Original Article

Association Between Pulse Pressure and Primary Open-Angle Glaucoma

Priyanka Sankaran[1], Anjali[2], Guru Prasad NS[3]

[1]Senior Resident, Department of Ophthalmology, Andaman and Nicobar Islands Institute of Medical Sciences, Sri Vijaya Puram, Andaman and Nicobar Islands, India. [2]Assistant Professor, Department of Ophthalmology, Andaman and Nicobar Islands Institute of Medical Sciences, Sri Vijaya Puram, Andaman and Nicobar Islands, India. [3]Senior Resident, Department of Ophthalmology, KVG Medical College & Hospital, Sullia, Karnataka, India

Abstract

Background: Primary open-angle glaucoma (POAG) is a leading cause of irreversible blindness worldwide. Other systemic vascular risk factors (e.g., pulse pressure) can affect the perfusion of the optic nerves and the progression of glaucoma. The objective is to examine the relationship between PP and PAOG and between PP and PAOG severity. **Material and Methods:** This was an analytic cross-sectional study at the hospital that included 110 cases of primary open-angle glaucoma. The difference between the maximum and minimum blood pressures was used to determine pulse pressure. All participants were examined systematically including intraocular pressure (IOP), gonioscopy, assessment of optic disc, standard automated perimetry (SAP) and retinal nerve fiber layer (RNFL) measurements by optical coherence tomography (OCT). Data was analyzed using SPSS version 25.0. **Results:** The average age of the participants was 58.6 ± 9.8 years, and 54.5% of the study population were males. PP was significantly correlated with the severity of glaucoma ($p<0.001$). Patients with the higher pulse pressure ≥60 mmHg exhibited significantly higher intraocular pressure, increased cup-to-disc ratio, decreased RNFL thickness, and poorer visual field mean deviation than the patients with the lower pulse pressure. There was a positive correlation of PP with intraocular pressure ($r=0.42$) and the cup-to-disc ratio ($r=0.51$) and negative correlations for RNFL thickness ($r=-0.56$) and the VF mean deviation ($r=-0.49$) (all $p<0.001$). Multivariate logistic regression revealed that PP ≥60 mmHg was an independent predictor of moderate to severe POAG (adjusted OR 3.84, 95% CI 1.55–9.51; $p=0.004$). **Conclusion:** PP is independently linked to the severity of primary OAG, and may be a useful non-invasive vascular biomarker to identify patients at increased risk of disease progression. When evaluating the progression of glaucoma, routine PP evaluation can be used in addition to ophthalmic exam and may help in the general management of glaucoma.

Keywords: Primary open angle glaucoma, PP, IOP, RNFL, OPTF, VRF.

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Introduction

Primary open-angle glaucoma (POAG) is an irreversible disease of the optic nerve (OPN) that involves loss of retinal ganglion cells with damage to the optic nerve head and resulting visual field loss. It is the most common form of glaucoma and is still one of the principle causes of irreversible blindness globally. While elevated intraocular pressure (IOP) is the most important modifiable risk factor for glaucoma, many patients develop glaucoma without any evidence of elevated IOP, thereby indicating the role of other risk factors, including vascular factors, in pathogenesis of the disease.[1]

Population ageing is worsening the global burden of glaucoma, as millions of people will be affected in the next few decades. Systemic risk factors must be identified early in order to avoid development of the disease and maintain visual function.[2,3]

Systemic hemodynamic parameters like blood pressure, OPP and arterial stiffness have emerged as important in the pathogenesis of POAG in recent studies. The difference between the arterial pressure during the systolic and diastolic pressures is termed as Pulse pressure and it indicates the stiffness of the arteries and their vascular compliance. The higher PP has been identified as a risk factor for glaucomatous OND due to the potential of creating vascular dysregulatory and ischemic damage to the ONH.[4,5]

Abnormal blood pressure parameters have been reported to be associated with POAG in several epidemiological studies. There are conflicting findings concerning the relationship between elevated pulse pressure and glaucoma prevalence and/or progression, and the same applies for altered OPP.[6,7]

The current study was therefore conducted to assess the association of PP with PAG in the patients of the tertiary care centre. Therefore the present study was designed to explore the association between PP and primary open angle glaucoma in the patients of a tertiary care centre.[8]

Materials and Methods

Study Design: This was a hospital-based analytical cross-sectional study conducted to evaluate the association between

Address for correspondence: Dr. Guru Prasad N S, Senior Resident, KVG Medical College & Hospital, Sullia, Karnataka, India. E-mail: guru.raju1294@gmail.com

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pulse pressure and primary open-angle glaucoma.

