Original Article

To Study Effect of Hypertension on Intraocular Pressure and Retinal Nerve Fibre Thickness Using Optical Coherence Tomography in Tertiary Health Care Centre

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ABSTRACT

Background: Hypertension and age-related ocular conditions, such as glaucoma, are increasingly prevalent, particularly due to aging and race as significant risk factors. This study investigates how hypertension influences intraocular pressure (IOP) and retinal nerve fiber layer (RNFL) thickness, critical indicators for glaucoma risk, utilizing optical coherence tomography (OCT).

Methods: A cross-sectional observational study was conducted at Index Medical College, Hospital and Research Center, Indore, MP, India from September 2022 to August 2023. A total of 100 hypertensive patients over 18 years were recruited. Comprehensive ophthalmic examinations were performed, including visual acuity testing, Goldmann applanation tonometry for IOP measurement, and spectral-domain OCT for RNFL thickness assessment. Statistical analyses were performed using SPSS version 24.0, with p-values <0.05 considered statistically significant.

Results: The study population had a mean age of 50.31 ± 9.697 years, with a higher proportion of males (55%). Mean systolic blood pressure (SBP) was 157.74 ± 21.58 mmHg, diastolic blood pressure (DBP) was 95.12 ± 9.70 mmHg, and mean arterial pressure (MAP) was 115.99 ± 12.80 mmHg. The average IOP was 15.41 ± 1.615 mmHg, and RNFL thickness averaged 89.65 µm. Significant positive correlations were found between SBP, DBP, MAP, and IOP ($p < 0.05$). Conversely, negative correlations between blood pressure levels and RNFL thickness were significant across all quadrants ($p < 0.05$).

Conclusion: The findings suggest that while SBP did not significantly correlate with IOP or RNFL thickness, DBP and MAP showed moderate correlations with RNFL thickness and IOP, respectively.

Keywords: Hypertension, intraocular pressure (IOP), retinal nerve fiber layer (RNFL), optical coherence tomography (OCT).

INTRODUCTION

Age-related conditions like glaucoma and arterial hypertension are anticipated to become increasingly prevalent due to their association with aging and race as a risk factor.[1] These conditions often coexist, and their interaction is complex, particularly in the relationships among intraocular pressure (IOP), blood pressure (BP), and ocular perfusion pressure (OPP), defined as the difference between mean BP and IOP.

Hypertension, or high blood pressure, is a common condition that affects the arteries, resulting in persistent high pressure against the arterial walls. The American Heart Association and American College of Cardiology classify blood pressure into four categories: normal BP, which is ≤120/80 mm Hg; elevated BP, with a systolic BP of 120–129 mm Hg and diastolic below 80 mm Hg; Stage 1 hypertension, where systolic pressure is 130–139 mm Hg and diastolic pressure is 80–89 mm Hg; and Stage 2 hypertension, where systolic BP is ≥140 mm Hg and diastolic BP is ≥90 mm Hg. A reading of 180/120 mm Hg is considered a hypertensive crisis.[2]

Intraocular pressure (IOP) is a key factor in assessing patients at risk for glaucoma. IOP is regulated by the production and drainage of aqueous humor by the ciliary body. This fluid drains through the trabecular meshwork and uveoscleral pathways, which are essential for maintaining the pressure within the eye. Notably, the vitreous humor in the posterior segment of the eye does not impact IOP management, as its volume remains relatively constant. [3]

Intraocular pressure, or the fluid pressure inside the eye, is measured by tonometry, a technique used by eye care professionals to assess this parameter. Normal intraocular pressure (IOP) is generally considered to range from 10 to 20 mmHg, with an average range of approximately 2.75 mmHg to 15.5 mmHg as measured by optometrists and ophthalmologists. [4]

