

A Comparative Study of Intraocular Pressure and Ocular Perfusion Pressure Changes between Prehypertensive and Normotensive Individuals in a Tertiary Care Centre

Sudeshna Roy¹, Neelam Mandal²

¹Associate Professor, Department of Ophthalmology, Nilratan Sircar Medical College and Hospital, Kolkata, West Bengal, India.

²Postgraduate Trainee, Department of Ophthalmology, Nilratan Sircar Medical College and Hospital, Kolkata, West Bengal, India.

Received: 02-04-2026 / Revised: 18-04-2026 / Accepted: 27-05-2026

Corresponding Author: Dr. Sudeshna Roy

Conflict of interest: Nil

Abstract:

Background: Prehypertension is considered a precursor to systemic hypertension and has been implicated in various vascular alterations. IOP (Intraocular Pressure) and OPP (Ocular Perfusion Pressure) are key factors in the development of glaucoma and are crucial indicators of the health of the optic nerve. Changes in these factors may raise the risk of glaucomatous damage and impair ocular blood flow. The purpose of this study was to assess the connection between glaucoma-related alterations and IOP and MOPP (Mean Ocular Perfusion Pressure) in prehypertensive and normotensive people.

Methods: A hospital-based cross-sectional study was conducted in the Department of Ophthalmology, Nil Ratan Sircar Medical College and Hospital, over 18 months. A total of 244 participants were enrolled, comprising 122 prehypertensive subjects and 122 age- and sex-matched normotensive controls. Blood pressure was measured using a sphygmomanometer, and IOP was assessed using Goldmann applanation tonometry. Mean arterial pressure and mean ocular perfusion pressure were calculated using standard formulas. Statistical analysis was performed to compare ocular parameters between the two groups.

Results: Prehypertensive individuals demonstrated significantly higher IOP values than normotensive subjects (right eye: 16.08 ± 4.15 vs. 14.40 ± 2.23 mmHg, $p=0.011$; left eye: 16.11 ± 4.20 vs. 14.57 ± 2.21 mmHg, $p=0.039$). MOPP was significantly lower in the prehypertensive group (right eye: 47.44 ± 3.87 vs. 49.34 ± 4.94 mmHg; left eye: 47.26 ± 3.74 vs. 49.30 ± 4.95 mmHg; $p<0.001$). A strong negative correlation was observed between IOP and MOPP among prehypertensive subjects. Glaucomatous disc changes (neuroretinal rim thinning) were significantly more frequent in the prehypertensive group than in normotensive individuals.

Conclusion: Prehypertensive individuals exhibit significantly higher IOP and lower MOPP compared with normotensive individuals, indicating altered ocular perfusion dynamics. These changes may increase susceptibility to glaucomatous optic nerve damage. Early identification and management of prehypertension may help preserve ocular health and reduce the risk of glaucoma.

Keywords: Prehypertension, Intraocular Pressure, Ocular Perfusion Pressure, Mean Ocular Perfusion Pressure, Glaucoma, Optic Nerve, Blood Pressure.

DOI: 10.25258/ijcpr.18.6.104

This is an Open Access article that uses a funding model which does not charge readers or their institutions for access and distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>) and the Budapest Open Access Initiative (<http://www.budapestopenaccessinitiative.org/read>), which permit unrestricted use, distribution, and reproduction in any medium, provided original work is properly credited.

