

## RELATIONSHIP BETWEEN INTRAOCULAR PRESSURE AND SYSTEMIC BLOOD PRESSURE IN A NIGERIAN COHORT

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### ABSTRACT

**Objective:** To determine the relationship between intraocular pressure and systemic blood pressure as a justification for making recommendations for better clinical investigation and management of patients.

**Methods:** The study was a hospital-based, cross-sectional analytical study conducted on non-glaucomatous patients aged 18 years and above in the eye clinic of Federal Medical Centre, Owerri. All participants filled informed consent forms and underwent visual acuity assessment, intraocular pressure measurement by applanation tonometry between 8am and 12 noon and blood pressure measurement using digital sphygmomanometer, anterior and posterior segment examinations.

**Results:** Four hundred and twenty-two participants were studied with a mean age of  $40.34 \pm 14.47$  years and a female to male ratio of 1.7:1. The prevalence of high systemic blood pressure was 35.8%. The prevalence of ocular hypertension with high systemic blood pressures was 19.9%.

There was a positive correlation between intraocular pressure and systemic blood pressure which was statistically significant ( $p=0.001$ ). The correlation coefficient ( $r$ ) for the strength of the relationship between intraocular pressure and systemic blood pressure was 0.193 (for systolic) and 0.139 (for diastolic) and these findings were statistically significant.

**Conclusion:** This study noted a higher intraocular pressure, systolic and diastolic blood pressures among older participants compared to the younger ones. There was a positive correlation between intraocular pressure and systolic blood pressure as well as intraocular pressure and diastolic blood pressure.

It is recommended that blood pressure and intraocular pressure measurements be routinely done on all patients attending the eye clinic (with emphasis on patients with systemic hypertension) in order to detect and manage ocular hypertension and glaucoma.

### Introduction

Normal intraocular pressure (IOP) is defined as the statistical average pressure which the normal eye can tolerate over a period of time without damage to its integrity.<sup>1</sup> When measured with the Goldmann applanation tonometer, the normal IOP ranges from 11–21 mmHg within the general population.<sup>2</sup> Intraocular pressure is a major and the only realistic modifiable risk factor for glaucoma.<sup>3,4,5,6,7</sup>

However, certain factors such as age, gender, central corneal thickness, blood pressure amongst others can affect IOP.<sup>6,8,9,10,11,12</sup>

Blood Pressure (or arterial blood pressure) is the pressure exerted by circulating blood in the systemic circuit upon the walls of the blood vessels.<sup>13, 14, 15</sup> Arterial blood pressure is a function of an individual's cardiac output and the resistance encountered in the peripheral blood vessels.<sup>13, 14, 15</sup> It is also measured in millimeters of mercury.<sup>13, 14, 15</sup> Blood pressure among adults can be classified according to the European Society of Cardiology (ESC) and European Society of Hypertension (ESH) as shown in the table below: Raised systemic blood pressure acting on the retinal, optic nerve head and choroidal blood vessels produces three distinct and unrelated manifestations, vis-a-viz. retinopathy, optic neuropathy and choroidopathy.<sup>19,20,21</sup> Sustained intravascular pressure produces the classical eye signs in hypertensive retinopathy with its end spectrum being "malignant hypertension".<sup>19,20,21</sup> These signs include cotton wool spots, flame-shaped haemorrhages, arteriolosclerosis, macular star and disc oedema.<sup>19,20,21</sup>

A significantly positive association has also been reported between blood pressure and IOP by some researchers<sup>3,22,23</sup> in contrast to the findings of other studies.<sup>24,25,26</sup> The effect of BP on IOP has been shown to be closely correlated with the systolic blood pressure and not the diastolic or mean pressure. It is postulated that systolic blood pressure may have a direct effect on ultra-filtration and, through this mechanism, on IOP.<sup>3</sup> This effect is thought to be due to an increase in the filtration fraction of aqueous humor resulting in a small but sustained rise in intraocular pressure. This implies a possible contribution of BP in some pathophysiological pathways of glaucoma. A positive association between IOP and SBP may predispose to the development of glaucoma, however, a low SBP may also contribute to the development of glaucoma through its effect on ocular perfusion pressure. Ocular perfusion pressure is the pressure that drives blood through the intraocular vasculature.<sup>27</sup> Ocular perfusion pressure is the difference between the arterial blood pressure (BP) and IOP.<sup>27</sup> Mean ocular perfusion pressure is calculated as  $2/3$  (mean arterial blood pressure minus intraocular pressure); where mean arterial blood pressure = diastolic BP +  $1/3$  (Systolic BP – diastolic BP).<sup>27</sup> Low systemic blood pressure in the presence of elevated IOP will cause a reduction in perfusion pressure at the optic nerve head, a reduction in the autoregulatory system and subsequently lead to the development of glaucoma.<sup>27</sup> Studies in Nigeria<sup>28,29</sup> and elsewhere have documented a positive relationship between intraocular pressure and systemic blood pressure.<sup>25,30,31</sup>



