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An investigation into the use of the ocular pulse as a diagnostic tool

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Abstract

If the IOP is measured continuously a cyclic fluctuation called the ocular pulse is noted. The diagnostic value of this pulse was studied by screening 80 subjects for their pulse amplitude values which when analyzed on the basis of the subjects' ages, were correlated with the presence or absence of diabetes and hypertension. Once the mean values for each age and condition group were calculated, it was found that, with age held constant, there was no significant difference between the mean values for the normal, diabetic, or hypertensive groups. While the inter-eye variation in ocular pulse amplitude values of one hypertensive population was significantly lower than that of the normal population, this difference approximated the measurement reliability. Still, the norms established by this study were able to isolate one subject with systemic vascular conditions which had not been previously determined by other objective methods.

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AN INVESTIGATION INTO THE USE OF THE OCULAR PULSE AS A DIAGNOSTIC TOOL

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ABSTRACT

If the IOP is measured continuously a cyclic fluctuation called the ocular pulse is noted. The diagnostic value of this pulse was studied by screening 80 subjects for their pulse amplitude values which when analyzed on the basis of the subjects' ages, were correlated with the presence or absence of diabetes and hypertension. Once the mean values for each age and condition group were calculated, it was found that, with age held constant, there was no significant difference between the mean values for the normal, diabetic, or hypertensive groups. While the inter-eye variation in ocular pulse amplitude values of one hypertensive population was significantly lower than that of the normal population, this difference approximated the measurement reliability. Still, the norms established by this study were able to isolate one subject with systemic vascular conditions which had not been previously determined by other objective methods.

INTRODUCTION

Tonometric measurements of the intraocular pressure (IOP) serve as an important tool in the detection and diagnosis of glaucoma. However, there may be additional information contained in these measurements that are of value to the eye-care practitioner. It has long been known that the IOP does not maintain a static level, but goes through a cyclic fluctuation that is synchronous with the heart beat. This cyclic fluctuation of the IOP has been referred to as the ocular pulse and it is produced by the bolus of blood entering the intraocular arteries with each heart beat.[1]

There are tonometers which can measure the ocular pulse amplitude such as the Schiotz and Goldmann tonometers. But since the average value for the ocular pulse amplitude varies between 2 to 3 mm Hg,[2] more sensitive readings are needed. Pneumatic applanation tonometry provides the sensitivity needed through its paper strip read-out which can be read quite accurately and retained for further study. This tonometer utilizes an air bearing which allows it to monitor the pressure needed to applanate a given area of the cornea on a continuous basis, thus recording the ocular pulse.[2] The pneumatic tonometer relates closely to the Goldmann tonometer,[3, 4] and can also accurately measure the IOP on grafted or diseased corneas when compared with readings taken from the MacKay-Marg tonometer.[5, 6] The pneumatic tonometer is also a portable instrument, which adds to its versatility. Most importantly, the pneumatic tonometer is capable of producing high fidelity measurements of the ocular pulse pressure oscillations.[7]

When the ocular pulse was measured on individuals having carotid stenosis, it was seen that the pulse amplitude in the affected eye was significantly reduced compared to that of the unaffected eye.[8] If the ocular pulse is affected by the presence of carotid stenosis, then other conditions affecting the circulatory system of the eye may also possibly affect the ocular pulse as well. If that should be true, then the ocular pulse can be an important diagnostic tool in the detection of these conditions. It is the goal of this project to measure changes in the ocular pulse amplitude seen in normal aging patients and then to compare these data with those taken from individuals with specific systemic conditions such as hypertension and diabetes. We wish to assess the usefulness of the ocular pulse in providing diagnostic information for persons with these conditions.

METHODS AND MATERIALS

A total of 80 subjects and 157 eyes were used in this project. The subjects consisted of volunteers from the King City retirement community in Oregon, Optometry students and Clinic patients from the Pacific University College of Optometry and patients from the Optometric Clinic of Barnes Veterans Administration Hospital in Vancouver, Washington. The age of the subjects ranged from 23 to 88 years old.