Ocular hypertension (OHT) refers to an elevated IOP above normal levels without optic nerve damage or loss of visual field. Primary open-angle glaucoma, a type of primary glaucoma with no clear systemic or ocular cause, is also known as chronic simple glaucoma of adult onset. This condition is characterized by a normal-appearing, open anterior chamber angle and a gradually increasing IOP (above 21 mmHg) documented over several readings. Other defining features include typical optic disc cupping and specific visual field deficiencies. Primary angle closure disease, on the other hand, involves the peripheral iris pressing against the trabecular meshwork, which obstructs aqueous outflow by closing the already narrow angle of the anterior chamber.[5]

The mechanical and vascular hypotheses of glaucoma pathophysiology propose that elevated intraocular pressure (IOP) either directly damages optic nerve fibers or restricts blood flow, leading to optic neuropathy. [6] Diagnosis of primary open-angle glaucoma (POAG) involves identifying optic disc changes and visual field loss, with IOP reduction as the main treatment goal to slow disease progression and preserve vision. [7]

Interactions between blood pressure (BP) and IOP are crucial; elevated BP can increase IOP, impacting the risk and progression of glaucoma. [8] Nocturnal BP dips and posture changes also affect ocular perfusion pressure (OPP), while sudden IOP fluctuations may harm eye tissue through gas emboli or ischemic pressure. [9-11]Autoregulation helps stabilize blood flow in the retina and optic nerve head, though hypertension may impair this mechanism, impacting retinal nerve fiber layer thickness and raising IOP. [12]

Hypertension is strongly associated with retinal microvascular abnormalities, such as retinal arteriolar constriction and retinopathy, which are linked to disrupted blood flow and increased vascular resistance in the retina, leading to retinal ischemia and optic nerve damage. [13] Retinal nerve fiber layer (RNFL) thickness, comprising ganglion cell axons responsible for visual signal transmission, diminishes with axonal injury, a common feature in various neurodegenerative diseases. [14]

Optical coherence tomography (OCT) has become an advanced imaging method for the eye, providing high-resolution, three-dimensional images. Based on low-coherence interferometry, OCT assesses the echo time delay between light reflected from different retinal layers and a reference mirror. It generates real-time tomographic images of the retina and optic nerve head with remarkable axial resolution (3 to 15 µm). [15,16]

This study utilizes spectral domain OCT to evaluate optic nerve head changes and retinal nerve fiber layer (RNFL) thickness in early to moderate glaucoma patients, comparing these findings to age-matched controls. The study aimed to determine the effect of hypertension on IOP using an applanation tonometer and thickness of retinal-nerve-fiber-layer (RNFL) using optical- coherence-tomography (OCT).

MATERIALS AND METHODS

After approval from the institutional ethics committee, this cross-sectional observational study was conducted in the Department of Ophthalmology at Index Medical College, Hospital, and Research Center, Indore, from September 2022 to August 2023 and 100 patients who presented to the outpatient department (OPD) with primary complaints of hypertension and satisfied the inclusion criteria were recruited through consecutive sampling. Prior to enrollment, each patient received a detailed explanation of the study, and written informed consent was obtained to ensure voluntary and informed participation.

Inclusion Criteria

- Patients giving consent for the study.
- Age of patient > 18 year
- Known patients of Hypertension.

Exclusion criteria

- Age= < 18 year
- Patient not willing to give consent
- Patients with known ocular pathologies
- Hazy media preventing fundus assessment
- Subjects with OCT signal-strength of < 6 or with any scan-error message.
- Patient with no other systemic illness other than hypertension.

Methodology

After obtaining informed consent and confirming eligibility based on inclusion and exclusion criteria, each participant underwent a comprehensive ophthalmic examination, which included a detailed history-taking followed by various assessments.

