Association between Blood Pressure and Intraocular Pressure in Relation to Glaucoma

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Abstract— *High blood pressure is not only associated with systemic cardiovascular complications, but also, ocular complications such as glaucoma. This study sought to determine the association between blood pressure, intraocular pressure and glaucoma. In this cross-sectional study, 162 hypertensive patients (with mean age of 57 (±14.26) years) visiting the St. Dominic's hospital, in Ghana were purposively sampled to participate in the study. Data on patient's history, blood pressure, intraocular pressure and cup-to-disc ratio were collected and analysed using Statistical Package for Social Sciences (SPSS) version 20. Descriptive statistics was computed and thestatistical significance of associations was assessed at a significance level of 0.01. The outcome of the study revealed a positive correlation of 0.364 and 0.309 between systolic blood pressure and the intraocular pressure of the right and left eye respectively.The correlation between diastolic blood pressure and intraocular pressure of the right and left eyes were 0.334 and 0.239 respectively. Out of the 104 patients with systolic blood pressure exceeding 139mmHg, 54 of them (51.9%) had intraocular pressures greater than 21mmHg and 58 of them (55.8%) had cup-to-disc ratio in the range of 0.7–1.0. A weak but positive correlation between systolic blood pressure and cup-to-disc was also established.Last but not least,a correlation of 0.441 between intraocular pressure and cup-to-disc ratio of the right eye of participants as against a correlation 0.256 for the left eye was reported.The susceptibility to glaucomawas thus, relatively high in patients withuncontrolled hypertension and higher intraocular pressure.Hence, pragmatic measures should be takenby all stakeholders towards managing hypertension and intraocular pressurein order to safeguard the health and sight of all.*

Keywords— Blood pressure; Intra-ocular pressure; Correlation; Glaucoma.

Abbreviations— *BP: Blood Pressure; DBP: Diastolic Blood Pressure; SBP: Systolic Blood Pressure; CDR: Cup-to-disc Ratio; LCDR: Left eye Cup-to-disc Ratio; RCDR: Right eyeCup-to-disc Ratio; IOP: Intraocular Pressure; LIOP: Left eye Intraocular Pressure; RIOP: Right eye Intraocular Pressure; OAG: Open Angle Glaucoma; OPP: Ocular Perfusion Pressure.*

I. INTRODUCTION

Glaucoma is an optic neuropathy with characteristic changes in the optic disc and specific visual field defects associated frequently, but not invariably with raised intraocular pressure [1].Intraocular pressure (IOP) refers to the pressure within the eye relative to the constant formation and drainage of the aqueous humor[2].Although intraocular pressure remains an important risk factor for glaucoma, it is clear that other factors including high blood pressure, high blood glucose, high body mass index, age, etc. can also influence the disease development and progression. Glaucoma is currently the second leading cause of blindness globally. The global prevalence of glaucoma in 1996 was estimated at nearly 66.8 million, of whom 6.7 million were blind [3]. It is estimated that the number of people with glaucoma will reach 80 million in 2020, and more than 70% of them will have open-angle glaucoma (OAG) [4].

Hypertension can be defined as blood pressure (BP) consistently $\geq 140 / 90$mmHg.This sustained increase in blood pressure is a major risk factor for the development of cardiovascular diseases [5]and unarguably, one of the most common causes of death in many countries including Ghana [5]. Hypertension is one of the major risk factors for coronary heart disease and stroke and is estimated that hypertension is implicated in 7.1 million deaths annually, accounting for 13% of all deaths globally.It is further estimated that by 2030, twenty-three million cardiovascular deaths would have occurred, with approximately 85% occurring in low and middle-income countries [6].

Hypertension affects approximately 11% to 42% of Africans. It is projected that by 2025, over 125 million people in sub-Saharan Africa will be affected [7]. Ghana is gradually experiencing urbanization and modernization, which invariably is causing changes in people's diet and physical activity particularly in the cities and towns. The prevalence of hypertension in Ghana has been estimated at 25% in urban and 20% in rural population. Life style changes such as preference for fast foods, cigarette smoking and alcohol consumption, among others, has been associated with the increase prevalence of hypertension –a major public health concern[8].

