Council Lecture

Comparison of ocular perfusion pressure in primary open angle glaucoma patients and non-glaucoma controls attending ophthalmology clinic in Aminu Kano Teaching Hospital, Kano

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ABSTRACT

Purpose: To compare ocular perfusion pressures (OPP) in primary open angle glaucoma (POAG) patients with age and sex-matched non-glaucoma controls and explore the relationship between the level of OPP and glaucoma.

Methods: In this cross-sectional comparative study, consecutive patients newly diagnosed with POAG at a tertiary hospital in northern Nigeria, along with age and sex-matched controls were selected and had detailed ocular examinations including intraocular pressure (IOP) and blood pressure measurements (systolic blood pressure, [SBP] and diastolic blood pressure, [DBP]) taken. The following were calculated: Mean ocular perfusion pressure (MOPP), Systolic ocular perfusion pressure (SOPP) and Diastolic ocular perfusion pressure (DOPP). The data was managed using IBM SPSS statistics version 20. T-test was used to determine the association between OPP and glaucoma. Level of significance was set at $p<0.05$.

Results: The mean IOP was significantly higher in POAG subjects (26.15mmHg ± 12.47 in POAG versus 13.10mmHg ± 3.10 in controls, p=<0.001). The MOPP (37.42 ± 12.37mmHg in the POAG group versus 48.05 ± 5.24mmHg in the control group, p<0.001), SOPP (97.03 ± 14.80mmHg in POAG group versus 105.09 ± 9.96mmHg in control group, p< 0.001) and DOPP (54.79 ± 12.93mmHg in POAG group versus 64.91 ± 7.46mmHg in control group, p< 0.001) were all significantly lower in the POAG group.

Conclusion: This study shows that MOPP, SOPP, and DOPP were all significantly lower in POAG patients compared to the control group. There is a need for further research to determine optimal ocular perfusion pressures that reduce the risk of glaucomatous damage.

Keywords: Glaucoma, ocular perfusion pressure, comparison

INTRODUCTION

Glaucoma represents a group of diseases defined by a characteristic optic neuropathy that is consistent with the remodeling of the connective tissue elements of the optic nerve head and with loss of neural tissue associated with the eventual development of distinctive patterns of visual dysfunction. [1] It is a disease of public health importance and the commonest cause of irreversible blindness accounting for 8% of all blindness (approximately 3.15 million blind people) in 2010[2], 2.9 million blind people in 2015 and 3.2 million blind people in 2020.[3] Primary open angle glaucoma (POAG) is defined by an open, normal-appearing anterior chamber angle, typically with elevated intraocular pressure (IOP), with no other underlying disease.[1] A 2021 estimate of

68.56 million (95% CI 59.99 ~ 79.98) people worldwide are affected by POAG with a global prevalence of 2.4% (95% CI 2.0 ~ 2.8%) in the last 20 years.[4]

Theories on the pathogenesis of glaucomatous optic neuropathy include mechanical and vascular theories. The vascular theory considers glaucomatous optic neuropathy to be a consequence of insufficient blood supply or other risk factors that diminish the ocular blood flow (OBF) which constitute problems in vascular auto-regulation.

The high prevalence and high rate of blindness make glaucoma a public health concern and a priority among healthcare planners and policymakers with an emphasis on the need for glaucoma care pathways for early detection and treatment to prevent blindness.[5]

Several studies[6-11] have implicated various vascular risk factors in the pathogenesis of glaucoma, of which blood pressure (BP) and ocular perfusion pressure (OPP) were the most studied. This vascular hypothesis is based on the theory that abnormal perfusion and the subsequent ischemia of the optic nerve head play a major role in the glaucomatous damage.[12]

Amongst many risk factors associated with POAG, raised intraocular pressure is the one measured and targeted for treatment. However, many patients with apparently "adequate" intraocular pressure control still show ongoing vision loss. Other than IOP, blood pressure and ocular perfusion pressure have been the most studied risk factors for POAG. [13] Ocular perfusion pressure and ocular blood flow (OBF) in POAG have been found to be reduced in some studies[14-16] carried out worldwide. Similarly, lower mean ocular perfusion pressure (MOPP) was found in POAG patients in studies[17-19] in South-west and South-eastern Nigeria. However, Omoti[20] found higher systolic ocular perfusion pressures (SOPP) in POAG patients. There exists paucity of such studies in North-west Nigeria.

Monitoring of OPP when coupled with the evaluation of macula and optic nerve head (ONH), retinal nerve fibre layer (RNFL) and ganglion cell complex (GCC) thickness, may alert physicians to possible glaucomatous damage.[21]

Findings from this study can therefore be used to suggest modification of vascular risk factors that influence ocular perfusion. The aim of the study was to assess ocular perfusion pressure levels as a risk factor for glaucoma by comparing the ocular perfusion pressures in non-glaucoma and newly diagnosed primary open angle glaucoma patients attending Aminu Kano Teaching Hospital, Kano, Nigeria and to explore the association between the levels of ocular perfusion pressure and primary open angle glaucoma.

METHODS

This was a hospital-based cross sectional (comparative) study carried out at the Ophthalmology clinics of the Aminu Kano Teaching Hospital (AKTH), Kano, Nigeria. Data was collected over a six-month period (December 2022 to June 2023).

Newly diagnosed POAG patients and age- and sex-matched (non-glaucoma patients and hospital staff) controls attending ophthalmology clinic in Aminu Kano Teaching Hospital were recruited into the study. The inclusion criteria were: age $\geq$18 years; newly diagnosed patients with primary open angle glaucoma, based on vertical cup–disc-ratio (VCDR $\geq$ 0.7), intraocular pressure, glaucomatous visual field defects and open anterior chamber angles on gonioscopy; and absence of identifiable secondary causes of open angle glaucoma.

