ORIGINAL ARTICLE

Ocular Perfusion Pressure and Pulsatile Ocular Blood Flow in Normal and Systemic Hypertensive Patients

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ABSTRACT

Purpose: The purpose was to compare the ocular perfusion pressure (OPP) and the pulsatile ocular blood flow (POBF) in normal and systemic hypertensive patients.

Materials and Methods: Totally, 121 individuals (normal $n = 60$, systemic hypertension patients $n = 61$) were enrolled in this prospective age-matched comparative study. Intraocular pressure (IOP) and systemic arterial pressure were measured in seated position with 2 min interval between the measurements using Goldmann applanation tonometer (GAT) and tycos sphygmomanometer, respectively. The OPP was calculated as 2/3 of mean arterial pressure (MAP) minus IOP. After 5 min in the seated position POBF measurements were taken with the ocular blood flow (OBF) tonograph.

Results: Mean age was 57.5 years (range 35-72 years) in the normal group and 59.6 years (range 36-78 years) in the hypertensive group; majority of the patients were female (68.5% and 71% respectively in each group). Measured parameters in both the groups showed, systolic blood pressure (BP) (143.6 ± 20.5 mmHg vs. 121.9 ± 17.5 mmHg), diastolic BP (90.7 ± 13.5 mmHg vs. 80.1 ± 9.9 mmHg), MAP (108.4 ± 14.2 mmHg vs. 94.2 ± 11.2 mmHg), and OPP (57.6 ± 14.6 vs. 48.7 ± 10.6 mmHg) were significantly greater ($P = 0.001$) in systemic hypertensive patients in comparison to normals. However, there was no difference in OBF tonograph values in both groups. The IOP measured by the OBF tonograph was higher than GAT in both groups, but the difference was not statistically significant ($P = 0.41$).

Conclusion: Systemic hypertensive patients have a higher OPP in comparison to normal patients, but they do not have higher POBF. More studies are required to evaluate the role of the OPP in different ocular pathologies affecting the POBF.

KEY WORDS: Ocular perfusion pressure, pulsatile ocular blood flow, systemic hypertension

INTRODUCTION

Measurement of ocular blood flow (OBF) is useful to study the pathophysiology of several eye diseases as well as for evaluation of new therapeutic approaches.[1]

The fact is that the reduction of the OBF frequently precedes the structural damage in many eye diseases.[2] Many techniques exist for the measurement of OBF, however, there are no techniques available that provide direct measurement of blood flow in the eye.[1]

Blood flow in the eye can be affected by both ocular and systemic factors.[1] Abnormalities of the blood flow have been evaluated with diverse techniques, including fluorescein angiography, color doppler, doppler laser flowmetry, and OBF tonograph.[3] It has been demonstrated that the posterior portion of the optic nerve is vulnerable to ischemia when the ocular perfusion pressure (OPP) is reduced.[4] The total OBF is approximately 1 ml/min.[1] More than 90% of the total OBF supplies the vasculature of the choroidal circulation.[5] Since the retinal blood flow accounts for only 2-5% of the total ocular circulation, it can be assumed that the pulsatile OBF (POBF) is almost entirely due to the choroidal circulation.[5]

The perfusion pressure of ocular vessels is the difference between intravascular pressure (blood

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pressure [BP]) and intraocular pressure (IOP).[1] The eye is supplied by the ophthalmic artery in which the vessel BP is estimated to be 2/3 of the brachial arterial pressure.[1]

The differences in the responses of the retinal and choroidal circulation are evident when the OPP is reduced with the reduction of the choroidal circulation while the retinal circulation remains stable.[1] Pulsatile blood flow to the eye induces IOP variations from which mean pulsatile component of the blood flow to the eye has been estimated to be approximately 0.724 ml/min.[6]

In agreement with the vascular theory, low systemic arterial pressure relative to IOP can lead to a low OPP. On the other hand, systemic hypertension can increase the risk of damage to the small vessels of the ocular circulation.[7]

A reduction in mean arterial pressure (MAP) or an increase in IOP could diminish the ocular perfusion, but the accurate mechanism of the regulation of the IOP is still unknown. If the autoregulation mechanisms are continuous, the sanguineous flow will remain steady with a substantial fall of the ocular perfusion.[8]

The pulse of the cardiovascular system is also expressed in the eye with each systolic-diastolic cycle. The blood flows in to the ocular blood vessels during systole and continues to flow more slowly during diastole. This phenomenon implies a maximum IOP during systole and a minimum IOP during diastole. In this way, admitting itself that this relationship is identical, transitory changes of the IOP allow us to calculate changes in ocular volume. Pneumatonometric methods have been used to estimate POBF on the basis of changes in the measurements of IOP during the cardiac cycle.[6,9] OBF tonograph is the equipment sensitive to evaluate minimum changes of the IOP pulse and to correlate them with volume. However, it cannot determine the OBF of isolated parts of the intrinsic vascular net of the eye. Therefore, its principle is based on the total influx of blood in each cardiac systole.[9,10] and measures mainly the OBF in the choroids and anterior portion of the head of the optic nerve, supplied by the posterior ciliary vessels that contribute 80-90% of the OBF.[3]

