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Relationship Between Blood Pressure and Intraocular Pressure in Patients at the Ophthalmology Clinic of Hospital X Jakarta, Indonesia

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Abstract

Background: Hypertension, a prevalent and often asymptomatic condition, has been associated with various ocular disorders. Ocular hypertension, in particular, is a notable risk factor for glaucoma. Understanding the relationship between systemic blood pressure and intraocular pressure is important for early detection of ocular hypertension and prevention of vision-threatening complications.

Objective: To analyze the relationship between blood pressure and intraocular pressure, as well as the association between hypertension and ocular hypertension.

Methods: This observational analytical study used secondary data from the medical records of 74 patients at the ophthalmology clinic of Hospital X Jakarta, collected between January and March 2023. The sample was selected using purposive sampling.

Results: Hypertension was observed in 30 individuals (41%), including 19 females (26%) and 11 individuals aged 70–79 years (15%). Ocular hypertension was reported in 17 individuals (23%), with ten (10) females (14%) and nine (9) individuals aged 60–69 years (12%). Chi-Square analysis showed a significant relationship between blood pressure and intraocular pressure, with a p-value of 0.004 ($p<\alpha=0.05$). In addition, Spearman's test showed correlations between systolic blood pressure and intraocular pressure in both the right eye ($r=0.395$; $p=0.001$) and the left eye ($r=0.290$; $p=0.012$). Additionally, there were correlations between diastolic blood pressure and intraocular pressure in the right eye ($r=0.234$; $p=0.045$) and the left eye ($r=0.230$; $p=0.049$).

Conclusion: The relationship between blood pressure and intraocular pressure is found to be significant in this study, suggesting that higher blood pressure levels are associated with an increased risk of elevated intraocular pressure.

Keywords: Blood pressure, hypertension, intraocular pressure, ocular hypertension.

Introduction

Cardiovascular pressure encompasses blood pressure, capillary hydrostatic pressure, and venous pressure. Blood pressure refers to arterial pressure, measured in millimeters of mercury (mmHg), and plays a crucial role in maintaining blood flow through the capillaries. According to the American Heart Association, normal blood pressure is typically around 120/80 mmHg.[1] A blood pressure reading of 140/90 mmHg or higher is classified as hypertension.[2] Globally, over 30% of the

population is affected by hypertension. In Indonesia, data from the 2018 Basic Health Research conducted by the Ministry of Health reports hypertension prevalence rate of 34.1%. The prevalence tends to increase with age, with a higher burden observed in individuals over 40 years old.[3] Hypertension is often asymptomatic, allowing it to silently damage organs and increase the risk of serious health complications before it is detected.[2]

Intraocular pressure refers to the fluid pressure within the eye, which is regulated by the balance between aqueous humor production and reabsorption, determining the total fluid volume and maintaining ocular stability.[1] Several factors contribute to the regulation of normal intraocular pressure, including aqueous humor production and the regulation of the blood-aqueous barrier, aqueous humor outflow dynamics, and episcleral venous pressure.[4] In a healthy eye, intraocular pressure remains constant at approximately 15 mmHg, ranging between 12 and 20 mmHg.[1] When the intraocular pressure exceeds 21 mmHg in the absence of optic disc abnormalities, visual field deficits, or indications of glaucomatous damage, the condition is classified as ocular hypertension. Epidemiological studies estimate that 4–7% of individuals over the age of 40 have ocular hypertension, with approximately 10% of those affected progressing to glaucoma within a decade.[5]