Introduction

The vascular condition of the optic nerve head is reflected in OPP (Ocular Perfusion Pressure), a crucial factor in determining ocular blood flow. It is typically calculated as the difference between IOP (Intraocular Pressure) and arterial BP (Blood Pressure), and it indicates the equilibrium between the two. Alterations in OPP may reduce ocular blood flow, resulting in ischemia and inadequate nourishment of neural tissues, thereby contributing to optic nerve damage and the development of glaucoma.[1]

One of the main causes of permanent blindness in the globe is glaucoma, a progressive optic neuropathy. Although vascular variables such as systemic hypertension, vasospasm, atherosclerosis, and decreased ocular perfusion have all been linked to the pathophysiology of glaucoma, elevated IOP is thought to be the most significant modifiable risk factor for the condition.[2] According to the vascular hypothesis, glaucomatous damage may be further exacerbated by insufficient blood flow to the optic nerve head.[3]

Ocular health and systemic blood pressure have a complicated relationship. A known risk factor for cardiovascular morbidity and mortality, hypertension is a serious public health issue. Higher blood pressure levels typically correlate with higher IOP values, as epidemiological studies have repeatedly shown.[4] However, the relationship between BP and glaucoma remains controversial, as both elevated and reduced perfusion pressures have been associated with optic nerve damage. [5,6]

Prehypertension, defined by systolic blood pressure of 120–139 mmHg and/or diastolic blood pressure of 80–89 mmHg according to JNC 7 guidelines, is considered a precursor stage to established hypertension. Although the vascular effects of hypertension on ocular structures have been widely studied, limited data are available regarding the impact of prehypertension on IOP and OPP.[4,7-8]

Studies have suggested that elevated IOP in prehypertensive individuals may result from increased sympathetic activity, excessive ultrafiltration, and reduced aqueous humor outflow. [6,7] Alterations in OPP may further influence ocular blood flow and optic nerve perfusion, thereby increasing the risk of glaucomatous changes. [4,9]

Considering the growing prevalence of prehypertension and the potential role of ocular vascular factors in glaucoma, evaluation of IOP and OPP in prehypertensive individuals may aid in the early identification of subjects at risk of developing optic nerve damage and glaucoma.

Aims and Objectives: The present study aims to evaluate the effect of prehypertension on ocular health by assessing changes in IOP and OPP. Specifically, the study seeks to determine whether prehypertensive individual's exhibit altered IOP values compared to normotensive individuals and to investigate the correlation between IOP and OPP in prehypertensive subjects. By examining these parameters, the study intends to explore the potential role of prehypertension as an early risk factor for impaired ocular perfusion and the development of glaucomatous changes.

Materials and Methods

Study Design: This institution-based observational cross-sectional study was conducted in the Department of Ophthalmology, N.R.S. Medical College and Hospital, over a period of 18 months following approval by WBUHS. A total of 244 participants were enrolled after obtaining informed consent.

Inclusion and Exclusion Criteria: The study included prehypertensive individuals aged 40–80 years of either sex, with SBP (Systolic Blood Pressure) of 120–139 mmHg and/or DBP (Diastolic Blood Pressure) of 80–89 mmHg, irrespective of

family history of hypertension. Age- and sex-matched normotensive individuals (BP <120/80 mmHg) served as controls. Participants were excluded if they were receiving antihypertensive medications or had hypertensive retinopathy, diabetic retinopathy, high myopia, ocular injury, corneal defects preventing accurate IOP measurement, inability to maintain a relaxed and immobile position during examination, angle-closure glaucoma, or any significant cardiac or respiratory disease.

Sample Size Calculation

244 (cases- 122, controls-122) [10]

According to the formula: sample size: $n = Z^* \{P(1-P)\}/I^2$

Where Z = 1.96 (taking 5% type 1 error), P = prevalence, and I = allowable error. Taking P = 76%, I = 10% of P, Z = 1.96,

$$n = 1.96^2(0.76(1-0.76)) / (0.076)^2$$

$$= 121.26$$

So approximately 122 cases are taken and controls are taken as per the ratio of cases: controls = 1:1

Data Collection Tools: Data were collected using a structured questionnaire and standard ophthalmic examination instruments. The study tools included a torch, slit-lamp microscope, Snellen visual acuity chart, direct ophthalmoscope, indirect ophthalmoscope, 90D lens, Goldmann applanation tonometer for intraocular pressure measurement, sphygmomanometer for blood pressure assessment, and gonioscopy for anterior chamber angle evaluation. Demographic details, medical history, ocular history, and examination findings were recorded in a predesigned case record form.