The reduced OBF can have a decisive implication on the pathophysiology of many ocular illnesses like diabetic retinopathy, age-related macular degeneration, pigmentary retinopathy, myopia, glaucoma, and many of these disorders will have an association with systemic hypertension. Hence in this study, our aim was to determine the variations of OPP and a pulsatile component of total OBF in normal individuals and persons with systemic hypertension.

MATERIALS AND METHODS

The study was performed in adherence to the guidelines of the Declaration of Helsinki. The study protocols were approved by the Ethics Committee and our Institutional Review Board. Informed consent was taken from all enrolled patients.

A total of 121 individuals (n = 60 normal and n = 61 newly diagnosed systemic hypertensive) were enrolled in this prospective age-matched comparative study and, underwent a complete ophthalmologic examination including history of systemic medications, and systemic disease which can affect the blood flow, previous ocular diseases, trauma or surgery, slit lamp examination, Goldmann applanation tonometry (GAT), stereoscopic fundus examination and OBF tonograph measurements. Both the GAT and the OBF tonograph were calibrated according to the manufacturer's guidelines. Two measurements of IOP and systemic arterial pressure were taken with GAT and Tycos sphygmomanometer respectively, in seated position with 2 min interval between the measurements. MAP is calculated as 1/3 systolic BP (SBP) + 2/3 diastolic BP (DBP).[11] Pulse pressure amplitude is calculated as SBP−DBP.[7] The OPP is defined as 2/3 of MAP minus IOP (OPP = 2/3 MAP−IOP).[7,8] After 5 min in the seated position OBF measurements were taken with the OBF tonograph (Ocular Blood Flow Laboratories [UK] Ltd.).

Normal patient group included: >35 years of age, no ocular or systemic diseases, no previous ocular surgeries, and not on any systemic medications. Systemic hypertensive patient group included: >35-year-old, no known ocular pathology or previous surgeries; diagnosis of hypertension was made, when the average of 2 or more diastolic BP measurements on at least 2 subsequent visits was ≥90 mmHg or when the average of multiple systolic BP readings on 2 or more subsequent visits is consistently ≥ 140 mmHg. Isolated systolic hypertension was defined as systolic BP ≥ 140 mmHg and diastolic BP <90 mmHg. In addition, both the groups had patients with refractive errors between ±6.00D spherical and ±3.00 cylindrical, best corrected visual acuity ≥20/40, IOP <21 mmHg and cup/disc ratio <0.4 and absence of cup/disc asymmetry.

The same examiner (SG) took OBF tonograph measurements in all patients after the instillation of topical anesthetic eye drop (proparacaine HCl 0.5%). The OBF tonograph has one pneumotonometer with disposable tips that is placed against an anesthetized cornea to measure the IOP pulses. During the examination, the OBF tonograph produces a sound that helps the examiner to capture 5 complete IOP pulses. If after 20 s the equipment is not capable of detecting 5 complete pulses, the test is automatically interrupted. The OBF tonograph is capable of detecting initial tensional levels ranging from 5 mmHg up to 127 mmHg. The data supplied after the detection of the 5 pulses of the IOP are: IOP, minimum IOP (in mmHg), pulse amplitude, pulse volume (in µl), pulse rate (beats/minute) and POBF (µl/min). Only the right eye's values were considered for calculation using the Student's *t*-test.

RESULTS

Mean age was 57.5 years (range 35-72 years) in the normal patient group and 59.6 in the systemic hypertensive group (range 36-78 years). Female patients were more in both the groups (68.5% and 71%, respectively). SBP (143.6 ± 20.5 mmHg vs. 121.9 ± 17.5 mmHg) and DBP (90.7 ± 13.5 mmHg vs. 80.1 ± 9.9 mmHg), MAP (108.4 ± 14.2 mmHg vs. 94.2 ± 11.2 mmHg) and OPP (57.6 ± 14.6 vs. 48.7 ± 10.6 mmHg) were significantly greater in the systemic hypertensive patients in comparison to normals (Figure 1 and Table 1). There was no difference in all OBF tonograph values in both groups (Table 2). The IOP measured by the OBF tonograph was higher than GAT in both groups, but the difference was not statistically significant (*P* = 0.41).

