article

Radiology Section

Correlation of Ophthalmic Artery Pulsatility Index with Systolic, Diastolic and Mean Arterial Pressure in Normotensive and Hypertensive Pregnancies: A Cross-sectional Study

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ABSTRACT

Introduction: Hypertensive disorders complicate 5-15% of pregnancies and are major contributors to maternal and neonatal morbidity and mortality, particularly in cases involving preeclampsia. Affecting approximately 3% of pregnancies, preeclampsia is linked to complications such as preterm birth and low birth weight and is often associated with ocular changes in 30-100% of cases, marked by altered orbital vascular resistance. Traditional blood pressure measurements, while essential, may not fully capture vascular changes, especially in microcirculation, during hypertensive pregnancies. Doppler ultrasonography of the Ophthalmic Artery (OA) provides a non invasive method for assessing these vascular changes. The Ophthalmic Artery Pulsatility Index (OAPI) serves as a measure of vascular resistance in the OA, offering potential as a marker for evaluating and monitoring hypertensive disorders in pregnancy.

Aim: To compare OAPI values between normotensive and hypertensive pregnant women and to analyse the correlation between OAPI and maternal blood pressure parameters.

Materials and Methods: This cross-sectional study was conducted in the Department of Radiology, IQ City Medical College and Hospital, Durgapur, West Bengal, India, from January to August 2023. Systematic random sampling was used to divide participants into three groups: 50 normotensive non pregnant women, 50 normotensive pregnant women and 50 hypertensive pregnant women. The hypertensive group was further subdivided into mild preeclampsia (n=18), severe preeclampsia (n=12), gestational hypertension (n=10) and chronic hypertension (n=10). Doppler ultrasonography was used to measure OAPI and blood pressure parameters, including Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Mean Arterial Pressure (MAP), were recorded. Data analysis employed the Kruskal-Wallis test to compare OAPI values across groups and Spearman's rho correlation was used to assess relationships between OAPI and blood pressure parameters, with statistical significance set at $p<0.05$.

Results: The mean age of the subjects was 26.6±5.6 years. The OAPI was notably lower in the hypertensive group at 1.5±0.3, compared to 2.27±0.15 in the normotensive pregnant group and 2.17±0.08 in the normotensive non pregnant group ($p<0.05$). Within the severe preeclampsia subgroup, the mean OAPI was 1.17±0.14, indicating the highest level of vascular resistance. Strong negative correlations were found between OAPI and blood pressure parameters, with Spearman's rho values of ρ=-0.731 ($p<0.01$) for SBP and ρ=-0.774 ($p<0.01$) for MAP.

Conclusion: The OAPI proves to be a valuable non invasive marker for detecting and monitoring hypertensive disorders in pregnancy. Its significant inverse correlation with blood pressure parameters highlights its potential for early diagnosis and effective management of hypertensive conditions, particularly severe preeclampsia.

Keywords: Doppler ultrasonography, Hypertensive disorders in pregnancy, Preeclampsia