Patients with ocular comorbidities such as features of diabetic retinopathy, hypertensive retinopathy, optic neuropathy, etc. were excluded from participation. In addition, patients with angle closure glaucoma, or a history of systemic diseases like hypertension, diabetes, sickle-cell disease etc. were excluded. Also excluded were patients on antihypertensive medications and patients who had undergone previous ocular surgery.

Consecutive newly diagnosed POAG patients and controls who fulfilled the inclusion criteria were recruited, briefed and a written informed consent obtained. Bio-data, clinical history and relevant systemic and ocular examination were carried out including: visual acuity (VA) assessment in each eye; anterior segment examination to examine the conjunctiva, cornea, anterior chamber, iris, pupil and lens; dilated fundus examination with the use of a 78D lens to assess the optic disc color and outline, vertical cup to disc ratio, optic disc vessels and neuro-retinal rim, retina blood vessels and macula; intraocular pressure measurement and gonioscopy.

Blood pressure measurement was performed using the mercury sphygmomanometer with the patient sitting comfortably upright, back supported and legs uncrossed, sphygmomanometer cuff of appropriate size on the supported left arm and mercury column at the level of the heart. A participant was considered hypertensive if systolic blood pressure readings on two separate days were $\geq$140 mmHg and/or the diastolic blood pressure readings on two separate days were $\geq$90 mmHg.

Intraocular pressure was measured using Goldmann applanation tonometer (GAT) following instillation of topical 1% amethocaine and staining of tear film with fluorescein dye. Patient's head was placed properly on the chin and head rest of the slit lamp with patient looking straight ahead and breathing normally. Goldmann applanation tonometer head placed on the apex of the cornea and semicircular mires visualized under cobalt blue light was adjusted to give centralized mires with appropriate thickness, and applanation pressure gradually applied by rotation of the dial till the inner margins of the mires align. Pressure at this point was read off the dial and multiplied by 10 to get the intraocular pressure in mmHg.

Mean ocular perfusion pressure (MOPP), Diastolic ocular perfusion pressure (DOPP), Systolic ocular perfusion pressure (SOPP) were calculated as follows[9, 13]:

MOPP =2/3Mean arterial pressure (MAP) – Intraocular pressure (IOP)

where MAP=Diastolic blood pressure (DBP)+1/3 pulse pressure (PP),

PP being Systolic blood pressure (SBP)-DBP

DOPP =DBP-IOP

SOPP =SBP-IOP

Standard automated perimetry was performed by a nurse assistant using the Humphrey visual field analyzer to confirm diagnosis and parameters noted in the questionnaire.

All findings were recorded in the data collection form and patients received appropriate further clinical management.

Data analysis: All data collected was entered and analyzed using the IBM SPSS Statistics for windows version 20. Socio-demographic variables of respondents were summarized using frequencies, percentages, mean and standard deviation.

Ocular Perfusion Pressure (OPP) was summarized using mean and standard deviation in both glaucoma and non-glaucoma patients. The student's t-test was used to determine significant differences between mean levels of ocular perfusion pressure, intraocular pressure and blood pressure among glaucoma and non-glaucoma patients. Chi-square tests and the Fisher's exact test were used as appropriate to analyze factors associated with OPP. In all tests of significance, $p<0.05$ was considered statistically significant.

Ethical considerations: Ethical approval for the study was obtained from Aminu Kano Teaching Hospital Health Research-Ethics Committee. An information sheet about glaucoma and its evaluation was given to the patients. The participants were given information on the examinations to be carried out, the parameters to be calculated from data gotten and its importance to patients' management. The informed written consent form was given to literate respondents to sign before the questionnaire was administered. For those who could not read and write, details of the consent form were explained to them by the researcher and they subsequently appended their thumbprint to the form to

indicate consent. Confidentiality of patients' details was maintained. Patients' names were not included in the questionnaires, rather codes were used (identification numbers) and personal data kept strictly confidential. The Helsinki declaration was upheld throughout the research.

RESULTS

Sociodemographic characteristics

A total of 160 participants were studied (Table 1), consisting of 80 POAG patients and 80 age and sex-matched controls. The mean age of the participants was 46.25±17.22 years in the POAG group and 46.74±16.82 years in the control group. There were 94 male and 66 female participants, giving a male:female ratio of 1.42:1. Majority of the participants in the control group had tertiary level of education, 47 (58.8%); while in the glaucoma group, 50 (62.5%) participants had less than tertiary level of education. Among the glaucoma participants, 37 (46.2%) participants were self-employed, while 28 (35.0%) of the controls were civil servants. The differences in the distribution of the educational level and occupation between the two groups were statistically significant (Table 1).

