Original Research

ASSOCIATION OF ESTIMATED TRANS LAMINA CRIBROSA PRESSURE AND OCULAR PERFUSION PRESSURE IN PATIENTS WITH GLAUCOMA

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ABSTRACT

Background: Glaucoma is a multifactorial optic neuropathy characterized by progressive retinal ganglion cell loss and visual field defects. While elevated IOP (Intraocular Pressure) is a major risk factor, other pressure-related factors such as TLCP (Trans Lamina Cribrosa Pressure) and OPP (Ocular Perfusion Pressure) may contribute to disease pathogenesis. TLCP represents the difference between IOP and CSFP (Cerebrospinal Fluid Pressure), whereas OPP reflects the relationship between systemic blood pressure and IOP. This study evaluated the association of glaucoma with estimated TLCP and OPP.

Methods: A hospital-based cross-sectional study was conducted in the Department of Ophthalmology of a tertiary care teaching hospital from October 2019 to June 2021. Sixty diagnosed cases of primary glaucoma satisfying the inclusion criteria were enrolled. All participants underwent a comprehensive ophthalmic evaluation, including visual acuity assessment, slit-lamp examination, gonioscopy, fundus evaluation, visual field analysis, and IOP measurement using Goldmann applanation tonometry. Blood pressure and BMI (Body Mass Index) were recorded to estimate CSFP, TLCP, and OPP using validated formulas. Statistical analysis was performed using chi-square test, Student's t-test, and ANOVA.

Results: The mean age of the study population was 49.6 ± 10.95 years, with females accounting for 55% of cases. POAG (Primary Open-Angle Glaucoma) constituted 67% of cases, NTG (Normal-Tension Glaucoma) 18%, and PACD (Primary Angle-Closure Disease) 15%. The mean IOP was 24.67 ± 5.46 mmHg, and 70% of patients had IOP >21 mmHg. The mean OPP was 38.80 ± 8.82 mmHg, with no significant correlation between OPP and IOP. Mean TLCP was 11.7 ± 6.51 mmHg and was significantly elevated compared to normal values. A strong positive association was observed between IOP and TLCP ($p<0.0001$), while TLCP demonstrated an inverse relationship with OPP.

Conclusion: Estimated TLCP showed a significant positive association with glaucoma and increased with rising IOP. OPP demonstrated an inverse relationship with TLCP, but its association with glaucoma was less clear. TLCP may serve as a more reliable pressure-related factor in glaucoma assessment than OPP.

Keywords: Glaucoma, Trans Lamina Cribrosa Pressure, TLCP, Ocular Perfusion Pressure, OPP, Intraocular Pressure, Cerebrospinal Fluid Pressure.

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INTRODUCTION

Glaucoma is a multifactorial optic neuropathy characterized by progressive loss of retinal ganglion cells, resulting in characteristic optic nerve head damage and visual field defects.[1] Although elevated IOP is the most important and modifiable risk factor for glaucomatous optic neuropathy, a considerable proportion of patients develop

glaucoma despite having normal IOP, a condition termed normal-tension glaucoma.[2] This observation suggests that factors other than IOP contribute to the pathogenesis and progression of glaucoma.

Among the proposed pressure-related factors, OPP (Ocular Perfusion Pressure) and TLCP (Trans Lamina Cribrosa Pressure) have gained increasing attention.[3,4] TLCP is defined as the difference between IOP and CSFP (Cerebrospinal Fluid Pressure).[3–6] Since the optic nerve head lies at the junction between the intraocular and retrobulbar spaces, the pressure gradient across the lamina cribrosa may play a more significant role in glaucomatous damage than the transcorneal pressure measured as IOP alone. CSFP surrounding the optic nerve can be estimated using the formula developed by Xie et al., which incorporates age, body mass index (BMI), and diastolic blood pressure.[7] BMI, calculated as weight (kg)/height² (m^2), serves as an important anthropometric measure in this estimation.[8]

Another important factor implicated in glaucoma is OPP, which reflects the blood supply to the optic nerve and ocular tissues. OPP is defined as the difference between mean arterial blood pressure and IOP.[3,4] Alterations in ocular perfusion may lead to ischemia and inadequate nourishment of the optic nerve head, thereby contributing to glaucomatous damage. Because systolic and diastolic blood pressures vary considerably, mean perfusion pressure is considered a more reliable indicator of ocular blood flow.[9,10] OPP can be estimated non-invasively using systemic blood pressure and IOP measurements obtained by Goldmann applanation tonometry.