INTRODUCTION

Hypertensive disorders complicate 5-15% of pregnancies and are significant contributors to maternal mortality and neonatal morbidity, particularly in cases involving prematurity [1]. These disorders encompass a range of conditions, from pre-existing hypertension to those that develop during pregnancy, including pregnancy-induced hypertension (with or without oedema or proteinuria), chronic hypertension and pregnancy-related hypertension exacerbations, such as superimposed preeclampsia and eclampsia [2]. Preeclampsia, which affects approximately 3% of pregnancies, is a major cause of maternal and neonatal morbidity and mortality [3]. Ocular involvement occurs in 30-100% of patients with preeclampsia, reflecting the systemic nature of the condition [4]. Preeclampsia is known to induce changes in vascular resistance, particularly in the orbital circulation, which can be assessed through Doppler ultrasonography. Doppler ultrasonography is a non invasive method used to evaluate maternal and foetal haemodynamics and the OA provides a useful window for observing cardiovascular changes in hypertensive pregnancies [5]. While blood pressure monitoring remains essential, it may not fully capture underlying microvascular alterations, particularly in hypertensive disorders [6]. The OA, the first branch of the internal carotid artery, is a critical site for evaluating vascular resistance changes during pregnancy using Doppler ultrasonography [7]. One of the key parameters measured via Doppler is the Ophthalmic Artery Pulsatility Index (OAPI), which reflects the resistance to blood flow within the OA. The OAPI is calculated by analysing the difference between the peak systolic and end-diastolic velocities, divided by the mean flow velocity during the cardiac cycle. A higher OAPI suggests increased vascular resistance, while a lower OAPI indicates reduced resistance [8]. Since the OA is closely connected to cerebral blood flow, OAPI measurements can provide crucial insights into the vascular dynamics affected by hypertensive disorders. The present study aimed to evaluate the utility of OAPI as a diagnostic and monitoring tool for hypertensive disorders in pregnancy. By comparing OAPI values between normotensive and hypertensive pregnant women and correlating them with maternal blood pressure, the study seeks to determine whether OAPI can serve as a reliable non invasive

marker for identifying and managing hypertensive complications. This focused approach may enable earlier detection, allowing for better management and improved clinical outcomes in hypertensive pregnancies.

MATERIALS AND METHODS

The present cross-sectional study was conducted in the Department of Radiology, IQ City Medical College and Hospital, Durgapur, West Bengal, India, from January to August 2023. The study adhered to the ethical principles of the Declaration of Helsinki and was approved by the IQ City Institutional Ethics Committee (Approval No: IQMC/IEC-12/LTR/12(07)/23). Informed consent was obtained from all participants after explaining the study's objectives, procedures and potential risks. It involved 150 systematically selected female participants from Durgapur through random sampling. The participants were categorised into three distinct groups based on pregnancy and hypertension status.

Inclusion criteria: Group I included 50 normotensive non pregnant women, serving as the baseline group. Group II consisted of 50 normotensive pregnant women, representing the physiological changes in pregnancy without hypertensive complications. Group III included 50 hypertensive pregnant women, subdivided further into four hypertensive conditions: mild preeclampsia, severe preeclampsia, chronic hypertension and gestational hypertension.

Mild preeclampsia is defined as hypertension that begins after the 20th week of gestation, with SBP between 140-159 mmHg or DBP between 90-109 mmHg, along with proteinuria (≥300 mg in a 24-hour urine collection or a protein/creatinine ratio ≥0.3). Severe preeclampsia is defined by SBP ≥160 mmHg or DBP ≥110 mmHg, with proteinuria and possible visual disturbances. Gestational hypertension is identified as a temporary rise in blood pressure after 20 weeks of gestation or postpartum, normalising by the 10th day without proteinuria. Chronic hypertension is diagnosed with elevated blood pressure before 20 weeks of gestation or before pregnancy [2].

Exclusion criteria: The exclusion criteria for the present study encompassed participants with diabetes, multiple pregnancies, foetal hydrops, molar pregnancies, or eclampsia. Additionally, individuals with pre-existing medical conditions, including renal disorders and cardiovascular diseases, as well as those with ocular conditions like glaucoma or retinopathy, were excluded to minimise potential confounding effects on Doppler measurements.

Study Procedure

The primary parameter assessed in the present study was the OAPI, measured via Doppler velocimetry. Doppler velocimetry of the OA was performed using a GE Voluson S8 ultrasound machine with a 4-12 MHz linear transducer. Each participant was positioned in a supine posture, with ultrasound gel applied to the closed eyelid to optimise imaging conditions. The OA was identified using colour Doppler flow imaging and velocity waveforms were recorded over five cardiac cycles to ensure consistency in the measurements. This approach provided reliable data for assessing Doppler parameters.

To reduce intraobserver and interobserver variability, all Doppler measurements were conducted by a single trained radiologist to maintain consistency in data collection. Each parameter was measured three times during the examination and the average value was used in the final analysis. This approach minimised potential measurement errors and improved the reliability of the results.