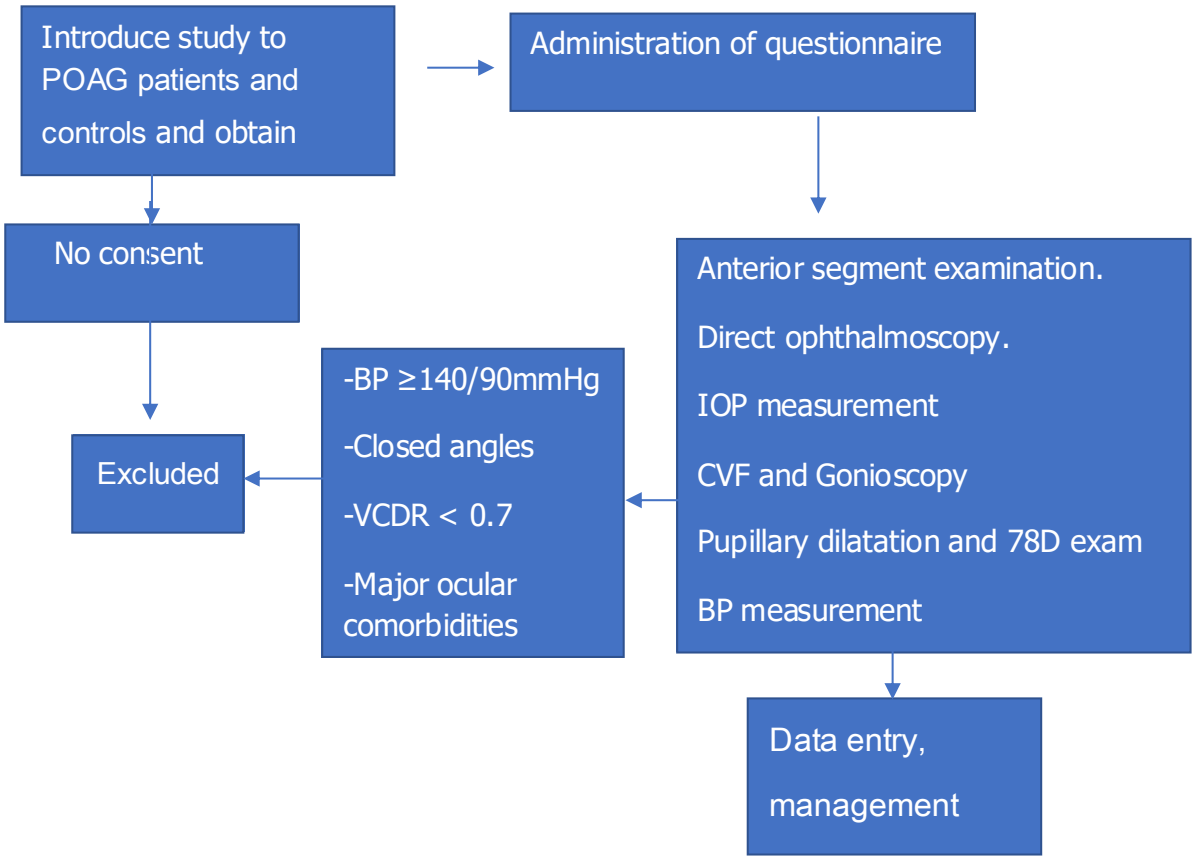

Figure 1: Study flow chart

Table 1. Comparison of socio-demographic characteristics of POAG patients and non-POAG controls.

Variable	Glaucoma n=80 (%)	Non-glaucoma n=80 (%)	Total N=160 (%)	χ^2	*p*-value
Age (years)					
< 20	4 (5.0)	4 (5.0)	8 (5.0)	0.313[F]	1.000
20 – 39	23 (28.8)	24 (30.0)	47 (29.4)		
40 – 59	36 (45.00)	36 (45.0)	72 (45.0)		
60 – 79	13 (16.2)	13 (16.2)	26 (16.2)		
≥ 80	4 (5.0)	3 (3.8)	7 (4.4)		
Mean ± SD	46.25±17.22	46.74±16.82		-0.181	0.856
Range	18 – 92	18 – 90			
Sex					
Male	46 (57.5)	48 (60.0)	94 (58.8)	0.103	0.748
Female	34 (42.5)	32 (40.0)	66 (41.2)		
Occupation					
Civil servant	12 (15.0)	28 (35.0)	40 (25.0)	9.016	**0.029***
Self employed	37 (46.2)	25 (31.2)	62 (38.8)		
Unemployed	19 (23.8)	17 (21.2)	36 (22.5)		
Others	12 (15.0)	10 (12.5)	22 (13.8)		
Religion					
Islam	73 (91.2)	78 (97.5)	151 (94.4)	2.943[F]	0.167
Christianity	7 (8.8)	2 (2.5)	9 (5.6)		
Marital status					
Single	15 (18.8)	14 (17.5)	29 (18.1)	0.239[F]	0.919
Married	60 (75.0)	62 (77.5)	122 (76.2)		
Widowed	5 (6.2)	4 (5.0)	9 (5.6)		
Education					
No formal education	13 (16.2)	6 (7.5)	19 (11.9)	13.979	**0.007***
Primary school	14 (17.5)	4 (5.0)	18 (11.2)		
Secondary school	21 (26.2)	23 (28.7)	44 (27.5)		
Tertiary	30 (37.5)	47 (58.8)	77 (48.1)		
Others	2 (2.5)	0 (0.0)	2 (1.2)		
Ethnicity					
Hausa	72 (90.0)	69 (86.2)	141 (88.1)	3.125[F]	0.389
Igbo	3 (3.8)	2 (2.5)	5 (3.1)		
Yoruba	1 (1.2)	0 (0.0)	1 (0.6)		
Others	4 (5.0)	9 (11.2)	13 (8.1)		

χ^2: Chi Square test; F: Fisher's exact test

**: p value <0.05 (i.e., statistically significant)*

Mean ocular perfusion pressure among POAG and control groups

The mean ocular perfusion pressure (± standard deviation) was 37.42 ± 12.37 right eye (RE) and 39.08 ±10.03 left eye (LE) in the POAG group; and 48.05 ±5.24 RE and 47.93± 5.20 LE in the control group (Table 2).

perfusion pressure groups and diastolic ocular perfusion pressure between POAG and control groups in the right eyes, and similar differences in the left eyes. IOP was significantly higher in POAG group while MOPP, SOPP and DOPP were significantly lower in the POAG group compared to controls.