This study assesses the relationship between intraocular pressure and systemic blood pressure in non-glaucomatous patients attending the Eye Clinic of Federal Medical Centre, Owerri, Imo State with a view to making recommendations for better clinical investigation and management of patients.

Table 1: ESC/ESH classification<sup>16, 17, 18</sup>

## Blood Pressure Categories

| BLOOD PRESSURE CATEGORY                              | SYSTOLIC mm Hg<br>(upper number) |        | DIASTOLIC mm Hg<br>(lower number) |
|------------------------------------------------------|----------------------------------|--------|-----------------------------------|
| NORMAL                                               | LESS THAN 120                    | and    | LESS THAN 80                      |
| ELEVATED                                             | 120 - 129                        | and    | LESS THAN 80                      |
| HIGH BLOOD PRESSURE<br>(HYPERTENSION) STAGE 1        | 130 - 139                        | or     | 80 - 89                           |
| HIGH BLOOD PRESSURE<br>(HYPERTENSION) STAGE 2        | 140 OR HIGHER                    | or     | 90 OR HIGHER                      |
| HYPERTENSIVE CRISIS<br>(cannot just delay treatment) | HIGHER THAN 180                  | and/or | HIGHER THAN 120                   |

### Materials and Methods

This was a hospital-based cross-sectional analytical study carried out on adult consecutive non-glaucomatous patients seen at the Eye Clinic of the Federal Medical Centre, Owerri, Imo State, Nigeria (FMCOW), a tertiary healthcare hospital. Patients aged 18 years and above, who had no ocular abnormality or surgery, were neither on any IOP reducing medication nor antihypertensive drug and willingly gave consent to participate in this study formed the study population.

Using the Leslie-Kish formula<sup>32</sup> a sample size of 422 was determined and data was collected using a questionnaire which was tested for reliability and validity in a pilot study. Participants in this study had visual acuity measurement, intraocular pressure measurement, blood pressure measurement and ocular examination. Intraocular pressure was measured using a Slit Lamp mounted Goldmann Applanation tonometer.

Blood pressure was measured according to the recommendations of the American Heart Association as documented by Smith<sup>33</sup> which required two measurements, a minute apart. The Omron series electronic, digital sphygmomanometer was used after correlating to the traditional mercury sphygmomanometer ( $r=0.92$ , systolic BP;  $r=0.79$ , diastolic BP).<sup>34</sup> The use of the electronic digital sphygmomanometer (Omron series) in this study was based on the comparability of its accuracy to that of the mercury sphygmomanometer.<sup>34</sup>

### Results

Two hundred and sixty-four (264) females and 158 males participated in the study. Majority (107: 25.4%) were in the 41-50 years age group. The minimum and maximum ages of participants were 18 years and 85 years respectively with a mean age of  $40.34 \pm 14.47$  years. Two hundred and ninety-eight (70.6%) had tertiary education, and 164 (38.9%) were skilled workers.

**Table 2: Distribution Pattern of IOP among participants in FMC, Owerri**

| Corrected IOP                     | Number of eyes |
|-----------------------------------|----------------|
| Ocular hypotensives (< 10mmHg)    | 15 (3.6%)      |
| Ocular normotensives (10-21 mmHg) | 354 (83.9%)    |
| Ocular hypertensives (>21mmHg)    | 53 (12.6%)     |
| Mean IOP(mmHg)                    | 17.26±4.59     |

Pearson Chi-Square = 1.0618 df = 2 p-value = 0.588

Out of 422 participants, 53 (12.6%) had intraocular pressures > 21 mmHg. However, this difference was not statistically significant.