The examination encompassed visual acuity testing, refraction, slit lamp evaluation, and intraocular pressure (IOP) measurement using Goldmann applanation tonometry (GAT). The tools used for the study included:

- *Visual Acuity Assessment:* Conducted using a Snellen's chart to evaluate the patient's ability to see at a distance.
- *Refraction:* Measured with an autorefractometer to determine the refractive error.
- *Blood Pressure Monitoring:* Performed using a mercury sphygmomanometer to assess arterial hypertension.
- *External Ocular Examination:* A thorough examination of the external structures of the eye.
- *Slit Lamp Examination:* To evaluate the anterior segment of the eye in detail.
- *IOP Measurement:* Utilized Goldmann Applanation Tonometry (GAT) for accurate assessment of intraocular pressure.
- *Retinal Nerve Fiber Layer Thickness:* Measured using spectral-domain optical coherence tomography (OCT).

Visual Acuity by Snellen's Chart: To assess visual acuity, the following steps were followed:

1. Ensure adequate natural light or proper illumination for the chart.
2. Clean and dry the occluder and pinhole if used.

3. Explain the process to the patient, instructing them to wash their hands if they will cover their eye with their hand.
4. Examine each eye independently, starting with the poorer eye.
5. Position the patient six meters away from the chart, either sitting or standing.
6. Ask the patient to read from the top of the chart while covering one eye and wearing any corrective lenses if needed.
7. Record the smallest line the patient can read as a fraction (e.g., 6/18), noting whether correction is required.

Intraocular Pressure Measurement Using Goldmann Applanation Tonometry (GAT): The IOP measurement process involved several steps:

1. Position the patient comfortably at the slit lamp biomicroscope and apply topical anesthetic drops to minimize discomfort.
2. Calibrate the tonometer according to the manufacturer's specifications.
3. Place a fluorescein-moistened contact prism tip gently on the cornea to aid in visualization and alignment.
4. Adjust the tonometer's alignment until the two semicircles of mires are concentrically aligned and evenly illuminated.
5. Gradually adjust the tension on the tonometer until the inner edges of the two mires touch, indicating corneal applanation. The reading on the tonometer at this point, multiplied by 10, represents the IOP in millimeters of mercury (mmHg). Multiple readings were typically taken for each eye, and the average was used for analysis.
6. After measurements, rinse the prism tip with sterile saline to prevent contamination, and document the IOP measurements, along with relevant details such as date and time, in the patient's medical records. Post-procedure instructions and follow-up appointments were provided as necessary.
7. *RNFL thickness measured by OCT* Retinal nerve fiber layer (RNFL) thickness was measured using spectral-domain optical coherence tomography (SD-OCT) in a series of procedural steps. After obtaining informed consent, patients were comfortably positioned, and topical anesthetic eye drops were administered to minimize discomfort. Their heads were stabilized to reduce movement, and the SD-OCT device was calibrated. High-resolution cross-sectional scans focused on the peripapillary area were captured using infrared light. The images were analyzed with specialized software to determine parameters like average RNFL thickness and quadrant thickness, with multiple scans taken to improve measurement reliability.
8. The data were recorded in the patients' medical records, along with relevant details and post-examination instructions.

Figure 1: Visual Acuity by Snellen's chart

Figure 2: Fluorescein staining of eye by fluorescent strip

Figure 3: IOP measurement by Goldmann Applanation Tonometer

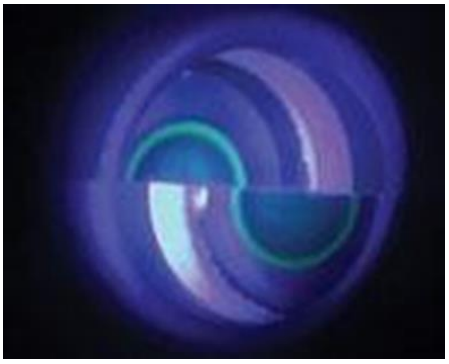

Figure 4: Mires made during tonometry

Figure 5: OCT Examination of patient in OPD

Statistical Analysis

Raw data collection was done and master chart was created using Microsoft excel 10.0. After entering each of the ten surveys, random forms were selected for verification to ensure accuracy, and an impartial party confirmed the data entry for two forms after the fifth questionnaire. Data analysis was performed using SPSS version 24.0, starting with univariate analyses displayed through various graphical methods. Descriptive statistics assessed categorical variables, while measures of central tendency characterized continuous variables. Bivariate analysis used the Fisher's Exact test and Chi-square test, with an unpaired t-test for quantitative variables, considering a p-value of less than 0.05 as statistically significant.