STATISTICAL ANALYSIS

The data were entered into Microsoft Excel and analysed using Statistical Package for Social Sciences (SPSS) version 20.0.1. Numerical variables were summarised as mean (standard deviation) or median (interquartile range), while categorical variables were presented as counts and percentages. The Kruskal-Wallis test was used to compare continuous variables (SBP, DBP, MAP and OAPI) between hypertensive and normotensive groups. Spearman's rho correlation analysis assessed the relationship between OAPI and blood pressure parameters (SBP, DBP and MAP) across all participants and within subgroups. A p-value of <0.05 was considered statistically significant.

RESULTS

The mean age of the subjects was 26.6±5.6 years. The hypertensive pregnant group (n=50) had significantly higher SBP, with a mean of 155±11 mmHg, compared to 116±3 mmHg in both normotensive groups (n=50 each). The Ophthalmic Arterial Pulsatility Index (OAPI) was significantly lower in the hypertensive group, with a mean of 1.5±0.3, compared to 2.17±0.08 and 2.27±0.15 in the normotensive groups [Table/Fig-1].

In the severe preeclampsia group, the mean SBP was the highest at 169±10 mmHg. Other groups showed lower mean SBP values: gestational hypertension at 148±7 mmHg, mild preeclampsia at 149±5 mmHg and chronic hypertension at 148±6 mmHg [Table/Fig-2].

Spearman's rho correlation analysis across all participants (N=150) revealed strong and significant negative correlations between OAPI and blood pressure parameters (p<0.01). SBP was inversely correlated with OAPI (ρ=-0.788), indicating that as SBP increases, OAPI decreases. Similarly, DBP and mean arterial pressure (MAP)

Blood pressure parameters	Measures	Normotensive non pregnant (n=50)	Normotensive pregnant (n=50)	Hypertensive pregnant (n=50)	Total (N=150)	p-value*
SBP	Mean±SD	116±3	116±3	155±11	129±19	0.031
	Median (IQR)	116 (115, 118)	116 (115, 119)	151 (146, 160)	118 (116, 146)	
	Range	110-122	108-120	140-184	108-184	
DBP	Mean±SD	79±3	79±4	105±9	88±14	0.042
	Median (IQR)	80 (77, 82)	79 (76, 80)	104 (100, 109)	81 (78, 100)	
	Range	74-90	70-90	90-140	70-140	
MAP	Mean±SD	91±3	91±3	121±9	101±15	0.022
	Median (IQR)	92 (90, 93)	91 (89, 93)	120 (115, 125)	93 (91, 115)	
	Range	86-98	83-99	110-155	83-155	
OAPI	Mean±SD	2.17±0.08	2.27±0.15	1.5±0.3	1.98±0.39	0.012
	Median (IQR)	2.17 (2.11, 2.23)	2.3 (2.2, 2.36)	1.48 (1.28, 1.73)	2.15 (1.73, 2.25)	
	Range	2.04-2.38	1.74-2.56	0.98-2.06	0.98-2.56	

[Table/Fig-1]: Comparison of blood pressure parameters and Ophthalmic Artery Pulsatility Index (OAPI) across study groups.
*Kruskal-wallis test; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure; OPAI: Ophthalmic artery pulsatility index

Blood pressure parameters	Measures	Mild preeclampsia (n=18)	Severe preeclampsia (n=12)	Chronic hypertension (n=10)	Gestational hypertension (n=10)	p-value*
SBP	Mean±SD	149±5	169±10	148±6	148±7	0.041
	Median (IQR)	150 (146, 152)	165 (161, 178)	147 (144, 150)	146 (144, 152)	
	Range	140-157	156-184	140-159	142-157	
DBP	Mean ±SD	101±4	114±11	102±3	97±7	0.034
	Median (IQR)	100 (100, 104)	110 (109, 116)	102 (100, 105)	96 (92, 103)	
	Range	93-109	106-140	98-106	90-107	
MAP	Mean ±SD	117±4	132±10	118±3	114±4	0.016
	Median (IQR)	118 (114, 120)	129 (127, 136)	119 (114, 120)	113 (111, 117)	
	Range	110-121	123-155	113-121	110-120	
OAPI	Mean ±SD	1.54±0.2	1.17±0.14	1.75±0.1	1.97±0.06	0.011
	Median (IQR)	1.49 (1.36, 1.68)	1.19 (1.03, 1.24)	1.73 (1.68, 1.76)	1.94 (1.93, 2.01)	
	Range	1.32-1.95	0.98-1.48	1.67-1.95	1.93-2.06	

