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The effect of ambient illumination and time in the dark on force required to perceive a pressure phosphene

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The effect of ambient illumination and time in the dark on force required to perceive a pressure phosphene

Abstract
Purpose: Intraocular pressure has been correlated with the force required to allow perception of a pressure phosphene. The Proview tonometer is based on this principle and can be used to self monitor intraocular pressure. This study explores the question of whether dark adaptation affects the force required and thus the intraocular pressure indicated with the Proview tonometer.

Methods: Fifteen healthy subjects measured and recorded intraocular pressure with the Proview tonometer at five minute intervals for 25 minutes in a dark room. They were also monitored throughout this time with the Tonopen tonometer. In addition, intraocular pressures were measured prior to and following the 25 minutes in the dark using the Goldmann tonometer.

Results: After ten minutes in the dark the intraocular pressure indicated by the pressure phosphene tonometer had increased significantly compared to baseline measurements and concurrent Tonopen measurement. The force required to allow perception of the phosphene increased with each successive five minute interval until the data collection was stopped at 25 minutes and the subjects returned to normal room illumination. The Goldmann and Tonopen measurements did not vary, indicating there had been no actual change in intraocular pressure.

Discussion: Intraocular pressure as measured with the pressure phosphene method is independent of ambient illumination as there was no difference after just five minutes in the dark, but length of time in the dark is highly correlated with an increase of measured pressure. Although this doesn't match the dark adaptation curve, it indicates that the force needed to create the phosphene perception is affected by some ocular change that occurs with prolonged period in dim illumination. Patients using the Proview tonometer should be advised to avoid taking measurements under such conditions in order to avoid spurious high readings.

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THE EFFECT OF AMBIENT ILLUMINATION AND TIME IN THE DARK ON FORCE REQUIRED TO PERCIEVE A PRESSURE PHOSPHENE

By
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Abstract

Purpose: Intraocular pressure has been correlated with the force required to allow perception of a pressure phosphene. The Proview tonometer is based on this principle and can be used to self monitor intraocular pressure. This study explores the question of whether dark adaptation affects the force required and thus the intraocular pressure indicated with the Proview tonometer. Methods: Fifteen healthy subjects measured and recorded intraocular pressure with the Proview tonometer at five minute intervals for 25 minutes in a dark room. They were also monitored throughout this time with the Tonopen tonometer. In addition, intraocular pressures were measured prior to and following the 25 minutes in the dark using the Goldmann tonometer. Results: After ten minutes in the dark the intraocular pressure indicated by the pressure phosphene tonometer had increased significantly compared to baseline measurements and concurrent Tonopen measurement. The force required to allow perception of the phosphene increased with each successive five minute interval until the data collection was stopped at 25 minutes and the subjects returned to normal room illumination. The Goldmann and Tonopen measurements did not vary, indicating there had been no actual change in intraocular pressure. Discussion: Intraocular pressure as measured with the pressure phosphene method is independent of ambient illumination as there was no difference after just five minutes in the dark, but length of time in the dark is highly correlated with an increase of measured pressure. Although this doesn't match the dark adaptation curve, it indicates that the force needed to create the phosphene perception is affected by some ocular change that occurs with prolonged period in dim illumination. Patients using the Proview tonometer should be advised to avoid taking measurements under such conditions in order to avoid spurious high readings.
Introduction

The finding that the amount of mechanical pressure applied to the eye can create the perception of a deformation phosphene, which can be then be related to intraocular pressure, is the basis for the Proview eye pressure monitor device. Fresco first described the pressure phosphene tonometer in 1997. Since that time the device ("Proview") has been licensed and distributed, principally for the purpose of home monitoring of intraocular pressure. The ability to have patients self-monitor intraocular pressure has significant practical application, particularly for the purpose of establishing diurnal pressure variation[4]. In 1998 Fresco published results indicating close agreement between the readings obtained with this device and the Goldmann applanation tonometer [1, 2]. The Proview eye pressure monitor is a pencil-like device which contains a small flat probe, an internal spring, and a readable pressure scale. [3]

The mechanism by which the phosphene is generated is not well understood. The phenomenon of the pressure phosphene was a subject of discussion among scholars long before the invention of Proview. As early as 327-287 B.C. Alcmaeon noted, “fire within the eye when pressing a closed eyelid”. [5] He believed that this was caused by light coming out of the pupil. About ten years later Aristotle agreed with Alcmaeon in the observation that “when the eye is pressed and moved, fire seems to flash out”. [5] He noted that this happened regardless of illumination. One of the original theories dealing with phosphenes was explained by the Arabian scientists (803-873 A.D.) and physicians who believed phosphenes could only be seen with eye movements. In 965-1040 A.D. the theories of phosphenes became more complex, involving the anatomy of the human eye. According to Ibn al-Haitham
"an image of the visual world is formed in the lens of the eye and the spritus visibilis produced in the brain near the chiasma of the optic nerves, flows in small vessels through the optic nerve to the retina and within the retina to the crystalline lens where it interacts with the image of the objects formed there." [5]