Data Collection Procedure: After obtaining institutional ethical clearance and written informed consent, 244 participants were recruited and categorized into prehypertensive and normotensive groups based on their blood pressure measurements. A detailed history regarding demographic characteristics, systemic illnesses, ocular diseases, medication use, and previous surgeries was obtained using an interviewer-administered questionnaire. In order to reduce diurnal variation, all participants underwent a thorough ophthalmic evaluation that included visual acuity testing, refraction, slit-lamp examination, fundus evaluation, gonioscopy, and IOP measurement using Goldmann applanation tonometry between 11:00 AM and 1:00 PM. Blood pressure was measured twice at 15-minute intervals in the sitting position using a sphygmomanometer following standard guidelines. Standard formulas were then used to compute MAP and MOPP, and all results were recorded in the case record form for analysis.

Results

Table 1: Age Distribution of Study Population (n=244)

Age Group (in years)	Frequency	Percentage (%)
21-30	6	2.5
31-40	37	15.2
41-50	101	41.4
51-60	53	21.7
61-70	33	13.5
71-80	14	5.7
Total	244	100

The age distribution of the study population is shown in Table 1. Middle-aged people made up the greatest section of the study population, with 41.4%

of participants falling into the 41-50 age groups and 21.7% falling into the 51-60 age groups.

Table 2: Sex Distribution of Study Population

Sex	Frequency	Percentage (%)
Male	128	52.5
Female	116	47.5
Total	244	100

Table 2 shows the gender distribution of the study population. Males constituted 52.5% and females

47.5% of participants, indicating a nearly equal representation of both sexes.

Table 3: Fundus Findings in Both Eyes

Fundus Finding	Right Eye n (%)	Left Eye n (%)
Glaucomatous Disc Changes	23 (9.4)	23 (9.4)
Healthy Fundus	221 (90.6)	221 (90.6)
Total	244 (100)	244 (100)

Table 3 depicts fundus findings in both eyes. Although none of the subjects had a prior diagnosis of glaucoma, glaucomatous disc changes were

detected in 9.4% of eyes during examination, while the majority had healthy fundi.

Table 4: Gonioscopic Findings in Study Population

Gonioscopic Finding	Right Eye n (%)	Left Eye n (%)
Angle Open	244 (100)	244 (100)
Angle Closure	0	0

Table 4 presents gonioscopic findings of both eyes. All participants demonstrated open anterior chamber angles and none had angle-closure glaucoma.

Table 5: Comparison of Mean Clinical Parameters between Normotensive and Prehypertensive Groups

Parameter	Normotensive Mean \pm SD	Prehypertensive Mean \pm SD	p-value
Age (years)	52.56 \pm 12.36	49.04 \pm 10.28	0.027
IOP Right Eye (mmHg)	14.40 \pm 2.23	16.08 \pm 4.15	0.011
IOP Left Eye (mmHg)	14.50 \pm 2.27	16.18 \pm 4.08	<0.05
MAP (mmHg)	89.65 \pm 4.04	98.50 \pm 3.88	<0.001
SBP (mmHg)	114.36 \pm 3.79	121.89 \pm 5.31	<0.001
DBP (mmHg)	77.30 \pm 3.72	85.84 \pm 3.51	<0.001
MOPP RE (mmHg)	49.34 \pm 4.94	47.44 \pm 3.87	<0.001
MOPP LE (mmHg)	49.30 \pm 4.95	47.26 \pm 3.74	<0.001

Table 5 compares the major study variables between normotensive and prehypertensive individuals. Prehypertensive subjects exhibited significantly

higher IOP, SBP, DBP, and MAP values, whereas MOPP values were significantly lower compared with normotensive individuals.