[Table/Fig-2]: Comparison of blood pressure parameters and Ophthalmic Artery Pulsatility Index (OAPI) across hypertensive disorders in pregnancy.
*Kruskal-wallis test; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure; OPAI: Ophthalmic artery pulsatility index

showed negative correlations with OAPI, with coefficients of ρ=-0.779 and ρ=-0.781, respectively [Table/Fig-3].

Blood pressure parameters	Correlation coefficient (ρ)	OAPI
SBP	Correlation coefficient	-0.788
	Sig. (2-tailed)	0.01
DBP	Correlation coefficient	-0.779
	Sig. (2-tailed)	0.01
MAP	Correlation coefficient	-0.781
	Sig. (2-tailed)	0.01

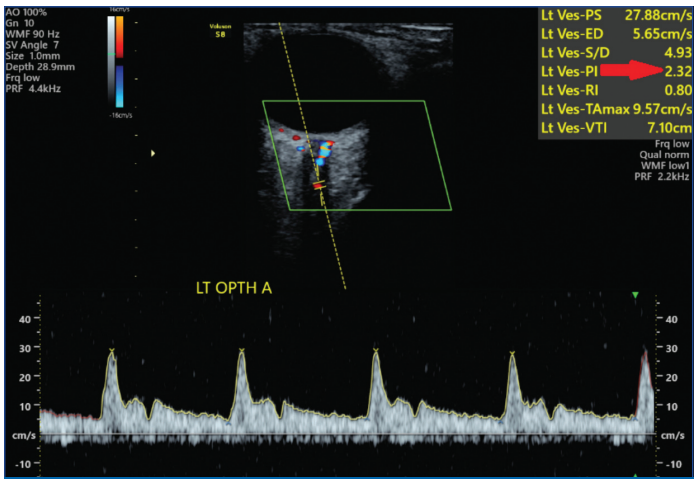
[Table/Fig-3]: Spearman's rho (ρ) correlation of Ophthalmic Artery Pulsatility Index (OAPI) with blood pressure parameters, including Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Mean Arterial Pressure (MAP) across all women in the study.
Correlation is significant at the 0.01 level (2-tailed); SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure (MAP); OPAI: Ophthalmic artery pulsatility index (OAPI)

In the normotensive non pregnant group (n=50), OAPI showed significant negative correlations with DBP (ρ=-0.337, p-value =0.033) and MAP (ρ=-0.324, p-value=0.041). The hypertensive pregnant group (n=50) demonstrated strong and highly significant negative correlations between OAPI and SBP (ρ=-0.731, p<0.01), DBP (ρ=-0.743, p<0.01) and MAP (ρ=-0.774, p<0.01) [Table/Fig-4].

The Doppler ultrasound of the left Ophthalmic artery (OA) in a normotensive non pregnant female shows a normal waveform with a pulsatility index (OAPI) of 2.32 [Table/Fig-5]. In a normotensive patient at 24 weeks gestation, Doppler ultrasound of the left OA demonstrates a normal waveform with a slightly lower OAPI of 1.97, indicative of physiological adjustments associated with pregnancy but within a healthy range [Table/Fig-6]. In contrast, the Doppler ultrasound of the right OA in a patient with severe preeclampsia at 32 weeks gestation reveals a reduced OAPI of 1.24, reflecting heightened vascular resistance linked with severe preeclampsia [Table/Fig-7].

