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Systemic hypertension and ocular perfusion parameters in primary open-angle glaucoma. A hospital-based case-control study.

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Abstract

Background

Primary open-angle glaucoma (POAG) is a major cause of irreversible blindness globally. Although multiple systemic and ocular factors contribute to its development, the influence of systemic hypertension and ocular perfusion parameters remains inconsistent across studies.

Objectives

To assess systemic hypertension as a risk factor for POAG and to evaluate the association between diastolic perfusion pressure and POAG.

Method

The study included 300 participants aged over 40 years, comprising 150 hypertensive patients and 150 age- and sex-matched non-hypertensive controls. All subjects underwent comprehensive ophthalmic evaluation, including intraocular pressure measurement, optic disc assessment, visual field analysis, and central corneal thickness measurement. Data on diabetes mellitus, myopia, and family history of glaucoma were collected. Diastolic perfusion pressure was calculated as diastolic blood pressure minus intraocular pressure. POAG was diagnosed using standard clinical criteria. Statistical analysis was performed to determine associations between risk factors and POAG.

Results

The mean age of participants was 53.8 ± 8.5 years, with male predominance. The overall prevalence of POAG was 9.0%. Age ≥60 years showed a significant association with POAG ($p = 0.001$). Diabetes mellitus demonstrated a borderline association ($p = 0.05$), while a positive family history of glaucoma was significantly associated with POAG ($p = 0.03$). Systemic hypertension and myopia did not show independent associations with POAG. The mean diastolic perfusion pressure was lower among POAG patients compared to non-POAG participants (63.3 ± 8.1 mmHg vs 64.8 ± 9.0 mmHg), but this difference was not significant ($p = 0.26$).

Conclusion

Advancing age and family history emerged as the strongest predictors of POAG, while systemic hypertension alone was not an independent risk factor, highlighting the multifactorial etiology of the disease.

Recommendations

Targeted glaucoma screening is advised for older adults, individuals with diabetes mellitus, and those with a family history of glaucoma to enable early detection and intervention.

***Keywords**: Primary open-angle glaucoma; Systemic hypertension; Diastolic perfusion pressure; Intraocular pressure*
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Introduction

Primary open-angle glaucoma (POAG) is a chronic, progressive optic neuropathy and a leading cause of irreversible blindness worldwide. It is characterized by progressive optic nerve head damage with corresponding visual field loss, often remaining asymptomatic until advanced stages. Because early disease is clinically silent,

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POAG represents a major public health challenge, particularly in developing countries where delayed presentation and limited access to eye-care services are common [1,6].

Although elevated intraocular pressure (IOP) remains the most important and only modifiable risk factor for POAG, the disease is increasingly recognized as multifactorial in origin. Several demographics, systemic, and ocular factors have been implicated, including advancing age, positive family history, diabetes mellitus, myopia, and vascular dysregulation [1–3]. Among these, systemic hypertension has attracted considerable interest due to its high prevalence in aging populations and its potential influence on ocular blood flow and IOP regulation [1,4].

The relationship between systemic hypertension and POAG, however, remains controversial. Elevated blood pressure may increase IOP and thereby contribute to glaucomatous damage. Conversely, long-standing hypertension and intensive antihypertensive therapy may impair autoregulation of optic nerve head circulation, leading to ischemic injury and increased susceptibility to glaucoma [3–5]. These opposing mechanisms have resulted in inconsistent epidemiological findings, with some studies demonstrating a positive association between hypertension and POAG, while others report no significant or independent relationship [1,2,6].

Ocular perfusion pressure, particularly diastolic perfusion pressure, has emerged as an important vascular parameter in glaucoma research. Reduced perfusion pressure may compromise optic nerve head blood supply, increasing the risk of glaucomatous damage, especially in individuals with disturbed vascular autoregulation [2,4,5]. Nevertheless, evidence regarding the role of perfusion pressure in POAG varies across populations and study designs.

Given these uncertainties, further evaluation of systemic hypertension and perfusion-related factors in relation to POAG is warranted. The present study was undertaken to assess systemic hypertension as a risk factor for primary open-angle glaucoma and to examine the association of diastolic perfusion pressure with POAG in a tertiary-care hospital setting.