Both glaucoma and hypertension at are asymptomatic at their incipient stages, hence leaving the clinician with poor prognosis to the conditions when detected at the later

stages [9].Amidst the available treatments,so many people in the world are losing their sight and lives to glaucoma and hypertension respectively due to the corresponding irreversible and insidious nature of the two diseases [7,10]. Aside that, longstanding hypertension comes with other ocular morbidities like hypertensive retinopathy [10] which may be vision threatening.

More recently, the effects of blood pressure on intraocular pressure as well as glaucoma development has attracted a lot of scholarly attention since it represents a clinically modifiable risk factor, which might provide the potential for new treatment strategies beyond IOP reduction.The interplay between BP and IOP determines the ocular perfusion pressure (OPP), which is an important indicator of blood flow to the optic nerve. In effect, controlling these factors will go a long way to protect ganglion cells from damage hence reducing the effect of glaucomatous damage to the eye if any [9].A plethora of studies have reported a positive correlation between BP, IOP and glaucoma [11,12,13].

Even though, people of the African ancestry have a high risk of glaucoma, little work has been done among this population. Africa as a whole has little published work on this all-important topic [14,15]. This study sought to come out with data on how BP, IOP and glaucoma may be correlated and to see if the outcome of this study may help improve the treatment regimen for patients with glaucoma, including ocular hypertension, systemic hypertension and other related cardiovascular problems.

1.1 Relationship between Blood Pressure and Intraocular Pressure

Several population-based studies have consistently found an association between high blood pressure and IOP. In general, each 10mmHg rise in systolic blood pressure is associated with a small increase in IOP- approximately 0.27mmHg [9,13,16,17].

As these studies spanned populations with different ethnic backgrounds including Caucasians, Africans and Asians, it is likely that they are widely applicable. Consistent with these epidemiological associations, animal experiments have shown that both chronic hypertension in rats [18] and short-term high blood pressure in rabbits resulted in elevated IOP[19].

The physiological basis of the relationship between blood pressure and IOP remains unclear. It has been hypothesized that both elevated IOP and BP might be driven by a common extrinsic factor such as an age-related increase in sympathetic tone [18].Alternatively, an increase in blood pressure tends to elevate ciliary artery pressure, thus increasing the ultrafiltration component of aqueous production, resulting in IOP elevation [20,21]. Moreover, because increased arterial pressure can produce a small increase in venous pressure, aqueous clearance will be reduced, which can also contribute to a higher IOP [9].

1.2 Relationship between Blood Pressure and Glaucoma

Despite the clear association between blood pressure and IOP, the exact relationship between blood pressure and open-angle glaucoma is complex. This is because, not only does blood pressure influence IOP and OPP, but long-standing hypertension might also reflect a compromised peripheral vascular capacity and autoregulation [9].

Notwithstanding this multifaceted relationship, several epidemiological studies around the globe have reported a significant correlation between high blood pressure and glaucoma [11,22,23]. These studies revealed that systemic hypertension increases an individual's susceptibility to glaucoma. In another sense, this association between high blood pressure and glaucoma is counter intuitive, given that a high blood pressure should produce a high OPP and thus should give a protective effect [12].

Against this backdrop, the current study was to investigate the association between blood pressure and intraocular pressure in relation to glaucoma.

II. MATERIALS AND METHODS

2.1 Recruitment of Study Participants

This cross-sectional study was situated at the St Dominics's Hospital, which is located at Akwatia in the Denchembour district in the Eastern region of southern Ghana and west of the Atewa Range in the Birim River basin. All hypertensive patients who, as of the time of study, were attending the eye/hypertensive clinic were recruited for the present study. After the data collection, potential confounders (cataract, diabetics, age etc.) were adjusted for.Those included in the study were known hypertensive patients between the ages of 30 – 90 years,who were on medications.The following groups of people were excluded from the study: known diabetics, patients with hypermature cataract, those who did not cooperate with their IOP measurements, patients with closed anterior chamber angle, those who have had intraocular surgeries and finally, those outside the age range of 30 – 90 years.

2.2 Sample size and Sampling Technique

The sample size of the study was 186 (out of which 162 patients satisfied the inclusion criteria). A purposive sampling technique was used in selecting the patients. On the average, data was collected on about 10 participants per day spanning 20 days.