RESULTS

In this study, 100 patients were evaluated, with the majority (84%) under 60 years of age with mean age being 50.31 ± 9.697 years. Males made up a higher proportion of the sample compared to females, representing 55% versus 45%.

The study recorded a mean systolic blood pressure (SBP) of 157.74 ± 21.58 mmHg, mean diastolic blood pressure (DBP) of 95.12 ± 9.70 mmHg, and mean arterial pressure (MAP) of 115.99 ± 12.80 mmHg. The mean visual acuity (VA) was 0.311 ± 0.309, with best-corrected visual acuity (BCVA) averaging 0.0522 ± 0.0821. Intraocular pressure (IOP) averaged 15.41 ± 1.615 mmHg. Retinal nerve fiber layer (RNFL) thickness was measured across quadrants, with mean values of 107.85 µm (SD = 10.43) in the Superior quadrant, 113.40 µm (SD = 11.07) in the Inferior, 73.08 µm (SD = 4.19) in the Nasal, and 64.67 µm (SD = 4.25) in the Temporal quadrant, giving an average RNFL thickness of 89.65 µm (SD = 6.13). [Table 1]

Table 1: Mean values of Blood pressure (SBP, DBP and MAP), Visual Acuity (VA and BCVA), IOP and RFNL (Superior, inferior, nasal and temporal) across the study participants

Parameter	Mean	Median	Standard Deviation	Range
Blood Pressure				
• SBP	157.740	160.00	21.5812	112.00 – 200.00
• DBP	95.120	98.000	9.6957	78.0 – 120.0
• MAP	115.9933	116.0000	12.79783	96.00 – 146.67
Visual Acuity				
• VA	0.3110	0.3000	0.30909	0.00-1.00
• BCVA	0.0522	0.000	0.08209	0.00-0.18
IOP	15.41	16.00	1.615	12-18
RNFL				
• Superior	107.85	107.00	10.425	93.00-131.00
• Inferior	113.40	114.00	11.067	97.00-140.00
• Nasal	73.08	72.00	4.189	68.00-92.00
• Temporal	64.67	65.00	4.250	56.00-81.00
Average	89.65	88.00	6.129	81.00-106.00

Significant positive correlations were found with SBP, DBP, and MAP, indicating that higher blood pressure levels are associated with increased IOP. This association could imply that elevated blood pressure contributes to increased ocular pressure, potentially raising the risk of glaucoma and other ocular conditions.

Across all measured regions (superior, inferior, nasal, and temporal), there were significant negative correlations between blood pressure levels and RNFL thickness. This finding suggests that higher blood pressure is associated with thinner RNFL, particularly in the superior and inferior quadrants. Thinning of the RNFL is commonly linked to optic nerve damage and can be an early indicator of glaucoma. Thus, elevated blood pressure may indirectly impact optic nerve health by contributing to RNFL thinning.

Table 2: The correlation coefficients between blood pressure (SBP, DBP, MAP) and intraocular pressure (IOP) as well as retinal nerve fiber layer (RNFL) thickness across various regions of the retina

		IOP	Retinal nerve fiber layer (RNFL)				
			Superior	Inferior	Nasal	Temporal	Average RNFL
SBP	Correlation Coefficient (r)	0.436	0-.210	-0.324	0.301	0.243	-0.243
	P value	0.001*	.024	0.001*	0.001*	0.012*	0.021*
DBP	Correlation Coefficient (r)	0.260	-0.224	-0.287	-0.238	-0.321	-0.250
	P value	0.021*	0.028*	0.010*	0.022*	0.001*	0.001*
MAP	Correlation Coefficient (r)	0.273	-0/325	-0.259	-0.254	-0.227	-0.201
	P value	0.001*	0.001*	0.002*	0.012*	0.020*	0.041*