**Table 3: Distribution Pattern of IOP by age among participants in FMC, Owerri**

| Age group<br>(years) | IOP                |                     |                     | Total        |
|----------------------|--------------------|---------------------|---------------------|--------------|
|                      | Ocular hypotensive | Ocular Normotensive | Ocular Hypertensive |              |
| <30                  | 0 (0.0%)           | 104 (89.7%)         | 12 (10.3%)          | 116 (100.0%) |
| 31-40                | 0 (0.0%)           | 78 (88.6%)          | 10 (11.4%)          | 88 (100.0%)  |
| 41-50                | 0 (0.0%)           | 95 (88.8%)          | 12 (11.2%)          | 107 (100.0%) |
| 51-60                | 0 (0.0%)           | 56 (90.3%)          | 6 (9.7%)            | 62 (100.0%)  |
| 61-70                | 0 (0.0%)           | 26 (76.5%)          | 8 (23.5%)           | 34 (100.0%)  |
| 71 +                 | 0 (0.0%)           | 12 (80.0%)          | 3 (20.0%)           | 15 (100.0%)  |
| Total                | 0 (0.0%)           | 371 (87.9%)         | 51 (12.1%)          | 422 (100.0%) |

Pearson Chi-Square = 5.864 df = 5 p-value = 0.320

The prevalence of ocular hypertension was 12.1%. The age groups (61-70 and 71+) had more participants with ocular hypertension than other age groups. The younger age groups had more participants with normal intraocular pressures than the other age groups. However, these differences were not statistically significant (p = 0.320).

**Table 4: Distribution Pattern of Systemic BP among participants in FMC, Owerri**

| Systemic Blood Pressure (SBP)<br>(mmHg) | Frequency | Percentage (%) |
|-----------------------------------------|-----------|----------------|
| Low SBP (< 90/60)                       | 12        | 2.8            |
| Normal SBP (90/60 – 139/89)             | 259       | 61.4           |
| High SBP (>139/89)                      | 151       | 35.8           |
| Total                                   | 422       | 100            |

Mean systolic blood pressure (mmHg) 134.98±20.03  
 Table 4 shows that majority (61.4%) of the participants had normal systemic blood pressure.

Mean diastolic blood pressure (mmHg) 79.06±12.37

**Table 5: Distribution Pattern of Systolic BP by age among participants in FMC, Owerri**

| Age group<br>(years) | Mean Systolic BP           |                                  |                              | Total        |
|----------------------|----------------------------|----------------------------------|------------------------------|--------------|
|                      | Low<br>SBP<br>(<90/60mmHg) | Normal SBP (90/60<br>139/89mmHg) | High<br>SBP<br>(>139/89mmHg) |              |
| <30                  | 0 (0.0%)                   | 103 (88.8%)                      | 13 (11.2%)                   | 116 (100.0%) |
| 31-40                | 0 (0.0%)                   | 68 (77.3%)                       | 20 (22.7%)                   | 88 (100.0%)  |
| 41-50                | 1 (9.0 %)                  | 63 (58.9%)                       | 43 (40.2%)                   | 107 (100.0%) |
| 51-60                | 0 (0.0%)                   | 23 (37.1%)                       | 39 (62.9%)                   | 62 (100.0%)  |
| 51-70                | 0 (0.0%)                   | 14 (41.2%)                       | 20 (58.8%)                   | 34 (100.0%)  |
| 71 +                 | 0 (0.0%)                   | 7 (46.7%)                        | 8 (53.3%)                    | 15 (100.0%)  |
| Total                | 1 (0.2%)                   | 278 (65.9%)                      | 143 (33.9%)                  | 422 (100.0%) |

Pearson Chi-Square = 71.920    df = 10    p-value < 0.001

Table 5 indicates that the age groups <30 years, 31-40 years and 41-50 years had more participants with normal systolic BP than those with high systolic BP and low systolic BP. This pattern changed among older participants with majority of them having high SBP than normal or low SBP. Overall, there is increasing high SBP among participants with increasing age. This finding of increasing SBP with age was statistically significant (p<0.001). There was also a positive correlation between mean systolic BP and age (r=0.400). This was statistically significant (p<0.001).