DISCUSSION

Previous studies consider the normal IOP to be between 10 and 20 mmHg.[12]

Table 1: Variables of the study

Variables	Normal	Hypertensive	*P* value
IOP	14.1±3.8	14.7±3.1	0.345
Systolic pressure	121.9±17.5	143.6±20.5	0.001
Diastolic pressure	80.1±9.9	90.7±13.5	0.001
MAP	94.2±11.2	108.4±14.2	0.001
OPP	48.7±10.6	57.6±14.6	0.001

IOP: Intraocular pressure, MAP: Mean arterial pressure, OPP: Ocular perfusion pressure

Table 2: Descriptive statistic of the POBF tonograph variability

Variables	Normal	Hypertensive	*P* value
IOP (mmHg)	15.4±3.6	15.3±4.52	0.831
Pulse amplitude (mmHg)	3.6±2.9	3.9±1.92	0.498
Pulse volume (µl)	7.4±2.5	7.4±2.5	0.994
Heart rate (bpm)	77.3±12.7	79.6±16.1	0.505
POBF (µl/min)	20.3±5.7	20.1±5.3	0.895

POBF: Pulsatile ocular blood flow, IOP: Intraocular pressure

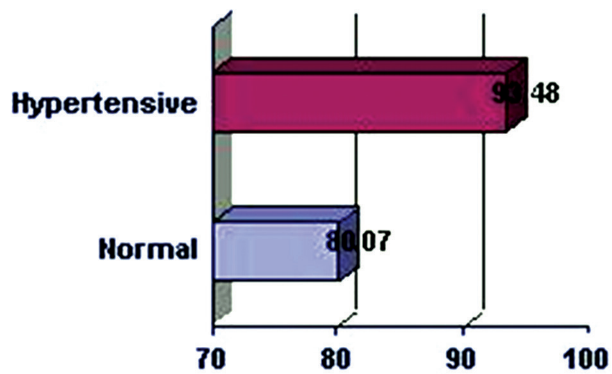

Figure 1: Comparison of the ocular perfusion pressure of normal and systemic hypertensive patients in mmHg (P = 0.001)

In this study, the mean IOP was 14.5 mmHg (standard deviation [SD] 3.5), with no significant difference between the groups and higher with the OBF tonograph. Confirming the good division of the groups, the MAP in our normal patients was 94.2 mmHg (SD 11.2), while in the systemic hypertensive patients was 108.4 mmHg (SD 14.78).

Leske *et al*. investigating the relationship between OPP and incidence of open-angle glaucoma reported a relative risk of 3.1 for patients with OPP <41.0 mmHg.[7] Our results have demonstrated an OPP of 48.7 mmHg (SD 10.6) in normal patients and of 53.5 mmHg (SD 14.6) in systemic hypertensive patients. This significant difference (P = 0.001) confirms a higher OPP in the systemic hypertensive patients.

Grunwald *et al*.[13] reported that glaucoma patients with systemic hypertension had higher optic nerve blood flow and may help to maintain adequate perfusion of the optic nerve. According to our results, although systemic hypertensive patients had greater OPP, they did not have greater POBF values measured by the OBF tonographsimilar to the findings of Niknam *et al*.[14] who used laser Doppler flowmetry.

There is evidence of an abnormal association between ocular perfusion parameters and systemic BP. However, these data refer to the long-term perfusion adaptation of the eye to BP rather than a short-term increase in BP.[15] Despite this, we cannot quantify with any current diagnostic method the real amount of blood in the anterior portion of the optic nerve, nor the level of existing gaseous exchange in this place. We also do not have a reliable technique to measure the blood flow in the anterior portion of the optic nerve. It is important to point out that although systemic arterial hypertensive patients have a better ocular OPP in comparison to the normal population, they do not necessarily have a better ocular nutrition, because of significant vascular alterations.[16]

Yang *et al*.[17] reported average POBF values of 11.16 µl/s for men and 14.03 µl/s for women, and suggested that this difference was a consequence of the faster cardiac frequency in the women. In another study, Massey and Crowhurst, found POBF values of 13.46 µl/s with women having greater POBF values. Myopia, increase of the IOP, and older age are related to reduced POBF values.[18] Our study showed POBF values were 20.31 µl/s (SD 0.98) in normal patients and 20.15 µl/s (SD 0.75) in systemic hypertensive patients. This difference was not statistically significant (P = 0.895).

The variability of the OBF tonograph measurements has been attributed to a great number of variables, e.g. age, sex, cardiac frequency, pregnancy, body position, and ocular axial diameter.[3] Although we observed a significant difference in systemic arterial pressure among normal and hypertensive patients they had close POBF readings suggesting the existence of intrinsic factors related to the ocular hemodynamics or extrinsic factors related to the device or its software that regulates the OBF or makes its measurement complex.

In summary, although the systemic hypertensive patients have a higher OPP in comparison to normal patients they do not have higher OBF. More studies are required to evaluate the role of the OPP and changes in POBF in various eye disorders.

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