Table 6: Correlation of MOPP (Right Eye) with Study Variables

Variable	Normotensive (r)	Prehypertensive (r)
Age	-0.184	-0.027
IOP RE	-0.178	-0.722
MAP	0.819	0.582
SBP	0.331	0.210
DBP	0.385	0.315

Table 6 demonstrates the correlation between MOPP and clinical variables in the right eye. A strong negative correlation was observed between IOP and

MOPP among prehypertensive individuals ($r = -0.722$), whereas the association was weak in normotensive subjects. MAP

Table 6B. Correlation of MOPP (Left Eye) with Study Variables

Variable	Normotensive (r)	Prehypertensive (r)
Age	-0.173	0.019
IOP LE	-0.139	-0.692
MAP	0.780	0.587
SBP	0.371	0.261
DBP	0.329	0.357

Table 6B demonstrates the correlation between MOPP and clinical variables in the left eye. A strong negative correlation was observed between IOP and MOPP among prehypertensive individuals ($r = -0.692$), whereas only a weak negative correlation was noted in normotensive subjects ($r = -0.139$). Mean arterial pressure (MAP) showed a strong positive correlation with MOPP in both normotensive ($r = 0.780$) and prehypertensive ($r =$

0.587) groups. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) exhibited mild-to-moderate positive correlations with MOPP in both groups, while age showed only a negligible association with MOPP. These findings indicate that ocular perfusion pressure in the left eye is strongly influenced by arterial pressure and inversely related to intraocular pressure, particularly among prehypertensive individuals

Table 7: Glaucomatous Disc Changes in Right Eye by Study Group

Finding	Normotensive n (%)	Prehypertensive n (%)	Total
Glaucomatous Disc Changes	2 (1.64)	21 (17.21)	23
Healthy Disc	120 (98.36)	101 (82.79)	221

Table 7 shows glaucomatous disc changes in the right eye. The prevalence of glaucomatous changes was markedly higher among prehypertensive

individuals (17.21%) compared to normotensive individuals (1.64%), suggesting an increased ocular risk in prehypertension.

Table 8: Glaucomatous Disc Changes in Left Eye by Study Group

Finding	Normotensive n (%)	Prehypertensive n (%)	Total
Glaucomatous Disc Changes	3 (2.46)	20 (16.39)	23
Healthy Disc	119 (97.54)	102 (83.61)	221

Table 8 presents glaucomatous disc changes in the left eye. Similar to the right eye, glaucomatous changes were significantly more frequent among prehypertensive individuals (16.39%) than normotensive individuals (2.46%), reinforcing the association between prehypertension and ocular changes suggestive of glaucoma.

Discussion

After obtaining informed consent, 244 participants who met the inclusion and exclusion criteria were enrolled. There were 122 prehypertensive and 122 normotensive participants in the study. The prehypertensive group's mean age was 49.04 ± 10.28 years, whereas the normotensive group's was 52.56 ± 12.36 years.

One important factor influencing ocular blood flow and optic nerve head perfusion is mean ocular perfusion pressure. It is calculated from the relationship between mean arterial pressure and intraocular pressure and reflects the adequacy of blood supply to ocular tissues. Alterations in MOPP have been implicated in the pathogenesis of glaucomatous optic neuropathy.

Several studies have reported that reduced MOPP is associated with optic nerve head damage and an increased risk of open-angle glaucoma. In the present study, MOPP was significantly lower in prehypertensive individuals compared with normotensive subjects. "Similar findings were reported by Kanadani FN et al. (2015), who demonstrated a statistically significant difference in

MOPP, between normotensive and hypertensive individuals ($p < 0.05$)."[11] Although their study compared hypertensive patients with normotensive controls, the observed reduction in ocular perfusion pressure is consistent with our findings in prehypertensive subjects.