**Table 6: Distribution Pattern of Diastolic BP by age among participants in FMC, Owerri**

| Age group<br>(years) | Mean Diastolic BP       |                                  |                           | Total        |
|----------------------|-------------------------|----------------------------------|---------------------------|--------------|
|                      | Low<br>( $<90/60$ mmHg) | Normal DBP (90/60<br>139/89mmHg) | High<br>( $>139/89$ mmHg) |              |
| $<30$                | 10 (8.6%)               | 97 (83.6%)                       | 9 (7.8%)                  | 116 (100.0%) |
| 31-40                | 3 (3.4%)                | 74 (84.1%)                       | 11 (12.5%)                | 88 (100.0%)  |
| 41-50                | 0 (0.0%)                | 74 (69.2%)                       | 33 (30.8%)                | 107 (100.0%) |
| 51-60                | 0 (0.0%)                | 43 (69.4%)                       | 19 (30.6%)                | 62 (100.0%)  |
| 51-70                | 2 (5.9%)                | 24 (70.6%)                       | 8 (23.5%)                 | 34 (100.0%)  |
| 71 +                 | 0 (0.0%)                | 13 (86.7%)                       | 2 (13.3%)                 | 15 (100.0%)  |
| <b>Total</b>         | 15 (3.6%)               | 325 (77.0%)                      | 82 (19.4%)                | 422 (100.0%) |

Pearson Chi-Square = 40.435      df = 10      p < 0.001

Table 6 indicates that all the age groups had a similar pattern with more participants having normal DBP than high and low DBP. This finding was statistically significant ( $p < 0.001$ ). There was a positive correlation between diastolic BP and age ( $r = 0.317$ ). This correlation was statistically significant ( $p < 0.001$ ).

**Table 7: Relationship between IOP and SBP among participants in FMC, Owerri**

| SBP (mmHg)                            | Ocular<br>Hypotensive | Ocular<br>Normotensive | Ocular<br>Hypertensive | Total |
|---------------------------------------|-----------------------|------------------------|------------------------|-------|
| <b>Low (<math>&lt;90/60</math>)</b>   | 0 (0.0%)              | 10 (83.3%)             | 2 (16.7%)              | 12    |
| <b>Normal (90/60 – 139/89)</b>        | 0 (0.0%)              | 240 (92.7%)            | 19 (7.3%)              | 259   |
| <b>High (<math>&gt;139/89</math>)</b> | 0 (0.0%)              | 121 (80.1%)            | 30 (19.9%)             | 151   |
| <b>Total</b>                          | 0                     | 371                    | 51                     | 422   |

Pearson Chi-Square Value = 14.343

df = 2

p-value = 0.001

Table 7 shows that majority of participants with normal IOP in the right eye had normal blood pressure. A significant number of participants with high IOP had high SBP. The relationship between the different categories of IOP and SBP were found to be statistically significant ( $P = 0.001$ ). There was a statistically significant positive correlation between IOP and mean Systolic BP ( $r = 0.193$ ,  $p < 0.001$ ). There was also a statistically significant positive correlation between IOP and mean diastolic BP ( $r = 0.139$ ,  $p = 0.004$ ). The scatter plot diagram in Fig 1 also illustrates a rise in SBP in association with a rise in IOP.