Table 2: Mean ocular perfusion pressure of POAG and control groups

Parameter	POAG group	Non-POAG group
Right eye MOPP (mmHg)		
Mean ± SD	37.42 ± 12.37	48.05 ± 5.24
Median (IQR)	39.29 (29.06 – 45.81)	48.10 (43.58 – 52.18)
Range	6.04 – 70.02	36.04 – 59.13
Left eye MOPP (mmHg)		
Mean ± SD	39.08 ± 10.93	47.93 ± 5.20
Median (IQR)	40.73 (31.47 – 46.46)	47.60 (44.44 – 51.76)
Range	14.89 – 57.35	34.04 – 59.13

SD: Standard deviation IQR: Interquartile range

Comparison of the IOP and ocular perfusion pressures between POAG patients and controls

This study revealed statistically significant differences (Table 3) in the mean IOP, mean ocular perfusion pressure, systolic ocular

Comparison of other continuous variables between POAG patients and controls

Mean deviation was significantly more negative in the POAG group compared to controls (Table

Table 3: Comparison of IOP and perfusion pressures between POAG patients and controls

Variable	POAG Mean± SD (mmHg)	Controls Mean± SD (mmHg)	t	*p* value
Right eye				
Intraocular pressure	26.15 ± 12.47	13.10 ± 3.10	9.085	**<0.001***
Mean Ocular Perfusion Pressure	37.42 ± 12.37	48.05 ± 5.24	-7.079	**<0.001***
Systolic Ocular Perfusion Pressure	97.03 ± 14.80	105.09 ± 9.96	-4.042	**<0.001***
Diastolic Ocular Perfusion Pressure	54.79 ± 12.93	64.91 ± 7.46	-6.067	**<0.001***
Left eye				
Intraocular pressure	24.49 ± 10.99	13.23 ± 3.09	8.825	**<0.001***
Mean Ocular Perfusion Pressure	39.08 ± 10.93	47.93 ± 5.20	-6.538	**<0.001***
Systolic Ocular Perfusion Pressure	98.69 ± 13.56	104.96 ± 9.89	-3.344	**0.001***
Diastolic Ocular Perfusion Pressure	56.45 ± 11.61	64.79 ± 7.45	-5.404	**<0.001***

t: Independent Samples T test;

**p value <0.05 (i.e., statistically significant)*

4). Pattern standard deviation, Systolic BP and diastolic BP were all significantly higher in the POAG group.

Table 4: Comparison of other continuous variables between POAG patients and controls

Variable	POAG	Non-glaucoma	t	*p* value
Mean deviation RE (dB)	-4.69 ± 9.01	-0.05 ± 0.43	-4.605	**<0.001***
Mean deviation LE (dB)	-4.81 ± 9.54	-0.04 ± 0.37	-4.468	**<0.001***
PSD RE (dB)	2.16 ± 3.63	0.02 ± 0.21	5.260	**<0.001***
PSD LE (dB)	2.28 ± 5.50	0.02 ± 0.19	3.673	**<0.001***
Systolic BP (mmHg)	123.18 ± 9.93	118.19 ± 10.18	3.137	**0.002***
Diastolic BP (mmHg)	80.94 ± 6.44	78.01 ± 6.85	2.783	**0.006***
PP (mmHg)	42.24 ± 9.16	40.18 ± 9.05	1.433	0.154

t: Independent Samples T test
**p value <0.05 (i.e., statistically significant)*
RE: Right eye
LE: Left eye
IOP: intraocular pressure
PSD: pattern standard deviation
PP: pulse pressure

Relationship between ocular perfusion pressure, IOP and BP in the POAG and control groups

In both the POAG and control groups, there was a negative correlation of MOPP with IOP and mean deviation. Also, there was a positive correlation of MOPP with systolic ocular perfusion pressure (SOPP), diastolic ocular perfusion pressure (DOPP), systolic blood pressure (SBP) diastolic blood pressure (DBP), pulse pressure (PP) and pattern standard deviation (PSD). (Tables 5 and 6).

Table 5: Correlation of mean ocular perfusion pressure with other study variables among POAG group

Variable	MOPP RE		MOPP LE	
	r	*p* value	r	*p* value
IOP	-0.939	**<0.001***	-0.922	**<0.001***
Mean deviation	-0.145	0.203	-0.111	0.337
PSD	0.159	0.163	0.154	0.179
SOPP	0.884	**<0.001****	0.860	**<0.001****
DOPP	0.968	**<0.001****	0.960	**<0.001****
Systolic BP	0.138	0.224	0.154	0.173
Diastolic BP	0.125	0.269	0.159	0.159
PP	0.061	0.589	0.055	0.627

r: Pearson Correlation coefficient
IOP: Intraocular pressure
MOPP: mean ocular perfusion pressure
DOPP: diastolic ocular perfusion pressure
SOPP: systolic ocular perfusion pressure
PSD: Pattern standard deviation
PP: Pulse pressure
** Statistically significant negative correlation of MOPP with IOP*
*** Statistically significant positive correlation of MOPP with SOPP and DOPP*

Table 6: Correlation of mean ocular perfusion pressure with other study variables among the non-POAG controls

Variable	MOPP RE		MOPP LE	
	r	*p* value	r	*p* value
IOP	-0.484	**<0.001***	-0.476	**<0.001***
Mean deviation	-0.118	0.296	-0.035	0.759
PSD	0.118	0.296	0.035	0.759
SOPP	0.751	**<0.001***	0.744	**<0.001***
DOPP	0.923	**<0.001***	0.924	**<0.001***
Systolic BP	0.588	**<0.001***	0.578	**<0.001***
Diastolic BP	0.786	**<0.001***	0.791	**<0.001***
PP	0.066	0.559	0.052	0.646

r: Pearson Correlation coefficient
****: p value <0.05 (i.e., statistically significant)***
IOP: Intraocular pressure
MOPP: mean ocular perfusion pressure
DOPP: diastolic ocular perfusion pressure
SOPP: systolic ocular perfusion pressure
PSD: Pattern standard deviation
PP: Pulse pressure

Relationship between IOP and BP in the POAG and control groups

IOP in POAG group: there was a weak positive relationship of intraocular pressure (IOP) with systolic blood pressure (SBP), which was not significant (Pearson's correlation coefficient, r=0.142, p=0.21 RE; r=0.163, p=0.149 LE) (Figure 2). Similarly, a weak positive relationship is shown between IOP and diastolic BP (r=0.021, p=0.855 RE; r=0.193, p=0.086 LE) (Figure 3).

IOP in Control group: a significant weak positive relationship was however demonstrated with SBP (r=0.221, p=0.049 RE; r=0.244, p=0.029 LE) (Figure 4) but no relationship demonstrated between IOP and DBP (r=0.021, p=0.855 RE; r=0.021, p=0.855 LE) (Figure 5).