Methodology

Study design and setting

This hospital-based analytical case–control study was conducted in the Department of Ophthalmology, Prathima Institute of Medical Sciences (PIMS), Nagunur, Karimnagar, Telangana, India, from October 2019 to October 2021. PIMS is a tertiary-care teaching hospital affiliated with Dr. KNR University of Health Sciences, serving both urban and rural populations of northern Telangana. The ophthalmology department provides comprehensive glaucoma services, including applanation tonometry, automated perimetry, pachymetry, and optic nerve imaging, and caters to a high outpatient volume, enabling systematic recruitment of eligible participants.

Participants

Cases comprised consecutive patients aged >40 years diagnosed with primary open-angle glaucoma (POAG) based on characteristic optic disc changes and/or reproducible glaucomatous visual field defects with open anterior chamber angles on gonioscopy. Controls were age- (±3 years) and sex-matched individuals attending the same outpatient department for refractive errors or routine ocular evaluation, with no evidence of glaucoma on detailed examination.

Case ascertainment was performed through clinical examination by experienced ophthalmologists using standardized diagnostic criteria. Controls were selected from the same source population to ensure comparability and minimize selection bias. A 1:1 ratio of hypertensive to non-hypertensive participants was maintained to facilitate evaluation of systemic hypertension as the primary exposure of interest. The rationale for this design was to efficiently compare vascular and systemic risk factors between individuals with and without POAG within a defined clinical population.

Study size

The study included 300 participants (150 hypertensive and 150 non-hypertensive individuals). The sample size was determined based on feasibility and the expected prevalence of POAG in hospital-based populations (approximately 8–10%). Assuming an anticipated exposure difference of 15–20% between groups, 80% statistical power, and a 5% level of significance, a minimum of 134 participants per group was required. To

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enhance statistical precision and compensate for potential incomplete data, the sample size was rounded to 150 per group, yielding a total of 300 participants.

Inclusion and exclusion criteria

Participants aged more than 40 years with open anterior chamber angles on gonioscopy were eligible for inclusion. Patients were excluded if they had secondary or angle-closure glaucoma, uveitis, corneal opacity interfering with posterior segment evaluation, recent ocular surgery within the preceding six months (except uncomplicated cataract surgery), or other causes of optic nerve atrophy.

Definitions and clinical assessment

Systemic hypertension was defined as a known history of hypertension on treatment or a systolic blood pressure >160 mmHg and/or diastolic blood pressure >90 mmHg at the time of examination, in accordance with standard guidelines. Diabetes mellitus was defined as a known diabetic on treatment or fasting venous blood glucose >140 mg%. Myopia was defined as a spherical equivalent refractive error greater than 1.00 diopter. A positive family history of glaucoma was recorded when first-degree relatives were affected.

Blood pressure was measured in the sitting position after a minimum of five minutes of rest using a standard sphygmomanometer.

Ophthalmological evaluation

All participants underwent a comprehensive ophthalmological examination, including best-corrected visual acuity assessment using Snellen's chart, slit-lamp biomicroscopy, and gonioscopy using a Goldmann single-mirror goniolens. Only eyes with open angles were included. Intraocular pressure was measured using a Perkins hand-held applanation tonometer (Mk2), with three readings taken per eye and the median value recorded. Central corneal thickness was measured using an ultrasound pachymeter (Pachymeter SP 3000, Tomey Corporation), and corrected intraocular pressure was calculated.

Optic disc evaluation was performed by slit-lamp biomicroscopy using a 78D lens. Visual field testing was carried out using the Humphrey Field Analyzer (Zeiss, Model 720) with the SITA standard 30-2 program. Visual fields were interpreted using Anderson–Patella criteria, and the severity of glaucomatous damage was graded according to the Hodapp–Parrish–Anderson classification.

Perfusion pressure assessment and diagnosis

Diastolic perfusion pressure was calculated as the difference between diastolic blood pressure and intraocular pressure. Primary open-angle glaucoma was diagnosed based on the presence of characteristic optic disc changes and/or glaucomatous visual field defects, with or without elevated intraocular pressure, in the presence of an open anterior chamber angle.