Glaucoma, a progressive optic neuropathy causing optic nerve damage, is regarded as one of the leading causes of blindness across the globe.[6]the critical risk factor for glaucoma, is generated and maintained by the aqueous humor circulation system. Aqueous humor is secreted from the epithelial layers of the ciliary body and exits the eye through the trabecular meshwork or the uveoscleral outflow pathways. IOP builds up in response to a resistance to aqueous humor flow in the trabecular outflow pathways. The trabecular outflow resistance is localized in the inner wall region, which comprises the juxtacanalicular connective tissue (JCT The Ocular Hypertension Treatment Study (OHTS) reported that heart disease is one of the factors significantly contributing to the progression of ocular hypertension to glaucoma.[5] The physiological mechanisms underlying this relationship remain an area of active research, but potential explanations include increased episcleral venous pressure due to elevated central venous pressure and fluctuations in intraocular pressure associated with systemic blood pressure changes.[7]IOP is known to vary throughout the 24-h period of a day, defined as a nyctohemeral rhythm in humans. In clinical practice, it is crucial to evaluate the changes in IOP over 24 h in several situations, including the diagnosis of ocular hypertension and glaucoma (IOP is often higher at night Additionally, chronic hypertension may lead to structural changes in the microvasculature of the eye, further contributing to the risk of optic nerve damage and glaucoma progression over time.[8]

Despite evidence of this association in other populations, data on the association between systemic blood pressure and intraocular pressure among Indonesian patients remain scarce. This study therefore aimed to examine the association between blood pressure and intraocular pressure, as well as the relationship between hypertension and ocular hypertension. It was hypothesized that elevated blood pressure would be significantly correlated with higher intraocular pressure and ocular hypertension.

Methods

The Ethics Committee of YARSI University has approved this study with the Ethical Research Approval Certificate No. 058/KEP-UY/EA.10/II/2024. This retrospective cross-sectional study used secondary medical record data from 74 patients at the ophthalmology clinic of Hospital X Jakarta between January and March 2023who met the predetermined inclusion and exclusion criteria. The inclusion criteria required all patients at the ophthalmology clinic to have undergone simultaneous blood pressure and intraocular pressure assessments. The exclusion criteria ruled out patients with diabetes mellitus, a history of topical steroid use within the past six weeks, or a history of intravitreal injections, as these conditions may independently affect intraocular pressure and confound the association under study. The sample was selected through purposive sampling, and data analysis involved univariate and bivariate techniques using IBM SPSS Statistics version 22.0. Both eyes were analyzed independently. No a priori sample size calculation or power analysis was performed, as all eligible patients within the study period were included. Hypothesis testing was carried out using the Chi-Square test with a significance level of $\alpha < 0.05$, while correlation testing was performed using the Spearman test.

Table 1 Summary of Blood Pressure Measurements in Patients (n=74)

Blood Pressure	Mean	Standard Deviation	Min.–Max.
Systolic	131.7	17.0	107.0 – 184.0
Diastolic	80.6	9.4	58.0 – 111.0

Mean, minimum, and maximum values are measured in mmHg

Table 3 Summary of Intraocular Pressure Measurements in Patients (n=74)

Intraocular Pressure	Mean	Standard Deviation	Min.–Max.
Right Eye	17.0	5.3	7.5 – 35.8
Left Eye	18.2	6.5	7.5 – 50.0

Mean, minimum, and maximum values are measured in mmHg.

Results

The total number of patient records from the ophthalmology clinic between January and March 2023 that met the inclusion and exclusion criteria was 74. Most patients were female, 43 individuals (58%), while 31 were male (42%). Patients' ages were grouped into the following ranges: 40–49 years, 50–59 years, 60–69 years, 70–79 years, and 80–89 years. The largest group was those aged 60–69 years, with 34 individuals (46%), while the smallest groups were those aged 40–49 years and 90–99 years, with only two individuals (3%) in each group.

Table 1 summarizes blood pressure measurements, with a mean systolic pressure of 131.7 mmHg, a standard deviation of 17, and a range of 107 to 184 mmHg. Mean diastolic pressure was 80.6 mmHg, with a standard deviation of 9.4, ranging from 58 to 111 mmHg.

Blood pressure measurements were then categorized into hypertensive and non-hypertensive groups, with hypertension defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg. Table 2 classifies patients based on their hypertension status, showing that among the 30 hypertensive individuals, 19 (26%) were female. The Chi-Square test found no significant association between gender and hypertension (p=0.452), and Spearman correlation analysis showed no significant association between gender and systolic (r=0.075, p=0.524) or diastolic blood pressure (r=-0.026, p=0.824). Similarly, 11 (15%) of hypertensive patients were aged 70–79 years, but Chi-Square analysis (p=0.077) and Spearman correlation tests (systolic: r=0.020, p=0.866; diastolic: r=0.046, p=0.694) showed no significant association with age.