2.3 Data Collection Procedures

All patients who willingly came to the clinic to partake of the study were made to rest for about 15 minutes after a comprehensive history was taken. This was followed by measurement of their BPwith the manual sphygmomanometer as well their pulse rates. The next phase of the data collection was slitlamp biomicroscopy, ophthalmoscopy and IOP measurement. The patient's anterior segment and adnexae was examined with the Haag streigt slit lamp (which is known for its excellent illumination system and flexibility) to rule out any ocular disorder (including uveitis,corneal disorder, closed anterior chamber angle, shallow anterior chamber, etc.). With the aid of WelchAllyn direct ophthalmoscope, the fundus of participants were viewed to rule out any pathology as well as to assess the cup-to-disc ratio of the eye. Finally, after instillation of a drop of flurocaine (alcaine plus fluorescein) on the eyes, the IOP was measured for both eyes using the Goldman applanation tonometer.Validity and reliability was ensured through frequent calibration of the instruments used for the data collection.

2.4 Ethical Consideration

Ethical approval was sought from the Committee on Human Research, Publication and Ethics (CHRPE) of the Kwame Nkrumah University of Science and Technology. A written consent was sent to the management of St Dominic's hospital and a communiqué was sent by the administrator to the various departments of concern to notify them about the study. A verbal consent of the participants was also sought before proceeding with the collection of their data. The purpose, associated risk and methodology of the study werethoroughly explained to each participant before the examination was carried out. Moreover, data and information collected from the participants was only used for the purpose of this study. Finally, the research methodology was carried out in conformity with the tenets of the declaration of Helsinki [24].

2.5 Data Analysis

The analysis was done using Statistical Package for Social Sciences (SPSS) version 20. Raw data was inputted and results were analysed using correlation, crosstab and the descriptive statistics function. The level of significance was set at a p-value of 1%. The results were displayed with tables.

III. Results

3.1 Demographic Characteristics of Study Participants

Out of a total number of 187 hypertensive patients who willingly presented to the eye clinic to participate in the study, only 162 of them were eligible, given the delimitations of the present study. The participants were in the age range of 30 – 90 years. Out of the 162 patients, there were 95 females as against 67 males representing 58.6% and 41.4% respectively. The patients within the 50 – 59 years age grouphad the highest frequency of 39 (24.1%) whilst the 80 – 90 years age group had the least frequency of 12(7.4%). Table 1 below provides ample information on the participants' demographics.

Table.1: Demographic Characteristics of Study Participants

Age	Frequency (n)	Percent (%)	N(female)	N(male)
30-39	18	11.1	7	11
40-49	35	21.6	14	21
50-59	39	24.1	30	9
60-69	37	22.8	27	10
70-79	21	13.0	11	10
80 - 90	12	7.4	6	6
Total	162	100.0	95	67

3.2 Descriptive Statistics of Variables Measured

The minimum and maximum age for participants who partook in the study was 30 and 87 years respectively with a mean age of 57 (±14.26) years.The minimum SBP stood at 100mmHg as against a maximum of 262mmHg with a mean SBP of 160mmHg (±37.9). The DBP was in the ranges of 60 – 155 mmHg with a mean value of 86mmHg (±16.3). The pulse rate per minute for the patients ranged from 59 – 117 beats per minute with a mean pulse of 80b/m (±16.2).The IOP for the right and left eye ranged from 8 – 68mmHg and 8 – 59mmHg respectively. The mean IOP for the right eye was 22mmHg (±11.2) as against 21mmHg (±10.8) for the left eye as shown in Table 2 below.

Table.2: Descriptive Statistics of Variables Measured

	Age/yrs	SBP/mmHg	DBP/ mmHg	Pulse/bpm	RIOP/ mmHg	LIOP /mmHg
N	**162**	**162**	**162**	**162**	**162**	**162**
Mean	56.55	160	86	80	22	21
Median	56.50	160	84	79	18	18
Mode	55	180	70	70	30	12
SD	14.26	37.91	16.25	16.15	11.16	10.78
Minimum	30	100	60	59	8	8
Maximum	87	262	155	117	68	59