DISCUSSION

Hypertension is known to affect ocular health, particularly through changes in intraocular pressure (IOP) and retinal nerve fiber layer (RNFL) thickness, both of which are essential to monitor for comprehensive patient management. This study explored hypertension's effects on IOP and RNFL thickness using applanation tonometry and Optical Coherence Tomography (OCT).

The average age of participants was 50.31 ± 9.697 years, with most (84%) under 60 years old, a distribution comparable to similar studies on hypertension and eye health. Research by Sajja et al. [3], Sahin OZ et al. [7], and Rezk MM et al. [8] examined participants with mean ages ranging from mid-40s to early 60s, reinforcing the relevance of this study's demographic. Additionally, studies like those by Rao K et al. [9] and Lee MW et al. [10] used age groups that align closely with this study's sample, enhancing comparability of findings on hypertension's impact on IOP and RNFL thickness across similar age demographics.

In this study, the gender distribution was 45% female and 55% male, which aligns with trends observed in similar research. [3-7] While many cited studies did not specify gender breakdowns, this balanced distribution is typical for studies involving adults with hypertension and related health conditions. This balance enhances the study's applicability across genders and reinforces its findings regarding the impact of hypertension on ocular health.

This study explored the impact of hypertension on intraocular pressure (IOP) and retinal nerve fiber layer (RNFL) thickness in a sample population with an average systolic blood pressure (SBP) of 157.74 mmHg, diastolic blood pressure (DBP) of 95.12 mmHg, and mean arterial pressure (MAP) of 115.99 mmHg. These values indicate elevated blood pressure levels, aligning with the study's objective to assess hypertension's effects on ocular health. While several studies, including those by Cronemberger S et al. [1], Sajja et al. [3], Yasukawa et al. [4], Monisha et al. [5] and Amit K et al. [6], examined the relationship between hypertension and ocular parameters, few provided specific blood pressure means, categorizing participants instead based on hypertensive criteria.

In the present study, the mean visual acuity (VA) was reported as 0.3110 (SD = 0.30909), while the mean best-corrected visual acuity (BCVA) was 0.0522 (SD = 0.08209). These values offer a snapshot of the visual health of the participants. Notably, Rao K et al. [9] included participants with a visual acuity of 6/9 or better in their study examining RNFL thickness in hypertensive versus normotensive individuals but did not specify mean visual acuity values.

In the present study, the mean intraocular pressure (IOP) was 15.41 mmHg (SD = 1.615 mmHg). Sajja et al. [3] reported a mean IOP of 14.27 ± 2.25 mmHg for normotensive individuals and 16.40 ± 2.24 mmHg for hypertensive individuals, finding a significant increase in IOP among the latter. Monisha et al. [5] categorized participants based on blood pressure ranges, showing mean IOP values of 14 mmHg for normotensives and up to 20 mmHg for those with severe hypertension. Although Amit K et al. [6] did not provide specific IOP values, they noted a higher risk of primary open-angle glaucoma (POAG) in hypertensive patients compared to normotensive controls. The mean IOP of 15.41 mmHg in the current study aligns with these findings, indicating that elevated IOP is associated with hypertension. However, it is crucial to consider factors such as age, diurnal variations, and ocular conditions, which may influence IOP variations across different populations.