A double blind procedure was utilized. One experimenter screened the subjects to determine the presence of systemic diseases based upon the case history. This experimenter also measured the blood pressures and used a table of age-specific norms[9] to determine the presence of hypertension. A second experimenter, blind to the information gathered by the first experimenter, then took three measurements of the IOP on each eye. The IOP and ocular pulse amplitudes were then measured from the paper strip read-out with the aid of a 7X loupe. The reliability of these measurements are with $\pm$ .1 mm Hg. The mean of the three IOP and three pulse amplitude measurements were then calculated for each eye.

Based on the information gathered, the subjects were divided into groups based on age (in 20 year increments), on the presence or absence of systemic conditions (hypertension, diabetes), and on sex. The t-test was then used to determine if the ocular pulse amplitudes were significantly different between the groups.

RESULTS

The data collected were divided into age and condition subgroups which were then analyzed with the results appearing in Table 1. The mean ocular pulse amplitude values for the normal population age groups can be found in the third column of the table along with their corresponding standard deviations. These means were further broken down into normal means for each sex in their specific age groups. Two age groups had enough female subjects to make a comparison with the male subjects. The means for the males and females in the 20 to 39 age group differed by .02 mm Hg. While the values for the 60 to 79 age group differed by .22 mm Hg, a t-test showed this variation to be insignificant at the .10 level ($t = .80$, $df = 23$). Since sex appeared to have no altering effect upon the mean values, the ocular pulse mean amplitudes for the total sample population in each age group were used for comparison with the remaining condition groups.

The 60 to 79 age group had enough diabetic and hypertensive subjects to be utilized for a statistical comparison with the normal population.

Table 1

Ocular Pulse Amplitudes
(mm Hg)

Condition Groups

Age Groups		Normal ♂	Normal ♀	Normal Total	Hypertensive ♂	Hypertensive ♀	Hypertensive Total	Diabetics ♂	Diabetics Total
20-39	n	19	4	23	---	---	---	---	---
	$\bar{x}$	1.88	1.86	1.87	---	---	---	---	---
	sd	.83	.78	.82	---	---	---	---	---
40-59	n	11	1	12	1	---	1	---	---
	$\bar{x}$	1.57	2.21	1.61	1.28	---	1.28	---	---
	sd	.65	---	.65	---	---	---	---	---
60-79	n	15	10	25	10	2	12	4	4
	$\bar{x}$	1.72	1.94	1.81	1.57	1.72	1.59	1.64	1.64
	sd	.69	.65	.67	.87	---	.79	.99	.99
80	n	3	---	3	1	1	2	---	---
	$\bar{x}$	1.51	---	1.51	.87	1.50	1.19	---	---
	sd	.56	---	.56	---	---	---	---	---

Table 2

Average Difference in Ocular Pulse Amplitude
Values (OD vs OS) Per Subject
(mm Hg)

Age Group	$\bar{x}$	sd
20-39	.25	.19
40-59	.29	.25
60-79		
normal group	.31	.25
hypertension group	.15	.17
80	.25	---

A t-test indicated no significant difference in the ocular pulse amplitudes between the normal population and the hypertensive population in this age group (t = .884, df = 35). Likewise, no significant difference between the diabetic population and the normal population amplitude values was indicated by a t-test (t = .443, df = 27). Therefore, as groups, the hypertensive and diabetic populations did not differ from the normal population based upon ocular pulse amplitude values.