3.3 Correlation between Blood Pressure and Intraocular Pressure

At a significance level of 0.01, there was a positive correlation of 0.364 between SBP and the IOP of the right eye of participants as against a correlation 0.309 for the intraocular pressures of the left eye among the 162-hypertensive patients.The correlation between DBP and IOP of the right and left eyes were 0.334 and 0.239 respectively.Out of the 162-hypertensive patients, 104 of them had systolic blood pressures of more than 139mmHg (SBP>139mmHg). The intraocular pressures measured for these participants were significantly high. With respect to the right eye: 54(51.9%) eyes had IOPs greater than 21mmHg, 47(45.2%) eyes had IOPs ranging from 10 – 21mmHg and lastly, only 3(2.9%) had IOPs of less than 10 mmHg. The IOPs of patients with SBP of more than 139mmHg correlated with the intraocular pressure of the left eye. The various correlations between BP and IOP have been explicitly illustrated in Tables 3, 4 and 5 below.

Table.3: Correlation between SBP and IOP

Parameters	Correlation	SBP	RIOP	LIOP
SBP	Pearson Correlation	1	**.364****	**.309****
	Sig. (2-tailed)		.000	.000
	N	162	162	162
RIOP	Pearson Correlation	.364**	1	.763**
	Sig. (2-tailed)	.000		.000
	N	162	162	162
LIOP	Pearson Correlation	.309**	.763**	1
	Sig. (2-tailed)	.000	.000	
	N	162	162	162

**** Correlation is significant at the 0.01 level (2-tailed).**

Table.4: Correlation between DBP and IOP

Parameters	Correlation	DBP	RIOP	LIOP
DBP	Pearson Correlation	1	**.334****	**.239****
	Sig. (2-tailed)		.000	.002
	N	162	162	162
RIOP	Pearson Correlation	.334**	1	.763**
	Sig. (2-tailed)	.000		.000
	N	162	162	162
LIOP	Pearson Correlation	.239**	.763**	1
	Sig. (2-tailed)	.002	.000	
	N	162	162	162

****. Correlation is significant at the 0.01 level (2-tailed).**

Table.5: Percentage of Patients with SBP>139mmHg versus IOP

		IOP/mmHg			Total
		0 – 9	10-21	≥22	
SBP > 139	**Right**	3(2.9%)	47(45.2%)	54(51.9%)	104
	Left	3(2.9%)	48(46.2%)	53(51%)	104

3.4 Correlation between Blood Pressure and Cup Disc Ratio (CDR)

At a significance level of 0.01, there was a correlation of 0.273 between SBP and the CDR of the right eye of participants as against a correlation 0.221 for the left eye among the 162-hypertensive patients (as showed in Table 6 below). Out of the 162-hypertensive patients, 104 of them had SBP of more than 139mmHg. The CDR measured for these participants were significantly higher. Measurements taken for the right eye showed that 58 participants (55.8%) had CDRs in the range of 0.7 – 1.0. Thirty-six of them (34.6%) had CDRs ranging from 0.1 – 0.4 whilst 10(9.6%) had CDRs in the ranges of 0.5 – 0.6. The CDRs of the left eye differed slightly from that of the right CDR as depicted in Table 7 below.

Table.6: Correlation between SBP and CDR

Parameters	**Correlation**	**SBP**	**RCDR**	**LCDR**
SBP	Pearson Correlation	1	**.273****	**.221****
	Sig. (2-tailed)		.000	.005
	N	162	162	162
RCDR	Pearson Correlation	.273**	1	.860**
	Sig. (2-tailed)	.000		.000
	N	162	162	162
LCDR	Pearson Correlation	.221**	.860**	1
	Sig. (2-tailed)	.005	.000	
	N	162	162	162

**** Correlation is significant at the 0.01 level (2-tailed).**

Table.7: Percentage of Patients with SBP>139 versus CDR

		CDR			Total
		0-0.4	0.5-0.6	≥0.7	
SBP >139mmHg	**Right**	36**(34.6%)**	10**(9.6%)**	58**(55.8%)**	104
Left		37**(35.6%)**	14**(13.5%)**	53**(51%)**	104

3.5 Correlation between Intraocular Pressures and Cup Disc Ratio

At a significance level of 0.01, there was a correlation of 0.441 between IOP and CDR of the right eye of participants as against a correlation 0.256 for the left eye among the 162-hypertensive patients (as indicated in Tables 8 and 9 below).