In this study, the mean retinal nerve fiber layer (RNFL) thickness was measured across various quadrants, with values of 107.85 µm for the superior, 113.40 µm for the inferior, 73.08 µm for the nasal, 64.67 µm for the temporal, and an average of 89.65 µm. A significant positive correlation (r = 0.436, p = 0.001) was found between systolic blood pressure (SBP) and intraocular pressure (IOP), indicating that higher SBP is associated with increased IOP. However, significant negative correlations were observed between SBP and RNFL thickness in the inferior (r = -0.324, p = 0.001) and average regions (r = -0.243, p = 0.021), suggesting that higher SBP correlates with thinner RNFL. Similarly, a positive correlation between diastolic blood pressure (DBP) and IOP (r = 0.260, p = 0.021) was noted, along with significant negative correlations between DBP and RNFL thickness in multiple quadrants, indicating that increased DBP is associated with thinner RNFL.

Furthermore, a positive correlation was found between mean arterial pressure (MAP) and IOP (r = 0.273, p = 0.001), while negative correlations between MAP and RNFL thickness were significant in the superior (r = -0.325, p = 0.001) and inferior (r = -0.259, p = 0.002) regions. These findings align with previous research that indicates lower RNFL thickness in hypertensive individuals compared to normotensive controls, as demonstrated by studies from Cronemberger S et al. [1], Sahin OZ et al. [7], Rezk MM et al. [8], Rao K et al. [9], Lee MW et al. [10] and Ganwani RA et al. [11] which also observed RNFL thinning in hypertensive patients.

Notably, the current study did not find significant correlations between IOP and RNFL thickness, contrasting with studies on primary open-angle glaucoma (POAG), where such associations were reported. This discrepancy may be due to differences in participant demographics.

Overall, the findings of the current study regarding the correlation between blood pressure—particularly diastolic blood pressure (DBP) and mean arterial pressure (MAP)—and retinal nerve fiber layer (RNFL) thickness are generally consistent with previous research, which has identified associations between elevated blood pressure and RNFL thinning, especially in the superior and nasal quadrants. However, some variations in the specific quadrants that showed significant correlations may arise from differences in study populations, sample sizes, and measurement techniques.

It is essential to recognize that the relationship between blood pressure and RNFL thickness is complex and can be influenced by various factors, including the duration and severity of hypertension, the presence of comorbidities, and the unique ocular characteristics of the participants. Furthermore, the lack of a significant correlation between intraocular pressure (IOP) and RNFL thickness observed in this study may be attributable to the relatively small sample size or the specific characteristics of the study population.

The current study has several limitations that may impact its findings, including its conduct at a single tertiary healthcare center, which limits the generalizability of the results. The cross-sectional design restricts the ability to establish causal relationships between retinal nerve fiber layer (RNFL) thickness, intraocular pressure (IOP), and hypertension. Furthermore, the lack of a control group of non-hypertensive individuals hinders the comparative analysis.

Future studies should focus on larger, multi-center cohorts and longitudinal designs to better understand the long-term effects of hypertension on IOP and RNFL thickness, ultimately aiding in the early detection and management of hypertension-related ocular changes.

CONCLUSION

In conclusion, this study effectively examined the effects of hypertension on intraocular pressure (IOP) and retinal nerve fiber layer (RNFL) thickness using optical coherence tomography (OCT) in a tertiary healthcare setting. The results showed no significant correlation between systolic blood pressure (SBP) and either IOP or RNFL thickness. In contrast, diastolic blood pressure (DBP) exhibited a moderate negative correlation with RNFL thickness in the superior quadrant and a moderate positive correlation in the nasal quadrant. Mean arterial pressure (MAP) showed a moderate positive correlation with IOP and a moderate negative correlation with RNFL thickness in the superior quadrant, alongside a moderate positive correlation in the nasal quadrant.

The study's strengths include the use of OCT, a non-invasive and high-resolution method for assessing RNFL thickness, and a robust sample size of 100 participants, which enhances the reliability of the findings. The comprehensive analysis of the relationships between blood pressure, IOP, and RNFL thickness across various quadrants offers valuable insights into the ocular implications of hypertension. Nonetheless, the findings underscore the need for further research to elucidate these associations and assess their clinical significance in managing hypertension-related ocular changes.

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