Pregnancy groups	Blood pressure parameters	Correlation coefficient (ρ)	OAPI
Normotensive non pregnant	SBP	Correlation Coefficient	-0.254
		Sig. (2-tailed)	0.114
	DBP	Correlation Coefficient	-0.337*
		Sig. (2-tailed)	0.033
	MAP	Correlation Coefficient	-0.324*
		Sig. (2-tailed)	0.041
Normotensive pregnant	SBP	Correlation Coefficient	-0.428**
		Sig. (2-tailed)	0.006
	DBP	Correlation Coefficient	-0.232
		Sig. (2-tailed)	0.149
	MAP	Correlation Coefficient	-0.28
		Sig. (2-tailed)	0.081
Hypertensive pregnant	SBP	Correlation Coefficient	-0.731**
		Sig. (2-tailed)	0.01
	DBP	Correlation Coefficient	-0.743**
		Sig. (2-tailed)	0.01
	MAP	Correlation Coefficient	-0.774**
		Sig. (2-tailed)	0.01

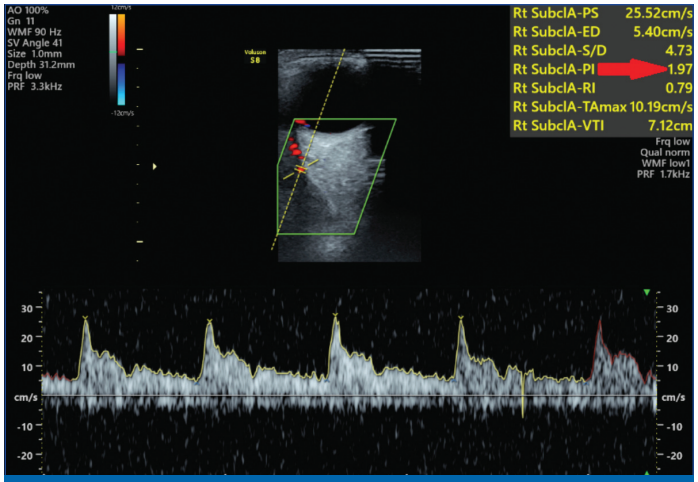
[Table/Fig-4]: Spearman's rho (ρ) correlation between Ophthalmic Artery Pulsatility Index (OAPI) and blood pressure parameters, including Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Mean Arterial Pressure (MAP) across pregnancy groups.
** Correlation is significant at the 0.01 level (2-tailed); *: Correlation is significant at the 0.05 level (2-tailed); SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure (MAP); OPAI: Ophthalmic artery pulsatility index (OAPI)



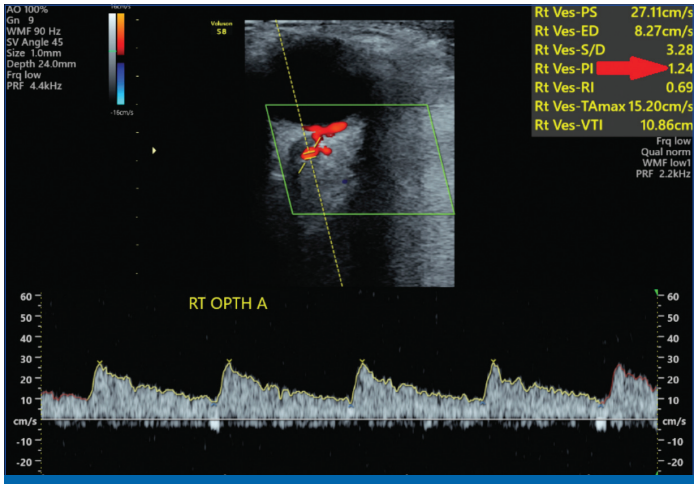
[Table/Fig-5]: Doppler ultrasound of the left ophthalmic artery in a normotensive non pregnant female shows a normal waveform, with a normal Ophthalmic Artery Pulsatility Index (OAPI) of 2.32.