Bias

Several measures were implemented to reduce potential bias. Selection bias was minimized by recruiting consecutive eligible cases and selecting controls from the same hospital setting. Matching for age and sex reduced confounding by major demographic variables. Standardized instruments and uniform protocols were used for blood pressure measurement, intraocular pressure recording, pachymetry, and visual field assessment to reduce measurement bias. Diagnostic criteria for POAG were predefined to prevent misclassification. Statistical adjustment was undertaken for relevant covariates during analysis.

Statistical analysis

Data were analysed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarised as mean ± standard deviation (SD) and categorical variables as frequencies and percentages. Comparisons between hypertensive and non-hypertensive groups were performed using the independent samples Student's t-test for continuous variables and the Chi-square test for categorical variables. Associations between categorical risk factors (systemic hypertension, age ≥60 years, diabetes mellitus, myopia, and family history of glaucoma) and POAG were assessed using univariate Chi-square analysis, and variables with $p < 0.10$ were entered into a multivariable logistic regression model to identify independent predictors, reporting adjusted odds ratios (aOR) with 95% confidence intervals (CI). Mean diastolic perfusion pressure between POAG and non-POAG participants was compared using the independent samples Student's t-test. A p-value < 0.05 was considered statistically significant.

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Results

Participants

During the study period, 342 individuals aged >40 years attending the ophthalmology outpatient department were assessed for eligibility. Of these, 22 were excluded due to secondary or angle-closure glaucoma, 11 were excluded because media opacity precluded adequate optic disc or visual field evaluation, and 9 declined to participate.

A total of 300 participants met the inclusion criteria and provided written informed consent. These comprised 150 individuals with systemic hypertension and 150 age- and sex-matched non-hypertensive controls. All enrolled participants underwent complete ophthalmic evaluation and blood pressure assessment. No participants were lost after enrolment, and complete data were available for all 300 individuals, who were included in the final analysis.

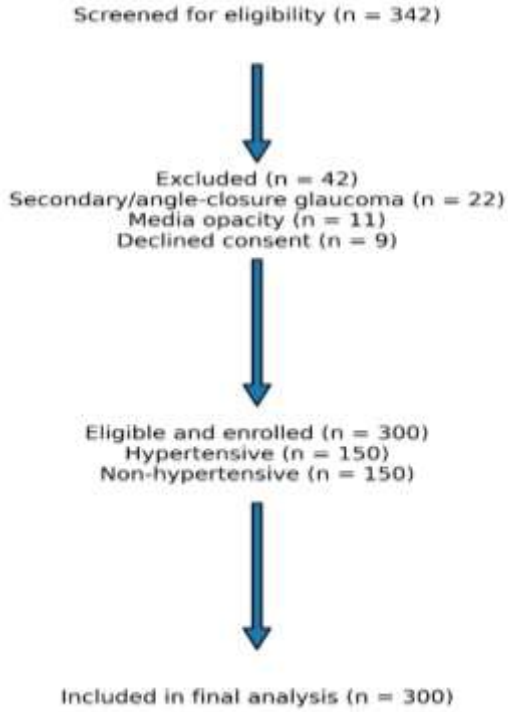

Figure 1: Participant Flow Diagram

A total of 300 participants aged above 40 years were included in the study. The mean age of the study population was 53.8 ± 8.5 years, with a slight male predominance (male:female = 164:136). Diabetes mellitus was present in 27.7% of participants, while myopia and a positive family history of primary open-angle glaucoma (POAG) were observed in 5.3% and 3.7% of cases, respectively. The overall prevalence of POAG in the study population was 9.0% (Table 1).