Since group analysis failed to indicate any diagnostic value of the ocular pulse, individual analysis was examined. Each age group was inspected for subjects who had average ocular pulse amplitude values falling outside of two standard deviations of the mean for their respective normal populations. Three such individuals were found. One in the 20 to 39 age group and one in the 60 to 79 age group were found to have amplitude values higher than two standard deviations from the mean, but neither was found to have any symptoms of systemic disorders. One individual in the 60 to 79 age group was found to have average values below two standard deviations of the mean and his data appears below:

> 61 year old white male, previous history of angina, hypercholesteremia, and hypertension which has been treated for the last 10 years.
>
> BP: 110/80.
> OD: IOP -- 13.78 mm Hg (avg) Pulse amp -- .27 mm Hg (avg)
> OS: IOP -- 13.16 mm Hg (avg) Pulse amp -- .25 mm Hg (avg)

The mean ocular pulse amplitude for his age group is 1.81 mm Hg, standard deviation .67 mm Hg.

One final test was performed on the data to indicate its usefulness. As the data was being collected, it was noted that there were small variations in the ocular pulse amplitude values between the two eyes from the same subjects. These variations were averaged and appear in Table 2. As can be seen, the average variation remains fairly constant for the normal population regardless of the age group. However, the mean variation of the normal population in the 60 to 79 age group ($\bar{X}$ = .31 mm Hg, SD = .25 mm Hg) differs significantly from the mean value of its hypertensive population ($\bar{X}$ = .15 mm Hg, SD = .17 mm Hg) as indicated by a t-test ($t = 2.025$, $df = 24$, significant beyond .025 level). Thus, the ocular pulse amplitude values obtained from the hypertensive subjects showed less inter-eye variation than those obtained from the normal subjects.

DISCUSSION

In order to determine if the value of the ocular pulse amplitude can be used as a diagnostic tool for identifying the presence of systemic conditions which may alter it, it is necessary to first thoroughly examine its range of values in the normal population. It was found that the normal population did have a change in its mean pulse value with increasing age, but no discernable pattern could be identified. If the mean pulse amplitude values for each age group were combined with their standard deviations to produce a range of values for each age category, the groups formed one large group which could not be separated based only upon ocular pulse values. It was also seen that sex had no noticeable effect upon the ocular pulse amplitudes in the normal population.

With the values of the normal population identified, populations with diagnosed systemic conditions could be examined for variations in their ocular pulse values. With age held constant, diabetic and hypertensive groups were found to have mean amplitude values which did not differ significantly from the mean values of the normal population. The only item which allowed separation of the hypertensive population from the normal population was the mean inter-eye variation in pulse amplitudes for a given subject. This difference in amplitudes between the two eyes for the hypertensive group was .16 mm Hg less than that seen in the normal group. But since the system used to measure the ocular pulse amplitude values had a reliability of $\pm$ .10 mm Hg, the significance of this difference is all but nullified for any practical usage. Therefore, based solely upon the use of ocular pulse amplitudes, it was not possible to determine the identity of one condition group from another.

Since group analysis did not indicated any real significance, individual analysis of the data was examined. Each age group was screened for individuals who had mean aplitude values which were outside two standard deviations of the mean for the normal population of that age group. Only one individual had values lower than two standard deviations from the mean and he had a combination of long-term angina, hypercholesteremia, and hypertension. Since his blood pressure and IOP were normal, his ocular pulse amplitudes were the only objective data which indicated any abnormality. This may indicate that while the system used here could not allow one to identify hypertensive or diabetic populations from the normal population, it may allow separation of some diabetic or hypertensive individuals from the normal population.

CONCLUSIONS

This project was designed to study whether routine IOP measurements made with the pneumatic tonometer could be used to yield additional information regarding the health of the patient. While it was not possible to separate the diabetic or hypertensive subject groups from the normal groups in the population screened in this project, a larger scaled study may yield age groups with less variation of their mean values enabling more precise separation of the condition groups. A print-out system which allowed greater enhancement of the ocular pulse amplitude might also improve the ability to separate the various condition groups. Nevertheless, this study did propose a series of age-specific normal values for ocular pulse amplitudes which were able to isolate a subject with a compound vascular disorder. If a patient is screened and is found to have mean ocular pulse amplitude values below two standard deviations of the mean value for his/her age group as established in this study, further evaluation of the patient's systemic and ocular health should be made to rule out the presence of a systemic disorder which may be responsible for the abnormal value.

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