Table 3 summarizes intraocular pressure measurements, with an average of 17.0 mmHg

Table 2 Classification of Patients Based on Hypertension Status (n=74)

Characteristic	Hypertension				p-value
	Yes		No		
	(n=30)	%	(n=44)	%	
Gender					
Male	11	15	20	27	0.452
Female	19	26	24	32	
Age (Years)					
40–49	2	3	0	0	
50–59	4	5	4	5	
60–69	9	12	25	34	0.077
70–79	11	15	14	19	
80–89	2	3	1	1	
90–99	2	3	0	0	
Total	30	41	44	59	

The p-value is obtained from the Chi-Square test

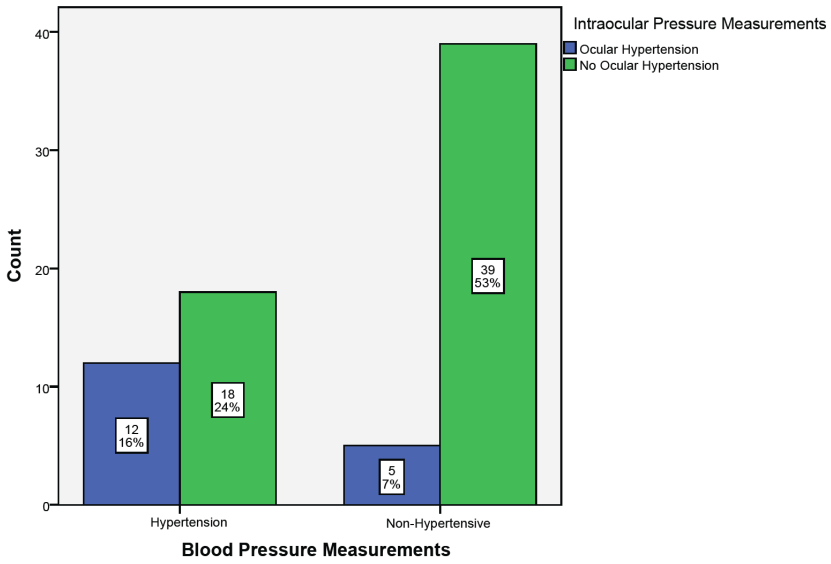

Fig. 1 Distribution of Ocular Hypertension Across Hypertensive and Non-Hypertensive Patients at Hospital X Jakarta

and a standard deviation of 5.3 in the right eye, while the left eye had an average of 18.2 mmHg and a standard deviation of 6.5. Intraocular pressure ranged from 7.5 to 35.8 mmHg in the right eye and 7.5 to 50.0 mmHg in the left eye.

Intraocular pressure measurements were then categorized into ocular hypertension and no ocular hypertension, with ocular hypertension defined as an intraocular pressure exceeding 21 mmHg in either eye. Table 4 classifies patients based on ocular hypertension status, showing that of the 17 individuals (23%) with ocular hypertension, 10 (14%) were female. The Chi-Square test showed no significant association between gender and intraocular pressure (p=0.946), and Spearman correlation analysis found no significant association for the right eye (r=-0.080, p=0.501) or left eye (r=-0.041, p=0.730). Similarly, 9 individuals (12%) with

Table 4 Classification of Patients Based on Ocular Hypertension Status (n=74)

Characteristic	Ocular Hypertension				p-value
	Yes		No		
	(n=17)	%	(n=57)	%	
Gender					
Male	7	9	24	32	0.946
Female	10	14	33	45	
Age (Years)					
40–49	2	3	0	0	
50–59	1	1	7	9	
60–69	9	12	25	34	0.080
70–79	4	5	21	28	
80–89	0	0	3	4	
90–99	1	1	1	1	

The p-value is obtained from the Chi-Square test

ocular hypertension were aged 60–69, but Chi-Square analysis (p=0.080) and Spearman correlation tests (right eye: r=-0.054, p=0.650; left eye: r=-0.025, p=0.835) showed no significant association with age.