Table 1. Baseline Characteristics of the Study Population (n = 300)

Variable	Value
Mean age (years)	53.8 ± 8.5
Male: Female	164: 136
Diabetes mellitus	83 (27.7%)
Myopia	16 (5.3%)
Family history of POAG	11 (3.7%)
Overall POAG prevalence	27 (9.0%)

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Original Article

Comparison between hypertensive and non-hypertensive groups showed that the two groups were well matched with respect to age and gender distribution. The mean age was comparable between hypertensive (53.68 ± 8.6 years) and non-hypertensive participants (53.92 ± 8.5 years). Although diabetes mellitus and family history of POAG were more frequent among hypertensive individuals, these differences did not reach statistical significance. The prevalence of myopia was low and similar in both groups, confirming baseline comparability (Table 2).

Table 2. Comparison of Hypertensive and Non-Hypertensive Groups

Parameter	Hypertensive (n=150)	Non-hypertensive (n=150)	p-value
Mean age (years)	53.68 ± 8.6	53.92 ± 8.5	0.80
Males (%)	82 (54.7%)	82 (54.7%)	0.81
Diabetes mellitus (%)	47 (31.3%)	36 (24.0%)	0.14
Myopia (%)	8 (5.3%)	7 (4.7%)	0.98
Family history of POAG (%)	7 (4.7%)	4 (2.7%)	0.35

Analysis of risk factors associated with POAG revealed a strong relationship with advancing age. Individuals aged ≥ 60 years demonstrated a significantly higher occurrence of POAG compared to younger participants (p = 0.001). Diabetes mellitus also showed a borderline significant association with POAG (p = 0.05). A positive family history of glaucoma was significantly more common among POAG cases (p = 0.03), highlighting its contributory role. In contrast, systemic hypertension and myopia did not show a statistically significant association with POAG in the present cohort (Table 3).

Assessment of vascular parameters demonstrated that mean diastolic perfusion pressure was slightly lower in patients with POAG compared to those without POAG; however, this difference was not statistically significant. Overall, the findings indicate that increasing age and family history are the strongest determinants of POAG in this population, while systemic hypertension alone did not emerge as an independent risk factor (Table 3).

Table 3. Association of Risk Factors with Primary Open-Angle Glaucoma

Risk factor	POAG present (n=27)	POAG absent (n=273)	p-value
Systemic hypertension	14	136	0.74
Age ≥ 60 years	13	63	0.001
Diabetes mellitus	11	72	0.05
Myopia	2	14	0.80
Family history of POAG	3	8	0.03
Diastolic perfusion pressure (mmHg)	63.3 ± 8.1	64.8 ± 9.0	0.26

Association of risk factors with POAG (keep this paragraph immediately after Table 3 in the Results section, before the Discussion): Associations between categorical risk factors and POAG were tested using the Chi-square test. Age ≥60 years was significantly associated with POAG ($\chi^2 = 10.83$, df = 1, p = 0.001), and family history of POAG was also significant ($\chi^2 = 4.71$, df = 1, p = 0.03), while diabetes mellitus showed borderline association ($\chi^2 = 3.84$, df = 1, p = 0.05). Systemic hypertension ($\chi^2 = 0.11$, df = 1, p = 0.74) and myopia ($\chi^2 = 0.06$, df = 1, p = 0.80) were not significantly associated. Mean diastolic perfusion pressure was lower in POAG than non-POAG participants (63.3 ± 8.1 mmHg vs 64.8 ± 9.0 mmHg), but the difference was not statistically significant on independent samples Student's t-test (t = −1.13, df = 298, p = 0.26).

Discussion

Primary open-angle glaucoma (POAG) is a chronic optic neuropathy with a complex and multifactorial etiology, and clarification of systemic and vascular risk factors is essential for improving early detection and risk stratification. The present study evaluated the association

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Original Article

of systemic hypertension and diastolic perfusion pressure with POAG in a tertiary-care hospital population.

The overall prevalence of POAG in this study was 9.0%, which is comparable with findings from other hospital-based Indian studies, though slightly higher than rates reported in population-based surveys. This discrepancy is likely related to the tertiary-care setting, where patients with systemic comorbidities and ocular complaints are more frequently encountered [12]. The observed male predominance and mean age in the mid-fifties are consistent with earlier regional and population-based studies [7–9].