Aims and Objectives

The present study was undertaken to compare the association of glaucoma with TLCP (Trans Lamina Cribrosa Pressure) and OPP (Ocular Perfusion Pressure). Specifically, the study aimed to evaluate whether TLCP is a reliable factor contributing to glaucoma, determine the significance of OPP in the development and progression of glaucoma, and identify which of these two pressure-related parameters, TLCP or OPP, serves as a more reliable factor associated with glaucomatous optic neuropathy.

MATERIALS AND METHODS

Study Design

This hospital-based cross-sectional study was conducted in the Department of Ophthalmology of a tertiary care teaching hospital affiliated with Dr. NTR University of Health Sciences between October 2019 and June 2021. The study included 60 patients with a confirmed diagnosis of glaucoma who attended the Ophthalmology Outpatient Department (OPD) and satisfied the predefined inclusion and exclusion criteria. All eligible participants were evaluated during the study period to assess the association of glaucoma with TLCP and OPP.

Inclusion and Exclusion Criteria

The study included patients attending the Ophthalmology OPD (Out-Patient Department) with a confirmed diagnosis of primary glaucoma, including primary open-angle glaucoma and primary angle-closure glaucoma. Patients were excluded if they had any other ocular disease that could influence visual field assessment or intraocular pressure measurements, were receiving medications known to affect intraocular pressure or visual fields, had high myopia of ≥8 dioptres with an axial length of ≥26.5 mm, or were diagnosed with secondary glaucoma.

Sample Size Calculation

- Formula: n= 4pq/d2
- P=0.04
- Q=1-p=0.96
- D=0.05
- Therefore, from this formula n=60

Data Collection Procedure

After enrolment, all eligible participants underwent detailed evaluation. Blood pressure was measured in the right arm in the supine position using an electronic sphygmomanometer (Omron HEM 7120). BMI was calculated as weight in kilograms divided by the square of height in metres. IOP was measured using GAT (Goldmann Applanation Tonometry). For the procedure, topical anesthesia was achieved with 2% proparacaine eye drops followed by fluorescein staining using a sterile fluorescein strip, and GAT was performed according to the standard technique. OPP was calculated using systolic and diastolic blood pressure values along with IOP measurements. Estimated CSFP (Cerebrospinal Fluid Pressure) was derived from age, BMI, and diastolic blood pressure using a validated formula, and TLCP was subsequently calculated as the difference between IOP and estimated CSFP. The collected parameters were used to evaluate the association of glaucoma with OPP and TLCP.

Statistical analysis

The collected data were compiled and subjected to statistical analysis. Descriptive statistics were used to summarize the study variables. Comparative analyses were performed using the chi-square test for categorical variables, Student's unpaired t-test for comparison of means between groups, and ANOVA (Analysis of Variance) for assessing differences among multiple groups. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Variable	Category	Frequency	Percentage
Age	20–29 years	3	5%
	30–39 years	9	15%
	40–49 years	16	27%
	50–59 years	21	35%
	60–69 years	9	15%
	70–79 years	2	3%
Gender	Male	27	45%
	Female	33	55%

Table 1. Demographic Characteristics of Study Participants (n=60)

Table 1 illustrates the demographic profile of glaucoma patients. Most participants belonged to the 50–59 years age group (35%)**,** followed by 40–49 years (27%). Females constituted a slightly higher proportion (55%) than males (45%).

Age Group (in years)	Male n (%)	Female n (%)	Total
20–29	2 (7.4)	1 (3.0)	3
30–39	6 (22.2)	3 (9.1)	9
40–49	6 (22.2)	10 (30.3)	16
50–59	8 (29.6)	13 (39.4)	21
60–69	3 (11.1)	6 (18.2)	9
70–79	2 (7.4)	0	2

Table 2. Age and Gender Distribution of Patients

Table 2 observes the age-wise distribution according to gender**.** The largest subgroup was females aged 50–59 years**,** while males were also predominantly concentrated in the same age category.

Parameter	Category	Frequency	Percentage
Type of Glaucoma	POAG	40	67%
	NTG	11	18%
	PACD	9	15%
BMI	Normal (18.5–24.9)	27	45%
	Overweight (25–29.9)	32	53%
	Obese (30–34.9)	1	2%
Blood Pressure	Normal	20	33%
	Elevated	40	67%

Table 3. Clinical Characteristics of Glaucoma Cases

Table 3 highlights the clinical profile of study participants. POAG was the predominant glaucoma subtype (67%). More than half of the patients were overweight (53%), and elevated blood pressure was observed in two-thirds (67%) of the cases.

Blood Pressure	Male's n (%)	Female's n (%)
Normal	8 (34%)	12 (37.5%)
Elevated	19 (66%)	21 (62.5%)
Total	27 (100%)	33 (100%)

Table 4. Blood Pressure Distribution According to Gender

Table 4 demonstrates the association between gender and blood pressure**.** Elevated blood pressure was common in both males and females, indicating a high prevalence of systemic vascular risk factors among glaucoma patients.