The association between blood pressure and intraocular pressure, as presented in Table 5 and Fig. 1, was analyzed using the Chi-Square test and a p-value of 0.004 was achieved ($p<\alpha=0.05$). Additionally, a Spearman test was performed to evaluate the strength of the correlation between systolic blood pressure and intraocular pressure for both the right eye (r=0.395; p=0.001) and the left eye (r=0.290; p=0.012), as well as between diastolic blood pressure and intraocular pressure for the right eye (r=0.234; p=0.045) and the left eye (r=0.230; p=0.049).

Discussion

Blood pressure and intraocular pressure are two important physiological parameters that influence cardiovascular and ocular health, respectively. Hypertension is a well-established risk factor for systemic vascular complications, while elevated intraocular pressure is a primary concern in the development of glaucoma. Several studies have explored the association between these two conditions, yet findings remain inconclusive due to variations in study populations, methodologies, and physiological compensatory mechanisms. In this study, the association between blood pressure and intraocular pressure was analyzed in an Indonesian clinical cohort to provide further insights into their association and its implications for ocular health.

This study found an average systolic blood pressure of 131.7 mmHg, which is higher than the normal average systolic pressure of 120 mmHg as proposed by the American Heart Association, while the diastolic pressure of 80.6 mmHg remains within the normal range. This finding is expected, as the study population consists of individuals aged 40 to 99 years, a range that falls within middle and older age, where blood pressure typically increases due to age-related vascular changes. These results align with Karayiannis's 2022 theory, which suggests that systolic blood pressure rises with age due to reduced arterial elasticity. As arteries stiffen, the aortic reservoir's ability to expand and store blood diminishes, leading to higher systolic pressure and lower diastolic pressure.[9]and age alone may not best reflect underlying risk. Therefore, an individualised approach to management of hypertension in the older person is required. Such an approach requires knowledge of frailty, the physiology of hypertension and ageing and a contextual understanding of best evidence. Management needs to be holistic and take account of the older person's care needs, wishes and priorities. This review describes physiological considerations and current guidelines and best practices regarding BP lowering in older people and highlights areas with paucity of evidence. A proposed and testable approach to managing hypertension in the older person (≥70 years.

Hypertension was more common in this study among women and older adults, aligning with Oparil's findings that it is more prevalent in older women (aged 65 and above) than in men. In younger women, endogenous estrogen provides protection against hypertension by supporting vascular function. However, as estrogen levels decline with age, women become more susceptible to hypertension and its associated cardiovascular complications. Women's higher hypertension rates may also be partly due to better awareness, treatment, and control of hypertension, whereas men may remain undiagnosed.[10]

No significant association was found between gender, age, and blood pressure in this study, as indicated by the Chi-Square test ($p>0.05$). Spearman correlation also showed a very weak, insignificant association between gender, age, and both systolic and diastolic blood pressure. Similarly, Supriyono and Andriyanto reported no significant association between gender (p=0.172) or age (p=0.961) and blood pressure in a sample of 30 individuals aged 31 to 55 years in the Training of Healthy Family Trainers program.[11]the prevalence of hypertension is still high at 25.8%, so hypertension is still one of the public health problems in Indonesia objectives.

This study aims to determine the relationship of characteristics (age, gender, and level of education In contrast, a 2024 prospective observational study by Hussainy at Osmania General Hospital, Hyderabad, involving 150 patients over six months, found a significant association between age (p=0.000) and gender (p=0.012) with hypertension.[12]

These differences may be due to population characteristics, as this study was conducted in an ophthalmology clinic rather than a general population setting. Additionally, the variability in age distribution and smaller sample size may have reduced statistical power, limiting the ability to detect significant associations.