Fig 1: Scatter plots of IOP versus Mean Systolic and Diastolic Blood pressures

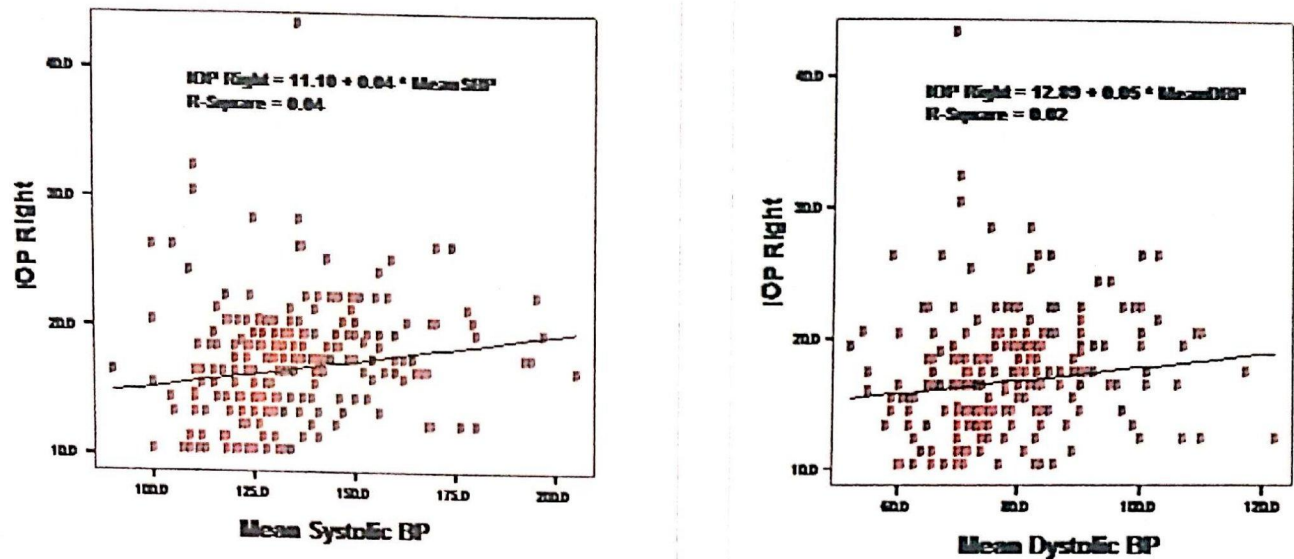


Fig 1 shows positive linear relationships between the blood pressures and IOPs. The relationships are represented by the given formulae-  $IOP = 11.10 + 0.04 \times \text{Mean SBP}$  (for systolic BP) and  $IOP = 12.89 + 0.05 \times \text{Mean DBP}$  (for diastolic BP).

### Discussion

The minimum and maximum ages of participants were 18 and 85 years respectively with a mean age of  $40.34 \pm 14.47$  years. This was comparable to the findings recorded by Anyika<sup>35</sup>, and Babalola et al.<sup>36</sup> The prevalence of normal IOP decreased slightly across the age groups from younger to older participants as shown in the results (table 3).

Similarly, the prevalence of elevated SBP and DBP was higher in the different older age groups ( $> 40$  years) than in the younger age groups. This implies that with increasing age, BP and IOP have a tendency to rise. Ajayi et al.<sup>37</sup> also reported a similar trend. This is not surprising as it is well-known that hypertension is commoner in people over 40 years of age. Age therefore, had demonstrable statistically significant positive correlations with both systolic and diastolic blood pressures in this study ( $P < 0.001$ ). These findings were similar to that documented by some studies in Nigeria<sup>28,29</sup> and elsewhere.<sup>3,4,5</sup>

The prevalence of ocular hypertension (high IOP) was higher in participants with high systemic blood pressure (19.9%) than those with normal (7.3%) and low blood pressures (16.7%). This is further illustrated in table 7. Older patients also had higher blood pressure measurements than younger patients.

The latter had a higher prevalence of normal IOP. There was a statistically significant positive correlation between intraocular pressure and systolic blood pressure in the study (see figure.1). A similar correlation was also noted between intraocular pressure and diastolic blood pressure contrary to reports in one of the cited literature.<sup>3</sup> This needs to be further investigated for a possible pathophysiological mechanism of action. The implication is that high blood pressure is a risk factor for the development of ocular hypertension and by extension glaucoma.

It is also important to note that some participants with low blood pressure in this study also had high IOP. This also has implications for the development of glaucoma in these participants as low blood pressure has been postulated to cause optic nerve hypoperfusion in the presence of raised IOP with glaucoma as the end result.<sup>27</sup> Similar findings were reported in the Beaver Dam longitudinal Eye study by Klein et al.<sup>38</sup> and others.<sup>3,22,23</sup> However, contrary to our study, some studies reported no positive correlation between intraocular pressure and blood pressure.<sup>24,25,26</sup> Variations in sample sizes, age ranges of participants and differences in methodology may account for the disparities noted.

## Conclusion

This study noted higher systolic and diastolic pressures as well as higher IOP among the older participants compared to the younger ones.

A positive correlation between intraocular pressure and systolic pressure as well as IOP and diastolic blood pressures respectively were also noted. This implies that there is a higher risk of development of ocular hypertension and glaucoma among the older age group(>40 years). In addition, participants with lower BP and high IOP are also at risk. It is therefore recommended that blood pressure and IOP measurements be routinely carried out on all patients attending the eye clinic. This would aid in early detection and management of those at risk of developing ocular hypertension and glaucoma.

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