Variable	Category	Frequency
IOP	≤21 mmHg	18 (30%)
	>21 mmHg	42 (70%)
NTG	≤21 mmHg	11
NTG	>21 mmHg	0
Non-NTG	≤21 mmHg	7

Non-NTG	>21 mmHg	42

Table 5. Intraocular Pressure Distribution and Association with Glaucoma Type

Table 5 illustrates the distribution of intraocular pressure (IOP). Most patients (70%) had IOP greater than 21 mmHg. All NTG patients were found in the normal IOP category, while elevated IOP was predominantly associated with non-NTG glaucoma.

Parameter	Category	Frequency (%)
OPP (mmHg)	20–29.9	10 (17%)
	30–39.9	21 (35%)
	40–49.9	24 (40%)
	50–59.9	4 (7%)
	60–69.9	1 (1%)
Estimated CSF Pressure (mmHg)	6–10.9	13 (22%)
	11–15.9	42 (70%)
	16–20.9	5 (8%)
TLCP (mmHg)	<0	1 (2%)
	0–5.9	11 (18%)
	6–10.9	16 (27%)
	11–15.9	18 (30%)
	16–20.9	7 (12%)
	21–25.9	5 (8%)
	26–30.9	2 (3%)

Table 6. Distribution of Ocular Perfusion Pressure (OPP), Estimated CSF Pressure, and TLCP

Table 6 summarizes the major pressure-related variables studied**.** Most subjects had OPP between 40 and 49.9 mmHg, CSF pressure between 11–15.9 mmHg, and TLCP between 11 and 15.9 mmHg**,** suggesting a tendency toward elevated trans-lamina cribrosa pressure in glaucoma patients.

Glaucoma Type	Mean IOP (mmHg)	Mean OPP (mmHg)	Mean TLCP (mmHg)
POAG	23.65 ± 5.23	39.70 ± 8.86	10.57 ± 5.93
PACD	30.44 ± 4.47	33.75 ± 9.08	18.74 ± 5.87
Parameter		**P Value**	
IOP		0.0005	
OPP		0.06	
TLCP		0.0003	

Table 7. Relationship of IOP, OPP, and TLCP with Glaucoma

Table 7 compares the mean IOP, OPP, and TLCP across glaucoma subtypes. PACD patients demonstrated significantly higher IOP and TLCP values than POAG patients. OPP did not show a statistically significant association, whereas both IOP and TLCP showed strong associations with glaucoma severity and subtype.

DISCUSSION

The present study evaluated the association between estimated TLCP and OPP in 60 patients with glaucoma. The mean age of the study population was 49.6 ± 10.95 years, with most participants belonging to the 40–59-year age group. Similar age distributions have been reported by Anand Palimkar et al. and Mathan JJ et al.[1,11] suggesting that glaucoma predominantly affects middle-aged and elderly individuals. Age-related structural and vascular changes may contribute to the increasing prevalence of glaucoma with advancing age.

Females constituted 55% of the study population, while males accounted for 45%, yielding a male-to-female ratio of 1:1.2. This finding is comparable to that reported by Mathan JJ et al.[11] indicating a relatively equal gender distribution among glaucoma patients. However, gender differences become more evident when glaucoma subtypes are considered.

POAG was the predominant subtype in the present study, accounting for 85% of cases, while PACD constituted 15%. This distribution differs from some Indian population studies that reported a more balanced prevalence of POAG and PACG, likely reflecting the hospital-based nature and sample selection of the present study.[12] Among open-angle glaucomas, POAG represented 78.5% and NTG 21.5% of cases.

Gender analysis of glaucoma subtypes showed that NTG was more common among females, consistent with previous observations.[13,14] Although PACD is

generally reported to be more prevalent in females because of anatomical and hormonal factors,[14] the present study demonstrated a slightly higher proportion of males among PACD cases, which may be attributable to the relatively small sample size.

BMI was evaluated because of its contribution to CSFP estimation. More than half of the study participants were overweight or obese. Previous studies have demonstrated a positive association between increased BMI and elevated IOP, suggesting that obesity may influence glaucoma risk through increased episcleral venous pressure, altered ocular blood flow, and systemic hypertension.[15]

Systemic blood pressure also showed a positive association with glaucoma. Two-thirds of the study participants had elevated blood pressure. Blood pressure influences ocular perfusion pressure and optic nerve circulation, and both hypertension and hypotension have been implicated in glaucoma pathogenesis. Elevated blood pressure may increase aqueous humor production and IOP, whereas reduced perfusion pressure can result in optic nerve ischemia and glaucomatous damage.[16]

Intraocular pressure remains the most important modifiable risk factor for glaucoma. In the present study, 70% of subjects had elevated IOP, with a mean IOP of 24.67 ± 5.46 mmHg. Most patients had IOP values between 21 and 30 mmHg, reinforcing the established role of elevated IOP in glaucoma development and progression. Increasing age was associated with higher IOP levels, consistent with previous reports describing age-related changes in aqueous outflow pathways.