In this study, intraocular pressure

measurements showed a higher average in the left eye (18.2 mmHg) than in the right eye (17.0 mmHg). Similarly, a 2022 cross-sectional study by Hoffmann *et al*. in Germany found greater intraocular pressure in the left eye (14.9±2.9 mmHg) than in the right eye (14.8±2.9 mmHg).[13] Intraocular pressure is often higher in the first measured eye, whether right or left, possibly due to mild ocular squeezing during tonometry.[14]

Ocular hypertension in this study was more frequently observed in females and individuals aged 60–69, similar to Hoffmann's findings, which reported higher intraocular pressure in females and older adults in a study of individuals aged 35–74.[13] Some studies suggest this may be linked to post menopause, as hormonal changes during this period can influence intraocular pressure. Furthermore, the higher proportion of body fat in females, along with postmenopausal hormonal changes, may contribute to age-related intraocular pressure fluctuations.[15] A meta-analysis of cohort studies in Europe also reported an inverted U-shaped trend, where intraocular pressure peaks around 60 years before declining.[16]Chinese, and whites. Design: Cross-sectional study. Methods: We prospectively recruited phakic nonglaucomatous participants (based on intraocular pressure < 21 mm Hg, normal optic nerve head and retinal nerve fiber, and cup-to-disc ratio < 0.6 No significant association was found between gender and intraocular pressure in this study, as indicated by Chi-Square and Spearman correlation tests. Age also showed no significant correlation, with weak negative associations in both eyes. Similarly, Yassin found no significant association between gender (p=0.268) and age (p=0.748) with intraocular pressure in a study of 458 healthy Saudi individuals.[17] In contrast, Hoffmann's 2022 study found a weak but significant association between female gender and higher intraocular pressure (p=0.05), while age had a strong positive correlation (p<0.001), suggesting intraocular pressure increases with age.[13] The differences in findings may be due to population characteristics, as this study was conducted in an ophthalmology clinic, where pre-existing eye conditions could influence intraocular pressure.

Blood pressure and intraocular pressure in this study showed a significant association according to the Chi-Square test analysis (p=0.004). The Spearman test shows that systolic blood pressure significantly correlates with intraocular pressure in the right eye (r=0.395; p=0.001) and left eye (r=0.290; p=0.012), with a positive correlation direction and weak strength. Diastolic blood pressure also significantly correlates with intraocular pressure in the right eye (r=0.234; p=0.045) and left eye (r=0.230; p=0.049), with a positive correlation direction and weak strength. Both test results indicate that higher blood pressure levels are modestly associated with increased intraocular pressure, supporting previous observations that elevated systemic blood pressure may contribute to ocular hypertension and risk of glaucoma. A comparable observation was carried out by Rofiq *et al*., showing a notable association between blood pressure and increased intraocular pressure in 115 patients at Primasatya Husada Citra Hospital (p=0.000), indicating that higher blood pressure increases the risk of elevated intraocular pressure.[18] In line with these findings, Baek *et al*. demonstrated that systolic blood pressure significantly correlates with intraocular pressure (p<0.001), whereas diastolic blood pressure showed no significant correlation (p=0.05).[15] A meta-analysis by Zhao also reported a consistent association, showing a 0.26 mmHg rise in intraocular pressure for every 10 mmHg increase in systolic blood pressure and a 0.17 mmHg increase for every 5 mmHg rise in diastolic blood pressure.[19]

Several theories explain the complicated interplay between blood pressure and intraocular pressure. Rubenstein *et al*. stated that intraocular pressure is maintained by aqueous humor production from the ciliary process and influenced by episcleral venous pressure, with Schlemm's canal draining blood into the ophthalmic vein, cavernous sinus, and internal jugular vein. The Goldmann equation defines intraocular pressure as:

Where IOP is intraocular pressure (mmHg), F is the rate of aqueous humor formation (μL/min), C is the drainage rate of aqueous humor (μL/min/mmHg), and EVP is episcleral venous pressure (mmHg).[20] This equation highlights the role of aqueous humor dynamics and episcleral venous pressure in maintaining intraocular pressure balance.