Out of the 162-hypertensive patients, 62 and 56 of them had their right and left eyes respectively having IOPs of greater than 21mmHg. Out of the 62 right eyes: 46 of them (74%) had CDRs ranging from 0.7-1.0; twelve of them (19.4%) had CDRs ranging from 0.1 - 0.4 and only four participants had CDRs ranging from 0.4to 0.6. The remaining details have been summarized in Table 10 below.

Table.8: Correlation between Right IOP and Right CDR

Parameters	Correlation	RIOP	RCDR
RIOP	Pearson Correlation	1	.411**
	Sig. (2-tailed)		.000
	N	162	162
RCDR	Pearson Correlation	.411**	1
	Sig. (2-tailed)	.000	
	N	162	162

**** Correlation is significant at the 0.01 level (2-tailed).**

Table.9: Correlations between Left IOP and Left CDR

Parameters	Correlation	LIOP	LCDR
LIOP	Pearson Correlation	1	**.256****
	Sig. (2-tailed)		.001
	N	162	162
LCDR	Pearson Correlation	.256**	1
	Sig. (2-tailed)	.001	
	N	162	162

**** Correlation is significant at the 0.01 level (2-tailed).**

Table.10: Distribution of CDRs in Patients with IOP ≥ 21mmHg

IOP	CDR			Total
	0-0.4	0.5-0.6	≥0.7	
RIOP > 21	12	4	46	62
LIOP > 21	15	4	37	56

3.6 Relationship between SBP, IOP and CDR

Out of the 162 hypertensive patients, 108 of them (66.7%) had SBP≤139 and RIOP≤ 21 as against 54(33.3%) patients with SBP>139 and RIOP>21. For the left eye, among the 162 patients, only 48 of them had their SBP>139 and LIOP>21. How these combined factors correlated with the CDR of both eyes are shown in Tables 11 and 12 below.

Table.11: Systolic Blood Pressure and Right IOP Versus Right CDR

SBP & RIOP	RCDR			Total
	0-0.4	0.5-0.6	≥ 0.7	
SBP≤139 RIOP ≤ 21	61(86%)	12(75%)	35(47%)	108
SBP>139 RIOP>21	10(14%)	4(25%)	40(53%)	54
Total	71	16	75	162

Table.12: High Systolic Blood Pressure and High Left IOP Versus Left CDR

HIGH SBP & LIOP	LCDR			Total
	0-0.4	0.5-0.6	≥ 0.7	
SBP>139/LIOP> 21	13(27%)	3(6%)	32(68%)	48
	13	3	32	48

IV. DISCUSSION

The main objective for the study was to determine the correlation between blood pressure, intraocular pressure and glaucoma among patients visiting the St. Dominic's hospital and more specifically, to determine any prevailing association between BP and IOP, BP and CDR and finally, IOP and CDR.

4.1 Demographic Characteristics of Study Participants

Out of the total of 162 participants, majority were females representing 58.6% of the total study population. The ages of participants ranged between 30 – 90 years with most participants within the age range of 50 – 59 years representing 24.1%of the total study population. That therisk of hypertension increases with age is a well-established fact and so one would expect a rather higher mean age of the participants [25]. Arelatively lower mean age in the present study could be attributed to the poor representation of people in the higher age subgroups. This poor presentation could further be ascribed to the supportive systems (physical and financial) that must be put in place before these patients can come for treatment.

4.2 Association between Blood Pressure and Intraocular Pressure

At a significance level of 0.01, there was a correlation of 0.364 between systolic blood pressures and the intraocular pressures of the right eye of participants as against a correlation 0.309 for the intraocular pressures of the left eye among the 162-hypertensive patients (as shown in Table 3). The correlation between the diastolic blood pressure and that of intraocular pressures of the right and left eyes were 0.334 and 0.239 respectively. However, out of the 162-hypertensive patients, 104 of them had systolic blood pressures of more than 139mmHg (SBP>139mmHg). Out of these 104 patients, 54.1% of them had RIOP greater than 21mmHg and 45.2% of them had LIOP greater than 21mmHg.

Despite the linear relationship between the BP and IOPin the hypertensive patients, this association was more pronounced in those with systolic blood pressures of more than 139mmHg. Hence, it can be inferred that patients with high blood pressure may have high intraocular pressure. This result is in conformity with other population-based studies on the subject [16]. The rise in IOP in patients with subnormal BP value (SBP>139mmHg) could be due to the rise in ciliary arterial pressure as a result of the increased systemic pressure. Consequently, an increase in ultrafiltration component of aqueous humour production occurs which in turn leads to an elevation of the IOP[20,21].