DISCUSSION

The present study reinforces the critical role of OA Doppler indices, particularly the OAPI, in assessing hypertensive disorders during pregnancy. The authors observed a significant reduction in OAPI among hypertensive pregnant women compared to both normotensive pregnant and non pregnant groups, indicating increased vascular resistance and associated haemodynamic changes in hypertensive disorders. In the hypertensive pregnant group, the mean OAPI was 1.5±0.3. These findings align with Hata T et al., who reported a mean Pulsatility Index (PI) of 1.17±0.08 in severe preeclampsia, which is lower than that in normotensive pregnancies (2.92±0.59) [5]. Similarly, the present normotensive



[Table/Fig-6]: Doppler ultrasound of the left Ophthalmic Artery (OA) in a normotensive patient at 24 weeks gestationn shows a normal waveform, with a normal Ophthalmic Artery Pulsatility Index (OAPI) of 1.97.



[Table/Fig-7]: Doppler ultrasound of the right Ophthalmic Artery (OA) in a patient with severe preeclampsia at 32 weeks gestation shows a waveform with a reduced Ophthalmic Artery Pulsatility Index (OAPI) of 1.24.

pregnant group exhibited a mean OAPI of 2.27±0.15, supporting the relationship between elevated vascular resistance and reduced pulsatility indices in hypertensive pregnancies. Takata M et al., found a significantly higher peak ratio in the OA in hypertensive pregnancies, particularly in severe preeclampsia [8]. In the present study, the hypertensive group consistently showed a marked decrease in OAPI, with values significantly lower than those in normotensive pregnancies, reflecting increased vascular stiffness and resistance. Diniz ALD et al., highlighted significant differences in Doppler indices, such as Peak Systolic Velocity (PSV) and End-Diastolic Velocity (EDV), between mild and severe preeclampsia, emphasising the progression of vascular resistance as preeclampsia severity increases [9].

De Oliveira CA et al., reported significantly lower mean PI and Resistive Index (RI) in severe preeclampsia, with PI at 1.13±0.31 and RI at 0.63±0.09 [10]. These values closely resemble our results, where the severe preeclampsia group had a mean OAPI of 1.17±0.14, indicating substantial vascular impairment in severe cases. Olatunji RB et al., found that the mean PI in preeclamptic patients was significantly lower than in controls, with pre-eclamptic women showing a mean PI of 1.35±0.46 compared to 2.1±0.4 in controls [11]. Our findings mirror this pattern, with the hypertensive group showing markedly lower OAPI than both normotensive groups, reinforcing OAPI's utility as a diagnostic tool in distinguishing between levels of hypertensive severity.

Madina SR et al., reported a significant negative correlation between the RI in uterine and ophthalmic arteries among pre-eclamptic women, paralleling the present findings of a strong inverse correlation between OAPI and blood pressure parameters (SBP, DBP, MAP) [12]. Onwudiegwu C et al., demonstrated that pre-eclamptic women had significantly lower Doppler indices and higher intraocular pressures compared to controls [13]. They reported a PI of 1.35±0.46 in preeclampsia versus 2.1±0.4 in normotensive women. These findings align with our observations, where hypertensive pregnancies exhibited reduced OAPI values compared to normotensive counterparts, underscoring OAPI's value as a marker for assessing preeclampsia severity.

Limitation(s)

The study's limitations include its single-centre design and a relatively small sample size within specific hypertensive subgroups, which may affect generalisability. Additionally, the cross-sectional design provides only a snapshot of Doppler changes, limiting insights into their progression over time. The exclusion of certain conditions, such as diabetes, may also slightly narrow the applicability of the findings to more diverse populations.

CONCLUSION(S)

The OAPI is a proven, non invasive tool for assessing the severity of hypertensive disorders in pregnancy, particularly in severe preeclampsia, where it shows a strong inverse correlation with blood pressure metrics. Its diagnostic value and role in monitoring disease progression and guiding treatment strategies highlight its importance in enhancing obstetric care and improving outcomes for both mothers and foetuses.

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