Study Setting: The study was carried out in the Department of Ophthalmology of a tertiary care teaching hospital.

Study Duration: The study was conducted over a period of 18 months.

Sample Size: A total of 110 participants diagnosed with primary open-angle glaucoma were enrolled consecutively during the study period.

Study Population: Adult patients attending the glaucoma clinic and diagnosed with primary open-angle glaucoma based on clinical examination and standard diagnostic criteria were included in the study.

Inclusion Criteria

- Patients aged 40 years and above.
- Diagnosed cases of primary open-angle glaucoma.
- Open anterior chamber angle on gonioscopy.
- Willingness to provide written informed consent.

Exclusion Criteria

- Primary angle-closure glaucoma or secondary glaucoma.
- History of ocular trauma or previous glaucoma surgery.
- Congenital or juvenile glaucoma.
- Advanced cardiovascular disease causing hemodynamic instability.
- Patients receiving systemic medications known to markedly alter blood pressure variability.
- Incomplete clinical records or refusal to participate.

Study Procedure: After obtaining informed consent, demographic details including age, sex, body mass index, smoking status, and medical history of hypertension, diabetes mellitus, and cardiovascular disease were recorded. Blood pressure was measured using a calibrated mercury or automated sphygmomanometer after the participant had rested for at least five minutes in the sitting position. Three readings were obtained at two-minute intervals, and the average value was recorded.

Pulse pressure (PP) was calculated using the formula:

Pulse Pressure = Systolic Blood Pressure − Diastolic Blood Pressure

Each participant underwent a comprehensive ophthalmic examination, including:

- Best-corrected visual acuity (BCVA)
- Slit-lamp biomicroscopy
- Goldmann applanation tonometry for intraocular pressure
- Gonioscopy
- Fundus examination with assessment of cup-to-disc ratio
- Optical coherence tomography (OCT) of the retinal nerve fiber layer
- Standard automated perimetry (Humphrey visual field analysis)

Primary open-angle glaucoma was diagnosed according to accepted international clinical guidelines based on optic disc changes, corresponding visual field defects, and open anterior chamber angles.

Outcome Measures

Primary Outcome

- Association between pulse pressure and primary open-angle glaucoma severity.

Secondary Outcomes

- Correlation of pulse pressure with intraocular pressure.
- Association of pulse pressure with cup-to-disc ratio.
- Correlation between pulse pressure and retinal nerve fiber layer thickness.
- Relationship between pulse pressure and visual field indices.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Independent Student's t-test, Chi-square test, Pearson's correlation coefficient, and multivariate linear or logistic regression analyses were performed where appropriate. A p-value <0.05 was considered statistically significant.

Results

A total of 110 patients with primary open-angle glaucoma were included in the study. The mean age of the study population was 58.6 ± 9.8 years, ranging from 40 to 79 years. Males constituted 60 (54.5%) participants, while 50 (45.5%) were females. The mean systolic blood pressure was 139.4 ± 17.2 mmHg, mean diastolic blood pressure was 82.1 ± 10.4 mmHg, and mean pulse pressure was 57.3 ± 13.8 mmHg.