Aptel *et al*. further explained that any change in systemic blood pressure directly affects intraocular pressure. A 10 mmHg increase in systolic blood pressure results in about a 1 mmHg rise in intraocular pressure.[7]IOP is known to vary throughout the 24-h period of a day, defined as a nyctohemeral rhythm in humans. In clinical practice, it is crucial to evaluate the changes in IOP over 24 h in

several situations, including the diagnosis of ocular hypertension and glaucoma (IOP is often higher at night Furthermore, Tobin and Weaver added that while arterial pressure does not directly impact intraocular pressure changes, approximately 30% of a rise in systolic blood pressure can be reflected in intraocular pressure.[21] It has been postulated that increased blood pressure raises ciliary artery pressure, enhancing ultrafiltration of aqueous humor and thereby increasing intraocular pressure.[15] This suggests that systemic blood pressure fluctuations, particularly increases in systolic pressure, may contribute to intraocular pressure regulation despite their indirect nature.

Beyond systemic blood pressure, central venous pressure also plays a crucial role in intraocular pressure regulation. An increase in central venous pressure affects aqueous humor drainage, leading to a rise in intraocular pressure by approximately 0.8 mmHg for each 1 mmHg increase. Similar effects occur with the Valsalva maneuver, coughing, or straining, which increases central venous pressure and subsequently intraocular pressure.[7]IOP is known to vary throughout the 24-h period of a day, defined as a nyctohemeral rhythm in humans. In clinical practice, it is crucial to evaluate the changes in IOP over 24 h in several situations, including the diagnosis of ocular hypertension and glaucoma (IOP is often higher at night Tobin and Weaver also emphasized that increased central venous pressure due to factors such as the Trendelenburg position, coughing, or elevated intrathoracic pressure can weaken aqueous humor drainage from the eye.[21] Central venous pressure, which shows heart preload, is influenced by venous blood volume and compliance.[22]

These findings indicate that fluctuations in venous pressure directly influence intraocular pressure. Tan *et al*. also noted that high systemic blood pressure increases the risk of glaucoma by elevating episcleral venous pressure, which reduces aqueous outflow.[23] Systemic hypertension further contributes to ocular hypertension and optic nerve vulnerability by reducing perfusion pressure at the optic nerve head and impairing capillary blood flow through increased vascular resistance and endothelial dysfunction.[24]as both are aging-related diseases. Yet, the pathogenesis of glaucoma is not entirely elucidated and the interplay between intraocular pressure, arterial blood pressure (BP[25] Over time, these changes compromise the eye's ability to maintain stable perfusion, and the inverse relationship between intraocular pressure and perfusion pressure further restricts optic nerve blood supply, potentially accelerating glaucomatous damage. [8]

A limitation of this study is that a significant portion of the initial patient records did not meet the inclusion criteria, reducing the sample size available for analysis. Many records were excluded due to incomplete data and the lack of simultaneous blood pressure and intraocular pressure measurements. Additionally, the reliance on paper-based medical records posed a potential risk to data accuracy, as manual data extraction increases the likelihood of errors. The retrospective cross-sectional design, small sample size (n=74), and purposive sampling limit generalizability and control over confounders, including diabetes, steroid use, medications, and lifestyle factors. Both eyes were analyzed independently, which may introduce intra-subject correlation. These limitations suggest that, although statistical significance was achieved, the findings should be interpreted with caution and may not fully represent broader clinical populations.

According to the results discussed, the conclusion is as follows: this study demonstrates a statistically significant but weak correlation between blood pressure and intraocular pressure in an Indonesian clinical cohort. While higher blood pressure may increase the risk of ocular hypertension, causality cannot be inferred due to the retrospective cross-sectional design. Despite international evidence linking blood pressure and intraocular pressure, local Indonesian ophthalmologic research data are scarce, and this study addresses that gap. Given the study limitations, and with caution in interpreting the results, this study provides preliminary evidence that elevated blood pressure is associated with higher intraocular pressure in Indonesian patients, supporting the rationale for routine intraocular pressure monitoring among hypertensive individuals and informing integrated care strategies aimed at early detection of glaucoma risk.

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