Elevated IOP is a well-established modifiable risk factor for glaucoma. In our study, prehypertensive individuals exhibited significantly higher IOP values than normotensive controls. These findings are in agreement with those of Baisakhiya S et al., who reported a significant positive correlation between systemic blood pressure and IOP among North Indian adults and observed progressively higher IOP values from normotensive to prehypertensive and hypertensive groups.[12]

Similarly, Baisakhiya SB et al., demonstrated significantly increased IOP in prehypertensive individuals and emphasized the importance of early detection and management of prehypertension to prevent future glaucomatous changes.[12] The findings of the current study are corroborated by Parajuli S. et al., who likewise found systemic blood pressure to be a key predictor of IOP and showed a substantial positive correlation between blood pressure and IOP.[13]

However, not all studies have demonstrated a direct association between blood pressure and IOP. The Rotterdam Eye Study's analyses revealed no statistically significant correlation between high blood pressure and elevated intraocular pressure, indicating that other factors might have an impact on this relationship.

Previous epidemiological studies have consistently demonstrated that elevated IOP and reduced MOPP are important risk factors for glaucoma. The Barbados Eye Study reported that individuals with low ocular perfusion pressure had a three- to four-fold increased risk of developing open-angle glaucoma. Similarly, Gore V et al., observed a strong and statistically significant association between low MOPP and increased prevalence of primary open-angle glaucoma.[13]

In comparison to normotensive people, prehypertensive subjects in this study had higher IOP and lower MOPP values, as well as a higher frequency of glaucomatous optic disc abnormalities such as neuroretinal rim thinning and notching. These findings suggest that prehypertension may represent an early vascular and ocular risk state that predisposes individuals to glaucomatous damage.

Even in the absence of confirmed glaucoma, the population-based Thessaloniki Eye Study found that people with low diastolic blood pressure on antihypertensive medication had decreased neuroretinal rim area and increased optic disc cupping.[14] This observation highlights the

importance of maintaining adequate ocular perfusion for optic nerve health.

Elevated IOP dramatically raises the chance of developing glaucoma, and prompt treatment of ocular hypertension can postpone or prevent the start of the illness, according to the seminal ocular hypertension treatment study. Additionally, low ocular perfusion pressure at baseline was linked to a three-fold greater chance of developing open-angle glaucoma, according to the Barbados Eye Studies' incidence phase.[15] Subsequent 9-year follow-up data confirmed that individuals with lower systolic, diastolic, and mean perfusion pressures had a significantly greater risk of glaucoma development, with relative risks ranging from 2.0 to 2.6.[6]

Although elevated IOP alone may not reliably predict glaucoma development, the combined presence of increased IOP and reduced ocular perfusion pressure appears to substantially increase the risk of optic nerve damage. Current recommendations from the American Academy of Ophthalmology emphasize comprehensive eye evaluation in adults above 40 years of age and acknowledge that both vascular and pressure-related factors contribute to glaucoma pathogenesis.[16]

The findings of the present study indicate that prehypertensive individuals exhibit significantly higher IOP and lower MOPP compared with normotensive subjects. These alterations may predispose them to glaucomatous optic nerve changes and highlight the importance of early identification and management of prehypertension to preserve ocular health and reduce the future risk of glaucoma.

Limitations

There are several restrictions on this study. As a cross-sectional study, it is unable to prove that prehypertension and changes in ocular parameters are causally related. Selection bias may have been introduced and the findings' generalisability restricted due to the comparatively small sample size and voluntary participation. Variability in measurements of intraocular pressure and blood pressure may have affected the accuracy of the results. In addition, potential confounding factors such as age, gender, lifestyle, and other systemic conditions were not fully controlled. Since the study was conducted in a specific East Indian population, the findings may not be directly applicable to other populations or ethnic groups. To validate these findings and get a deeper comprehension of the connection between prehypertension and ocular health, more extensive longitudinal research is required.