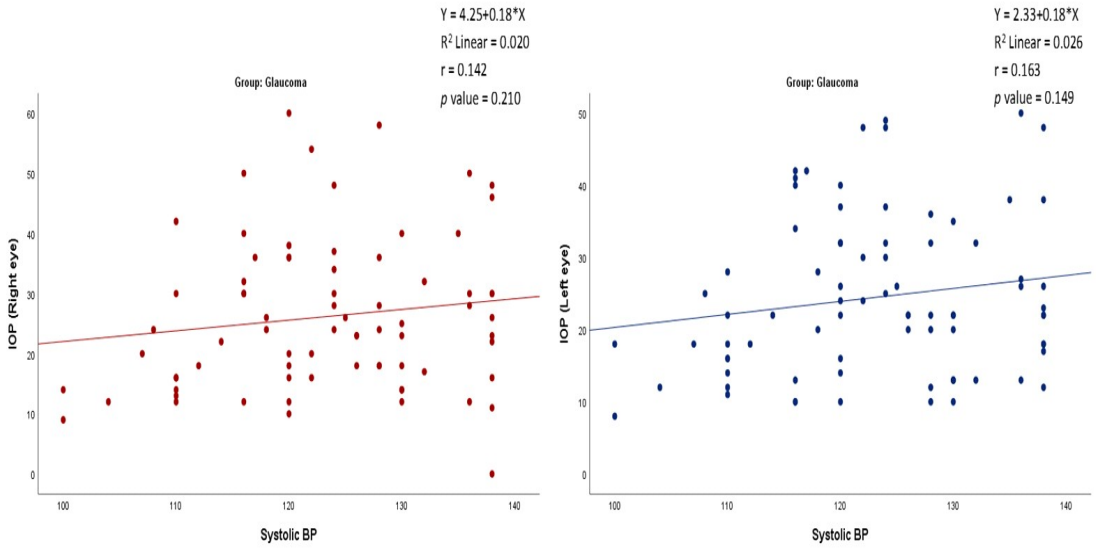

Figure 2: Relationship between IOP and systolic BP among POAG patients

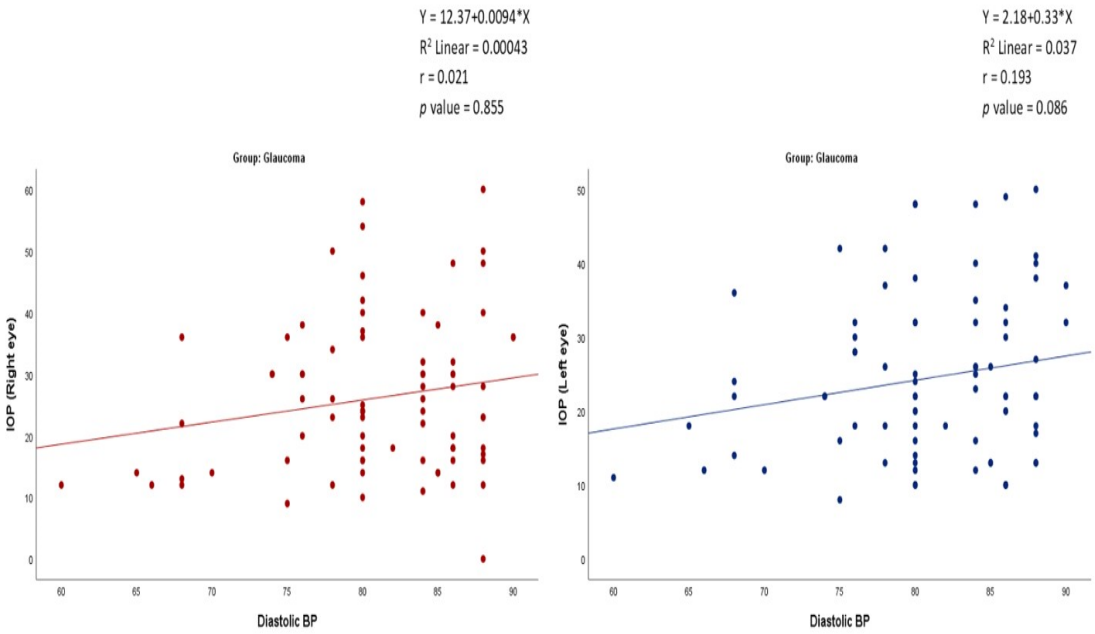

Figure 3. Relationship between IOP and diastolic BP among POAG patients

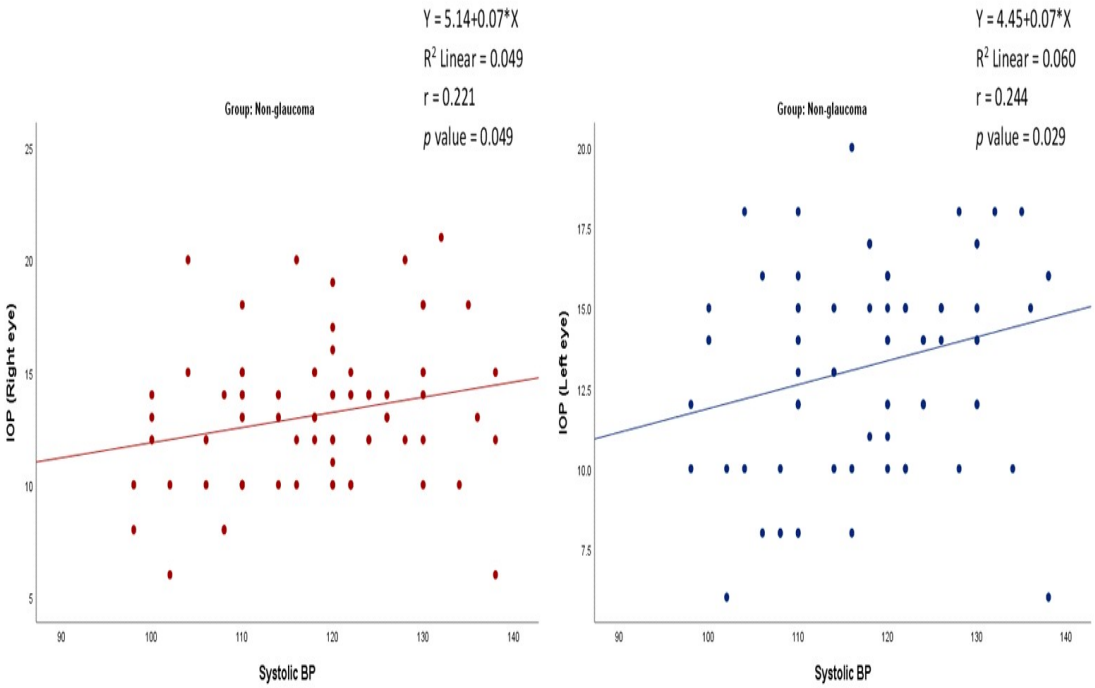

Figure 4. Relationship between IOP and systolic BP among controls

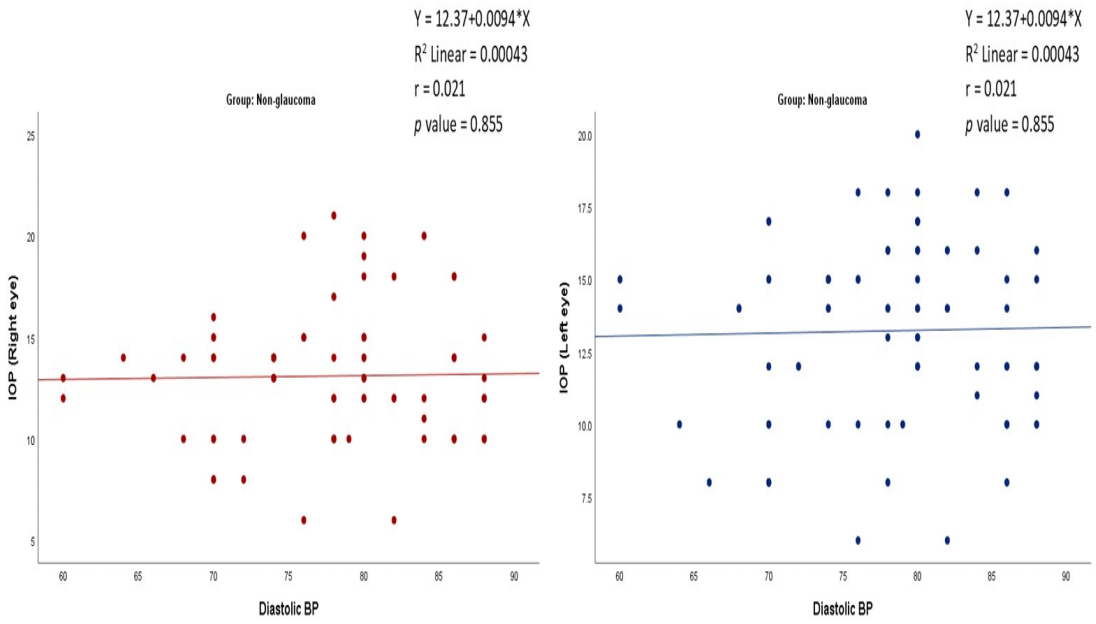

Figure 5. Relationship between IOP and diastolic BP among controls.

Level of ocular perfusion pressures optimal for normal functioning of the optic nerve

Receiver Operating Characteristic (ROC) curve analysis were used to determine the level of ocular perfusion pressure considered optimal for normal functioning of the optic nerve, potentially protective against POAG. The optimal threshold for each ocular perfusion pressure parameter was selected based on the maximum Youden Index (J = Sensitivity + Specificity - 1). Calculating the Youden index for the various MOPP, SOPP and DOPP values in POAG and control groups (summarized in Table 7), the optimal cut-off values in these participants were: MOPP > 40.62 - 42.57mmHg; SOPP > 94mmHg; DOPP > 58 - 59mmHg.

DISCUSSION