Table 1: Demographic and Clinical Characteristics of Study Participants

Variable	Number (%) or Mean ± SD
Age (years)	58.6 ± 9.8
Age group	
40–49 years	20 (18.2)
50–59 years	36 (32.7)
60–69 years	38 (34.5)
≥70 years	16 (14.6)
Gender	
Male	60 (54.5)
Female	50 (45.5)
Hypertension	58 (52.7)
Diabetes mellitus	31 (28.2)
Smoking history	25 (22.7)
Systolic blood pressure (mmHg)	139.4 ± 17.2
Diastolic blood pressure (mmHg)	82.1 ± 10.4
Pulse pressure (mmHg)	57.3 ± 13.8
Intraocular pressure (mmHg)	20.8 ± 4.5
Cup-to-disc ratio	0.68 ± 0.14

RNFL thickness (µm)	72.6 ± 12.8
Visual field mean deviation (dB)	−9.7 ± 6.3

Most patients belonged to the 60–69-year age group. More than half had hypertension, while approximately one-fourth had diabetes mellitus. The mean pulse pressure was elevated, with corresponding glaucomatous optic nerve and visual field changes.

Table 2: Distribution of Patients According to Pulse Pressure and Glaucoma Severity

Pulse Pressure Category	Mild POAG n (%)	Moderate POAG n (%)	Severe POAG n (%)	Total
<50 mmHg	20 (58.8)	10 (29.4)	4 (11.8)	34
50–59 mmHg	13 (35.1)	16 (43.2)	8 (21.7)	37
≥60 mmHg	6 (15.4)	14 (35.9)	19 (48.7)	39
Total	39	40	31	110

Chi-square = 18.74; p < 0.001

Severe POAG was more frequently observed among patients with pulse pressure ≥60 mmHg. In contrast, mild disease was more common among patients with pulse pressure below 50 mmHg. The association between increasing pulse pressure and glaucoma severity was statistically significant.

Table 3: Comparison of Ophthalmic Parameters According to Pulse Pressure Category

Parameter	PP <50 mmHg (n=34)	PP 50–59 mmHg (n=37)	PP ≥60 mmHg (n=39)	p-value
Intraocular pressure (mmHg)	18.9 ± 3.7	20.5 ± 4.1	22.8 ± 4.8	<0.001
Cup-to-disc ratio	0.59 ± 0.12	0.67 ± 0.12	0.77 ± 0.11	<0.001
RNFL thickness (µm)	80.5 ± 10.2	73.4 ± 10.7	64.9 ± 11.5	<0.001
Visual field mean deviation (dB)	−5.4 ± 3.8	−8.8 ± 5.1	−14.2 ± 6.3	<0.001

Patients with pulse pressure ≥60 mmHg had significantly higher intraocular pressure and cup-to-disc ratio. They also had significantly lower retinal nerve fibre layer thickness and more negative visual field mean deviation, indicating greater structural and functional glaucomatous damage.

Table 4: Correlation Between Pulse Pressure and Glaucoma Parameters

Glaucoma Parameter	Pearson Correlation Coefficient (r)	p-value
Intraocular pressure	0.42	<0.001
Cup-to-disc ratio	0.51	<0.001
RNFL thickness	−0.56	<0.001
Visual field mean deviation	−0.49	<0.001

Pulse pressure showed a moderate positive correlation with intraocular pressure and cup-to-disc ratio. A significant negative correlation was observed with retinal nerve fibre layer thickness and visual field mean deviation, suggesting that increased pulse pressure was associated with greater glaucomatous damage.

Table 5: Multivariate Logistic Regression Analysis of Factors Associated with Moderate-to-Severe POAG

Variable	Adjusted Odds Ratio	95% Confidence Interval	p-value
Pulse pressure ≥60 mmHg	3.84	1.55–9.51	0.004
Age ≥60 years	2.27	1.03–5.01	0.041
Hypertension	1.82	0.82–4.03	0.138
Diabetes mellitus	1.43	0.61–3.34	0.409
Intraocular pressure >21 mmHg	2.96	1.29–6.78	0.010

After adjustment for age, hypertension, diabetes mellitus, and intraocular pressure, pulse pressure ≥60 mmHg remained an independent predictor of moderate-to-severe POAG. Patients with elevated pulse pressure had approximately four times higher odds of having more advanced glaucoma.