Conclusion

This study demonstrated that prehypertensive individuals have significantly higher IOP and lower MOPP compared to normotensive individuals. These alterations may increase the risk of glaucomatous optic nerve damage and suggest that prehypertension can adversely affect ocular vascular health even before the onset of established hypertension. Regular monitoring of blood pressure, IOP, and MOPP in prehypertensive individuals may facilitate early detection of ocular changes and help prevent the development and progression of glaucoma. Further longitudinal studies are required to confirm these findings and establish a causal relationship between prehypertension and glaucoma risk.

References

1. Moore D, Harris A, Widen D, et al. Dysfunctional regulation of ocular blood flow: a risk factor for glaucoma? *Clin Ophthalmol* 2008;2:849-61.
2. Leske MC, Wu SY, Hennis A, et al. Risk factors for incident open-angle glaucoma: the Barbados Eye Studies. *Ophthalmology* 2008;115:85-93.
3. Flammer J. To what extent are vascular factors involved in the pathogenesis of glaucoma? In: Kaiser HJ, Flammer J, Hendrickson P, eds. *Ocular blood flow: new insights into the pathogenesis of ocular diseases*. Basel, Switzerland: Karger Medical and Scientific Publishers 1996.
4. Hulsman CA, Vingerling JR, Hofman A, et al. Blood pressure, arterial stiffness, and open-angle glaucoma: the Rotterdam study. *Arch Ophthalmol* 2007;125(6):805-12.
5. Parikh RS, Parikh SR, Navin S, et al. Practical approach to medical management of glaucoma. *Indian J Ophthalmol* 2008;56:223-30.
6. Vingrys AJ. The many faces of glaucomatous optic neuropathy. *Clin Exp Optom* 2000;83(3):145-60.
7. Topouzis F, Coleman AL, Harris A, et al. Association of blood pressure status with the optic disk structure in non-glaucoma subjects: the Thessaloniki eye study. *Am J Ophthalmol* 2006;142:60-7.
8. Mitchell P, Lee AJ, Rochtchina E, et al. Open angle glaucoma and systemic hypertension: the Blue Mountains Eye Study. *J Glaucoma* 2004;13:319-26.
9. Bonomi L, Marchini G, Marraffa M, et al. Vascular risk factors for primary open angle glaucoma: the Egna-Neumarkt Study. *Ophthalmology* 2000;107:1287-93.
10. Kass MA, Heuer DK, Higginbotham EJ, et al. The ocular hypertension treatment study: a randomized trial determines that topical ocular hypotensive medication delays or prevents the onset of primary open-angle glaucoma. *Arch Ophthalmol* 2002;120(6):701-13.
11. Kanadani FN, Figueiredo CR, Miranda RM, et al. Ocular perfusion pressure and pulsatile ocular blood flow in normal and systemic hypertensive patients. *J Curr Glaucoma Pract* 2015;9(1):16-9.
12. Baisakhiya S, Singh S, Manjhi P. Correlation between intraocular pressure and blood pressure in North Indian subjects. *Int J Adv Res* 2015;3(7):1545-54.
13. Parajuli S, Mandelbrot DA, Aziz F, et al. Characteristics and outcomes of kidney transplant recipients with a functioning graft for more than 25 years. *Kidney Dis* 2018;4(4):255-61.
14. Kook MS, Lee SU, Sung KR, et al. Pattern of retinal nerve fiber layer damage in Korean eyes with normal-tension glaucoma and hemifield visual field defect. *Graefes Archive for Clinical and Experimental Ophthalmology* 2002;240:448-56.
15. Gore FM, Bloem PJ, Patton GC, et al. Global burden of disease in young people aged 10–24 years: a systematic analysis. *The Lancet* 2011; 377(9783):2093-102.
16. Tielsch JM, Katz J, Sommer A, et al. Hypertension, perfusion pressure, and primary open-angle glaucoma: a population-based assessment. *Arch Ophthalmol* 1995; 113(2): 216-21.