The mean ocular perfusion pressure (37.42mmHg in POAG group versus 48.05mmHg in the control group), systolic ocular perfusion pressure (97.03mmHg in POAG group versus 105.09mmHg in control group) and diastolic ocular perfusion pressures (54.79mmHg in POAG group versus 64.91mmHg in control group) were all found to be lower in the POAG group. This is similar to findings in a previous study done in South-east Nigeria[18] where lower mean ocular perfusion pressure in POAG subjects was found (RE = 43.6, LE = 41.9) mmHg compared with the control group (RE = 53.9, LE = 53.7) mmHg, ($p < 0.001$). Similarly, the study by Khandelwal et al.[10] showed lower mean ocular perfusion pressure in primary open angle glaucoma patients (46.23mmHg) than in non-POAG normotensive patients (55.35mmHg). However, Omoti et al.[20] and Orzalesi *et al*.[22] found significantly higher systolic ocular perfusion pressures in POAG patients compared with controls (113.51mmHg in POAG versus 107.30mmHg in controls in Omoti's study and 122.7mmHg in POAG versus 121.7mmHg in controls in Orzalesi's study). Diastolic ocular perfusion pressures were not significantly different between POAG and control groups in these two studies[20,22], although higher than in the current study. The higher levels of SOPP and DOPP in Orzalesi's study compared to the current study may be related to patient selection criteria (most POAG patients either had normal IOP or were on IOP lowering drugs in the study by Orzalesi et al).