No significant gender-based difference in IOP was observed. Similar findings have been reported in the Framingham Eye Study and the Health and Nutrition Examination Survey, although other studies have demonstrated variable gender associations with IOP. All NTG patients exhibited IOP values within the normal range, with a mean IOP of 17.45 mmHg, whereas non-NTG patients demonstrated significantly higher IOP values. This finding highlights the multifactorial nature of glaucomatous optic neuropathy and suggests the involvement of factors other than IOP in disease progression.

The mean OPP in the present study was 38.80 ± 8.82 mmHg, which was lower than values reported in the Central India Eye Study. Previous studies have reported inconsistent relationships between OPP and glaucoma.[17] In the current study, lower OPP values were frequently observed among glaucoma patients, particularly in PACD cases, suggesting a possible role of vascular insufficiency in disease progression. Reduced OPP has been identified as a risk factor for glaucomatous optic nerve damage and visual field loss.[18]

A significant association was observed between elevated IOP and reduced OPP. Among patients with elevated IOP, 62% demonstrated OPP values below 40 mmHg. This finding supports previous evidence that impaired ocular perfusion may contribute to optic nerve head damage in glaucoma.[13]

Estimated CSFP ranged from 6.83 to 18.71 mmHg, with a mean value of 12.8 ± 2.48 mmHg. Most participants had CSFP values within the physiological range. Previous studies have demonstrated that reduced CSFP may contribute to glaucoma pathogenesis, particularly in patients with normal-tension glaucoma, by increasing the pressure gradient across the lamina cribrosa.

The mean TLCP in the present study was 11.7 ± 6.51 mmHg, which was significantly higher than values reported by Jonas et al.[17] Since TLCP represents the pressure difference between IOP and CSFP, it may more accurately reflect the biomechanical stress experienced by the optic nerve head than IOP alone. Elevated TLCP has been increasingly recognized as an important factor in glaucomatous optic neuropathy.

A strong positive association was observed between IOP and TLCP. Patients with elevated IOP had significantly higher TLCP values than those with normal IOP, indicating that increasing IOP directly contributes to an increased trans-laminar pressure gradient. These findings support observations by Jonas et al.[17] who proposed TLCP as a key determinant of optic nerve damage.

The principal objective of this study was to evaluate the relationship between TLCP and OPP. A significant inverse relationship was observed between these variables. Lower OPP values were associated with higher TLCP measurements, whereas higher OPP values corresponded to lower TLCP values. Similar findings have been reported by other studies who demonstrated a significant negative correlation between TLCP and OPP. These results suggest that reduced ocular perfusion and increased trans-laminar pressure gradients may act synergistically in glaucoma pathogenesis.

Analysis of glaucoma subtypes demonstrated significantly higher TLCP values in PACD compared with POAG. This finding indicates that trans-laminar pressure imbalance may play an important role across different glaucoma subtypes and may be particularly relevant in angle-closure disease. Previous studies have similarly reported associations between increased TLCP and structural optic nerve damage in glaucoma.[17]

The findings of the present study support the concept that glaucoma is a multifactorial disease influenced not only by elevated IOP but also by vascular factors such as OPP and biomechanical factors such as TLCP. Among these parameters, TLCP demonstrated a strong association with glaucoma severity and subtype distribution, while OPP showed an inverse relationship with TLCP. These observations highlight the importance of considering both vascular and trans-laminar

pressure mechanisms in the understanding and management of glaucomatous optic neuropathy.

CONCLUSION

This hospital-based cross-sectional study evaluated the association between TLCP and OPP in 60 patients with glaucoma. The findings demonstrated that TLCP showed a significant positive association with glaucoma and was strongly correlated with elevated IOP, suggesting its important role in glaucomatous optic nerve damage. OPP exhibited an inverse relationship with TLCP, with lower OPP values being more frequent among patients with glaucoma, particularly in angle-closure disease. The study also identified positive associations of elevated blood pressure, higher BMI, and reduced estimated CSFP with glaucoma pathogenesis. Among glaucoma subtypes, TLCP showed a stronger association than OPP, particularly in PACD. These findings suggest that, in addition to IOP, trans-laminar pressure dynamics and ocular perfusion status play important roles in glaucoma pathogenesis and may provide valuable insights for disease assessment and management.

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