Discussion

Primary open-angle glaucoma (POAG) is a multifactorial optic neuropathy in which vascular factors, in addition to intraocular pressure, contribute significantly to disease onset and progression. The present study evaluated the association between pulse pressure and POAG and demonstrated that elevated pulse pressure was significantly associated with increased glaucoma severity, higher intraocular pressure, greater cup-to-disc ratio, thinner retinal nerve fiber layer (RNFL), and worse visual field defects.

The results of the present study corroborate those found by Bowe et al,[8] who pointed to the role of systemic vascular dysregulation in glaucoma. Their review highlighted that hypertension and elevated arterial stiffness can both affect blood flow to the eye and optic nerve perfusion, which can promote glaucoma damage. In the present study, it was found that the more severe structural and functional damage of the optic nerve was observed in patients with higher PP.

In accordance with our results, other studies, such as Khawaja et al,[9] showed that blood pressure parameters, especially higher pulse pressure and arterial stiffness, correlated with higher

incidence of POAG. An increase in pulse pressure is associated with a decrease in compliance of the arteries and may lead to impaired autoregulation of blood supply to the optic nerve head and make this area more vulnerable to ischemic damage.

The Rotterdam Study that Ramdas et al,[10] conducted also found that the parameters of arterial stiffness and high blood pressure were independently linked to the presence of open-angle glaucoma. In line with these findings, the present study revealed a significantly higher ratio of the cup-to-disc diameter and thinner RNFL among patients with PP ≥60 mmHg, indicating that vascular changes also may play a role in advancing optic nerve degeneration.

Previous epidemiological studies by Tielsch et al,[11] showed that systemic blood pressure elevated above normal and ocular perfusion pressure decreased are risk factors for POAG. Similarly, the present study found that patients with high pulse pressure were significantly more severely affected by glaucoma, which lent support to the hypothesis that impaired ocular perfusion (caused by vascular dysfunction) is an important contributing factor to glaucomatous optic neuropathy.

The Egna-Neumarkt Study by Bonomi et al,[12] also shows systemic vascular abnormality as being an important risk factor for POAG. They said their results indicated that vascular insufficiency could coexist with elevated intraocular pressure, and could play a role in disease progression. Our results were similar, finding a significant association between PP and moderate-to-severe glaucoma that persisted even after adjusting for age, hypertension, DM, and IOP.

Memarzadeh's group at the Los Angeles Latino Eye Study showed strong relationship between ocular perfusion pressure and systemic BP with the prevalence and severity of glaucoma.[13] The present study corroborates these results with significant associations found between pulse pressure and structural indices (RNFL thickness and cup to disc ratio) and functional indices (visual field mean deviation) of glaucomatous damage.

In addition, an association between open-angle glaucoma and systemic hypertension has been documented by Mitchell et al,[14] in the Blue Mountains Eye Study, especially in the elderly. Because of arterial stiffening with age, greater pulse pressure (PP) could be a simple, clinical way to distinguish between glaucoma patients who are more likely to progress. On multivariate analysis, a pulse pressure of ≥60 mmHg was still an independent risk factor for moderate-to-severe POAG in the present study.

The results of the present study highlight the potential role of PP, an easily measurable and affordable cardiovascular measure, as a source of information about vascular risk in primarily open-angle glaucoma patients. Consideration of pulse pressure as part of the standard eye exam could aid in early detection of individuals at risk and help expedite early management to minimize disease progression.

Conclusion

The present study was able to show that there is a significant relationship between the increase in PP and primary open-angle glaucoma severity. Higher PP was associated with higher IOP, higher cup-to-disc ratio, thinner retinal nerve fiber layers and more advanced VF loss. After adjusting for other clinical variables, PP continued as an independent predictor of moderate-to-severe glaucoma. A simple, non-invasive and cost-effective tool to assist identifying patients at higher risk of glaucoma progression could be routine measurement of pulse pressure. Further studies in larger, potential multicenter trials are needed to confirm the effect of pulse pressure as a vascular biomarker in the treatment of primary open-angle glaucoma.

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Conflicts of interest

There are no conflicts of interest.

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