Using receiver operating curves in a bid to determine an optimal level of ocular perfusion pressure above which the development of glaucoma is less likely, this study found MOPP below 40.62mmHg RE and 42.57mmHg LE,

Table 7 Ocular Perfusion Pressure Levels Associated with POAG Diagnosis Based on ROC Analysis

Parameter	Criterion (mmHg) RE	Criterion (mmHg) LE	Sensitivity (%) RE	Sensitivity (%) LE	Specificity (%) RE	Specificity (%) LE	Youden Index (J) RE	Youden Index (J) LE	AUC (p-value) RE	AUC (p-value) LE
Mean Ocular Perfusion Pressure (MOPP)	≤40.62	≤42.57	57.50	60.00	93.75	86.25	0.5125	0.4625	0.788 (<0.001)	0.755 (<0.001)
Systolic Ocular Perfusion Pressure (SOPP)	≤94.00	≤94.00	47.50	42.50	86.25	86.25	0.3375	0.2875	0.677 (<0.001)	0.643 (<0.001)
Diastolic Ocular Perfusion Pressure (DOPP)	≤59.00	≤58.00	63.75	55.00	82.50	85.00	0.4625	0.4000	0.746 (<0.001)	0.715 (<0.001)

RE = Right Eye;

LE = Left Eye;

AUC = Area Under the Curve

SOPP below 94mmHg and DOPP below 58mmHg RE and 59mmHg LE to be associated with glaucoma diagnosis.

These were similar to findings in the study by Leske *et al*[23] in the Barbados eye study where those with a MOPP under 42 mm Hg, SOPP lower than 101 mm Hg or a DOPP below 55 mm Hg at baseline had a 3.1-, 2.6- and 3.2-fold increased risk, respectively, of developing glaucoma at 4 years.[24]

The similarities are probably due to the similarity in the populations studied (populations of African descent). This brings to light the potential effect of genetics along with vascular mechanisms in POAG development.[25]

Other such similar findings occurred in the Baltimore eye study[26] where diastolic ocular perfusion pressure below 50mmHg was associated with POAG prevalence (odds ratio [OR] 1.72 in the subgroup with 40-49mmHg DOPP, OR 2.14 in 30-39mmHg DOPP subgroup, OR 6.22 in subgroup with DOPP less than 30mmHg); and the Egna-Neumarkt Glaucoma study where lower diastolic perfusion pressure (<68mmHg) was associated with a marked, progressive increase in the frequency of hypertensive glaucoma (odds ratio for POAG 1, $p < 0.001$).[27] Proyecto VER study in Hispanics (reported mean perfusion pressure lower than 50mmHg as having 4 times greater risk of open-angle glaucoma) and the Rotterdam Eye study reported diastolic perfusion pressure lower than 50mmHg as having 4 times greater risk of open-angle glaucoma than those with a perfusion pressure of 80mmHg.[28, 29, 30]

In Latino individuals, those with a mean ocular perfusion pressure of 50 mm Hg or less were nearly four times more likely to have open-angle glaucoma. However, those with a high systolic ocular perfusion pressure (>150 mm Hg) also had a higher prevalence of open-angle glaucoma. There was a trend toward an association of open-angle glaucoma with higher mean ocular perfusion pressure, although it did not reach statistical significance.[15] Racial and genetic differences are likely explanatory factors for these.

It is thus imperative for ocular perfusion pressures to be assessed and modified appropriately in the management of glaucoma patients.

Study limitations

1. Blood pressure and intraocular pressure were measured once during one visit. Consequently, the study did not account for circadian fluctuations in ocular perfusion pressure.
2. The study's cross-sectional design prevents establishing a temporal sequence between low ocular perfusion pressure (OPP) and glaucoma. Therefore, it remains unclear whether low OPP precedes glaucoma or vice versa.
3. The absence of multivariable analysis to control for potential confounders in the relationship between OPP and glaucoma is also a limitation.

CONCLUSION

The mean ocular perfusion pressures, systolic ocular perfusion pressures and diastolic ocular perfusion pressures were all found to be significantly lower in POAG patients compared to the control group.

The relationship between IOP with SBP and DBP in the POAG patients and controls were non-significant weak positive relationships similar to that between MOPP with SBP and DBP in glaucoma patients. However, significant moderately positive relationships were found between MOPP with SBP and DBP in the control group.

RECOMMENDATIONS

Ophthalmologists need to research along with physicians in the area of blood pressure modification in patients at risk of developing glaucoma. Focus should be on adequate and not overzealous blood pressure reduction. Routine blood pressure, IOP and ocular perfusion pressure should be measured for POAG patients, suspects as well as those presenting for glaucoma screening in the eye clinics. More studies to determine optimal ocular perfusion pressures that will protect the optic nerve head from glaucoma should be

carried out. Ophthalmologists should determine ocular perfusion pressure for glaucoma patients and attempt to titrate target IOP such that adequate perfusion of the optic nerve head is maintained.

Conflict of interest: There were no conflicts of interest in this research.