4.3 Association between Blood Pressure and Cup-to-disc Ratio

In line with the present study, there was a correlation of 0.273 between SBP and RCDR of participants as against a correlation 0.221 with the LCDR among the 162-hypertensive patients (as shown in table 6).Among the104 patients who had systolic blood pressures of more than 139mmHg (SBP>139mmHg), the CDR measured for these participants were significantly higher: with 58 of them (55.8%) having RCDR in the range of 0.7-1.0; thirty-six of them (34.6%) having RCDR within 0.1–0.4 and lastly, ten participants (9.6%) having RCDR of 0.5 – 0.6. The CDR of the left eye differed slightly from that of the right CDR as depicted in table 7.

Even though there was a linear relationship between the BP and CDR of both eyes as seen with BP and IOP, the correlation was more linear in those with systolic blood pressures of more than 139mmHg. Most of the patients with subnormal blood pressures presented with CDRs greater than 0.4 as against the normal CDR of either equal to or lesser than 0.4 [9]. On the basis of this, it may be inferred that patients with high BP could have higher tendencies of having larger CDR, which increases their susceptibility to developing glaucoma. This result is very much in consistency with other population-based studies [11,23]. Larger CDR could be as a result of either loss of peripheral blood supply to the optic nerve or mechanical damage to the nerve as a result of increased IOP triggered by prolong subnormal blood pressures [9,12].

4.4 Association between Intraocular pressure and Cup-to-disc Ratio

The present study revealed a correlation of 0.441and 0.256 between intraocular pressures and the cup-to-disc ratio of the right and left eye respectively among the 162-hypertensive patients (as shown by tables 8 and 9). Out of the 162-hypertensive patients, 62 and 56 of them had their right and left eyes respectively having an IOP of greater than 21mmHg. Out of the 62 right eyes with IOP greater than 21mmmHg, 80.6% of this number had CDR of more than 0.4 and out of 56 left eyes with IOP greater than 21mmHg, 73.2% of this number had CDRs of more than 0.4. This result is an indication that, high IOP may be associated with large CDR and hence an increased susceptibility to optic nerve damage (glaucoma).

4.5 Association between the Interactive Effect of Blood Pressure and Intraocular Pressure on Glaucoma

Out of the 162 hypertensive patients, 108 of them (66.7%) had SBP $\leq$ 139 and RIOP$\leq$ 21 as against 54 participants (33.3%) with SBP > 139 and RIOP > 21. For the left eye, among the 162 patients, only 48 of them had their SBP > 139 and LIOP >21. When the right eye was compared,

86% of the patients with normal BP and IOP (SBP ≤ 139 and RIOP≤ 21) hadCDR of less than 0.5 whilst only 14% of patients with subnormal BP and IOP(SBP > 139 and RIOP > 21) had CDR of less than 0.5.A greater majority of the participants with high blood pressure and high intraocular pressure had CDRwithin the range of 0.5-1.0. The situation in left eye was no different from the findings in the right eye. It can, therefore, be deduced that even though there may be an association between the individual factors (BP and IOP) and glaucoma, their synergistic effect in an individual is relatively adverse [22].

V. CONCLUSION

This study has revealed a positive association between hypertension, intraocular pressure and open angle glaucoma in a cross-section of Ghanaian patients. The glaucoma burden was relatively severe in patients with both uncontrolled hypertension (SBP>139mmHg and/or DBP>94mmHg) and higher intraocular pressure (IOP>21mmHg). A remarkable observation made in this study was the fact that, although all study participants were known hypertensivepatients who were on medication; in which case one would expect a fairly normal to marginally high blood pressure, the situation revealed otherwise. Most of the patients presented with significantly high blood pressures, which brings to question, patients' compliance with medications, the efficacy of anti-hypertensive drugs and lastly, blood pressure-elevating lifestyles of patients. This study has revealed how increased blood pressure could affect the eye and consequently impair vision.Hence, pragmatic measures should be takenby all stakeholders towards managing these conditions to safeguard the health and sight of all.

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