Advancing age emerged as the strongest risk factor for POAG in the present cohort. Participants aged 60 years and above demonstrated a significantly higher prevalence of disease, supporting well-established evidence linking aging with increased susceptibility to glaucomatous optic neuropathy. Age-related alterations in trabecular meshwork function, optic nerve head biomechanics, and vascular autoregulation have been proposed as underlying mechanisms [7,8].

A positive family history of glaucoma showed a significant association with POAG, reinforcing the role of genetic predisposition in disease development. Similar observations have been reported in population-based studies, where first-degree relatives of affected individuals demonstrate higher prevalence and earlier onset of POAG [9]. Diabetes mellitus demonstrated a borderline association with POAG in the present study, which may reflect microvascular compromise and impaired ocular blood flow, as suggested in earlier clinical studies [10].

Systemic hypertension, despite its high prevalence in the study population, did not show an independent association with POAG. This finding is consistent with several epidemiological investigations that have failed to demonstrate a direct causal relationship between hypertension and glaucoma [7,9]. The lack of association may be explained by the dual and opposing effects of hypertension on optic nerve perfusion, wherein elevated blood pressure may initially improve ocular perfusion, while long-standing hypertension and antihypertensive therapy can impair vascular autoregulation and contribute to microvascular damage [11].

Diastolic perfusion pressure was marginally lower among patients with POAG, although this difference did not reach statistical significance. Previous studies have suggested that reduced perfusion pressure may increase susceptibility to glaucomatous damage, particularly in individuals with impaired autoregulation [7,10]. However, the present findings suggest that reduced diastolic perfusion pressure alone may not be sufficient to cause POAG and likely acts in conjunction with other risk factors such as age and genetic predisposition [8,12].

Generalizability

The findings of this study are generalizable to similar tertiary-care hospital populations in South India, particularly among adults aged above 40 years. Caution is required when extrapolating results to community-based or ethnically diverse populations due to differences in healthcare access and disease detection patterns.

Conclusion

This study highlights the multifactorial nature of primary open-angle glaucoma and reinforces the importance of demographic and hereditary factors in its development. Advancing age and a positive family history emerged as the strongest predictors of POAG, while diabetes mellitus showed a borderline association. Systemic hypertension, despite its high prevalence, did not independently increase the risk of POAG in this cohort. Diastolic perfusion pressure was marginally lower among POAG patients, suggesting a possible contributory but non-dominant role. These findings underscore that glaucoma risk assessment should extend beyond intraocular pressure alone and incorporate comprehensive evaluation of individual risk profiles. Early identification of high-risk individuals remains crucial to prevent irreversible visual impairment.

Limitations

The hospital-based design limit external validity and introduce selection bias. The cross-sectional nature of the study restricts causal inference between risk factors and POAG. Blood pressure measurements were recorded at a single time point, and nocturnal blood pressure variations were not assessed. Longitudinal follow-up to evaluate disease progression was not undertaken.

Recommendations

Routine glaucoma screening should be emphasized for individuals aged 60 years and above, especially those with a positive family history of glaucoma or coexisting diabetes mellitus. Comprehensive ophthalmic evaluation,

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including optic disc assessment and visual field testing, should be incorporated into regular eye examinations for high-risk groups. Clinicians should adopt a multifactorial risk-based approach rather than relying solely on intraocular pressure measurements. Integration of glaucoma screening into general health check-up programs may facilitate earlier detection. Further longitudinal and population-based studies are recommended to clarify the long-term impact of vascular factors and perfusion pressure on glaucoma development and progression.

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Abbreviations

POAG – Primary Open-Angle Glaucoma
IOP – Intraocular Pressure
DPP – Diastolic Perfusion Pressure
SPP – Systolic Perfusion Pressure
CCT – Central Corneal Thickness
BCVA – Best Corrected Visual Acuity

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The study had no funding.

Conflict of interest

The authors declare no conflict of interest.

Author contributions

BK-Concept and design of the study, results interpretation, review of literature and preparing first draft of manuscript. Statistical analysis and interpretation, revision of manuscript. RP- design of the study, results interpretation, review of literature and preparing first draft of manuscript, revision of manuscript. SMPH--Review of literature and preparing first draft of manuscript. Statistical analysis and interpretation.

Data availability

Data available on request

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