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REFERENCES

1. American Academy of Ophthalmology. BCSC Section 10:Glaucoma. In: Basic and Clinical Science Course. Cantor L, Rapuano C, Cioffi G, editors. Basic and Clinical Science Course. 2018-2019. SanFrancisco: EBO; 2018; 3-5.
2. Pascolini D and Mariotti SP. Global estimates of visual impairment: 2010. Br J Ophthalmol. 2012;96(5):614-618.
3. Flaxman SR, Bourne RR, Resnikoff S, Ackland P, Braithwaite T, Cicinelli MV, *et al.* Global causes of blindness and distance vision impairment 1990-2020 a systematic review and meta-analysis. Lancet Glob Health. 2017;12(5):1221-1234.
4. Zhang N, Wang J, Li Y, and Jiang B. Prevalence of primary open angle glaucoma in the last 20 years: a meta-analysis and systematic review. Sci Rep. 2021;11(1):1–12.
5. Murdoch IE, Cousens SN, Babalola OE, Yang YF, Abiose A, Jones BR. Glaucoma prevalence may not be uniformly high in all "black" populations. Afr J Med Med Sci 2001;30(4):337–339.
6. Onakoya AO, Ajuluchukwu JN, Alimi HL. Primary open angle glaucoma and intraocular pressure in patients with systemic hypertension. East Afr Med J 2009;86(2):74–78.
7. Kanadani FN, Figueiredo CR, Miranda RM, Cunha PL, Kanadani TC, Dorairaj S. Ocular perfusion pressure and pulsatile ocular blood flow in normal and systemic hypertensive patients. J Curr Glaucoma Pract 2015;9(1):16–19.
8. Ahmad SS. Controversies in the vascular theory of glaucomatous optic nerve degeneration. Taiwan J Ophthalmol 2016; 6(4):182-186.
9. Gore V, Shah P, Kanhere M, Gore S. Relationship between optical perfusion pressure and systemic blood pressure on glaucoma: Case-control study. Oman J Ophthalmol 2019;12(3):150-5.
10. Khandelwal R, Khandelwal R, Raje D, Kumar D, Rathi A. Correlation of open-angle glaucoma and ocular perfusion pressure in hypertensive individuals. J Clin Ophthal Res 2020;8(1):5-9.
11. Kyari F, Abdull MM, Wormald R, Evans JR, Nolan W, Murthy GV, et al; Nigeria National Blindness and Visual Impairment Study Group. Risk factors for open-angle glaucoma in Nigeria: results from the Nigeria National Blindness and Visual Impairment Survey. BMC Ophthalmol 2016;16:78.
12. Cherecheanu AP, Garhofer G, Schmidl D, Werkmeister R, Schmetterer L. Ocular perfusion pressure and ocular blood flow in glaucoma. Curr Opin Pharmacol 2013;13(1):36–42.
13. Harris A, Guidoboni G, Arciero JC, Amireskandari A, Tobe LA, Siesky BA. Ocular hemodynamics and glaucoma: the role of mathematical modeling. Eur J Ophthalmol 2013;23(2):139-146.
14. Brent AS, Alon H, Annahita A, Brian M. Glaucoma and ocular blood flow: an anatomical perspective. Exp Rev Ophthalmol 2012;7(4):325-40
15. Memarzadeh F, Ying-Lai M, Chung J, Azen SP, Varma R. Blood pressure, perfusion pressure, and open-angle glaucoma: The Los Angeles Latino Eye Study. Invest Ophthalmol Vis Sci 2010;51(6):2872–2877.
16. Leske MC, Wu SY, Nemesure B, Hennis A. Incident open-angle glaucoma and

blood pressure. Arch Ophthalmol 2002;120(7):954–959.
17. Ihemedu C, Adeoye AO, Adegbehinge BO. Relationship between ocular perfusion pressure, intraocular pressure, systolic blood pressure in hypertensive and non-hypertensive primary open angle glaucoma patients at Obafemi Awolowo University teaching hospitals (OAUTH) complex, Ile-Ife [dissertation]. Department of Ophthalmology, OAUTH, Ile-Ife; 2014.
18. Arinze IC, Onwubiko SN, Nwachukwu NZ, Maduka-Okafor FC, Aghaji AE, Nkwegu MO, *et al.* Distribution of ocular perfusion pressure and its relationship with intraocular pressure in patients with primary open angle glaucoma in Enugu, South East, Nigeria. Niger J Clin Pract. 2022;25(9):1430-1434.
19. Ekwufulem ON, Edema OT, Okechukwu I. Primary open angle glaucoma and ocular perfusion pressure in hypertensives and non-hypertensives attending Federal Medical Centre, Umuahia [dissertation]. Department of ophthalmology, University of Benin teaching hospital, Edo; 2019.
20. Omoti AE, Enoch ME, Okeigbemen VW, Akpe BA, Fuh UC. Vascular risk factors for open angle glaucoma in African eyes. Middle East Afr J Ophthalmol 2009; 16(3):146-150.
21. Vawda N and Munsamy A. A review of ocular perfusion pressure and retinal thickness: A case for the role of systemic hypotension in glaucoma. Afr Vis Eye Heal. 2021; 80(1): 630.
22. Orzalesi N., Rossetti L., Omboni S. Vascular risk factors in glaucoma: the results of a national survey. Graefes Arch Clin Exp Ophthalmol 2007; 245:795–802.
23. Leske MC, Wu SY, Hennis A, Honkanen R, Nemesure B. Risk factors for incident open-angle glaucoma: the Barbados Eye Studies. Ophthalmology 2008;115:85-93
24. Weinreb RN, Liebmann JM, Pasquale LR. Peer Review: The Role of Perfusion Pressure. Glaucoma Today. 2017;14–16.
25. Trivli A, Zervou MI, Goulielmos GN, Spandidos DA, Detorakis ET. Primary open angle glaucoma tgenetics: The common variants and their clinical associations (Review). Mol Med Rep 2020 ;22(2):1103-10.
26. Tielsch JM, Katz J, Sommer A, Quigley HA, Javitt JC . Hypertension, perfusion pressure, and primary open-angle glaucoma: a population-based assessment. Arch Ophthalmol 1995; 113 :216–221.
27. Bonomi L, Marchini G, Marraffa M, Bernardi P, Morbio R, Varotto A. Vascular risk factors for primary open angle glaucoma: The Egna-Neumarkt Study. Ophthalmology 2000;107(7):1287–1293.
28. Quigley HA, West SK, Rodriguez J, Munoz B, Klein R and Snyder R. The prevalence of glaucoma in a population-based study of Hispanic subjects: Proyecto VER. Arch Ophthalmol 2001; 119: 1819-1826.
29. Moore D, Harris A, Wudunn D, Kheradiya N, Siesky B. Dysfunctional regulation of ocular blood flow: A risk factor for glaucoma. Clin Ophthalmol 2008; 2: 849–861.
30. Huck A, Harris A, Siesky B, Kim N, Kanakamedala P, Amireskandari A, *et al.* Vascular considerations in glaucoma patients of African and European descent. Acta Ophthalmol. 2015; 92(5): 1–11.