In 1619 Christoph Scheiner, a leading scientist of his time, observed that the phosphene perception is localized on the opposite side of physical deformation and that phosphene observation occurs regardless of room illumination. Scheiner postulated the phosphene is due to generation of light through the vitreous body and transmission of it to the retina. [5]

Through experimentation in 1742, Morgagni showed that mechanical forces on the retina, but not light emitting from the pupil, caused the light perception called phosphene. In 1819 Purkinje wrote a doctoral thesis in which he came to the conclusion that phosphenes were caused by stretching of optic nerve, which results in "the substance of nerve electrical antagonistic processes causing the development of light." [5]

More recent research on animal models occurred between 1981 and 1987 [5,6,7,8,9]. After extensive experimentation performed on cats, Grusser and colleagues concluded the deformation of the globe causes a pulling of the retinal cells. Consequently, a chain reaction occurs, affecting numerous cells of the retina, more specifically horizontal and ganglion cells. They surmised that the stretch of horizontal cells and consequent stimulation of retinal ganglion cells are the fundamental basis for perception of pressure phosphenes. [7]

One question explored by Grusser and co-workers centered around the idea that ambient light conditions or dark adaptation might affect the perception or generation of the phosphene. In the Grusser study, a clamp or a rod-shaped mechanical device was used for eyeball indentation on anaesthetized cats. The mechanical deformation of the eyeball was measured using an electrical stimulation that was applied near the optic chiasm. The Grusser experiment on animals had both benefits and shortcomings. The
anatomy of the eyeball in cats is similar to the anatomy of the human eye. On the other hand, since animal models were used, a direct correlation to humans cannot be made. The firing pattern of neurons was used to determine the amount of pressure needed to perceive a phosphene in the cat models. These experiments were conducted in both light and dark conditions. It is questionable how much pressure was required in order for the cat to perceive the phosphene. After the analysis of the cat study results, Grusser and colleagues came to the conclusion that the effect of dark adaptation was minimal when the eyeball was deformed. On the contrary others have suggested that there are significant differences in the amount of pressure required to stimulate the phosphene in light versus dark conditions [10]. If ambient lighting or status of dark adaptation has a significant effect, this could in turn potentially alter the results obtained during home monitoring of intraocular pressure using this technique.

In order to explore the question of whether dark adaptation affects the force required to see the phosphene, and thus the intraocular pressure measured with the Proview tonometer, we evaluated the effect of time in a dark room on Proview measurements at five minute intervals. Intraocular pressures were monitored throughout this time with the Tonopen tonometer, in order to rule out an actual change in intraocular pressure. In addition, intraocular pressures were measured prior to and following the dark period using the Goldmann tonometer.

Methods

Subjects. Fifteen subjects, seven males and eight females, with ages ranging from twenty to thirty, completed the experiment. Recruited subjects were screened for and
excluded if they had any corneal problems or a history of corneal surgery. In addition, one week prior to the experimentation, the subjects were screened on their ability to perceive phosphenes using Proview. During the screening, all subjects were told that a phosphene should appear as a dark circle with a yellow or orange ring around it. Using the right hand, the subjects were asked to press nasally with their index finger on their upper eyelid, above their lash line, until a phosphene was perceived. This technique (using the index finger to practice seeing the phosphene) differed from the Proview manual, but was done in order to ensure subject comprehension of the instruction set. Next, the subjects were given the Proview and were instructed, as described in the instruction manual, to look down towards their right shoulder. Then the subjects were told to press the Proview probe on their closed eyelid until the perception of a phosphene was achieved. Finally, the subjects were instructed to remove the Proview and hand it to the experimenter. [3] All of the screenings were conducted in ambient room illumination. This process was repeated until they were able to obtain four consistent readings, all within two mmHg. Five subjects were unable to get repeatable measures with the device and were therefore excluded. The excluded group did not differ from the experimental group in gender, age, or refractive error.

Procedure. All of the pressure readings were done on the right eye only and repeated three times at each interval. Visual acuity and slit lamp evaluation were performed on both eyes at the start and conclusion of each subject's turn. Goldmann tonometry and Proview measurement were performed under normal room illumination for baseline measurement and the subject was then escorted to the photographic dark
room for the dark phase. The dark room was located in a separate building from where the initial and final Goldmann and Proview readings were conducted to minimize experimenter bias. Proview measurements were then taken in a dark room at 5 minute intervals for a period of 25 minutes. The subjects were asked to hand the Proview directly to the experimenter immediately after seeing the phosphene without looking at the pressure indicator on the device.

The Tonopen reading was taken in the dark room immediately upon entering, after fifteen minutes and after twenty-five minutes. Goldmann tonometry required one drop of fluress, in the right eye only, both before and after the dark room phase. The tonopen required one drop of propracaine, 0.5%, in the right eye only, and was instilled three to four times depending on the subject's sensitivity.
Results

Measurements taken before and after the dark room session showed no change in the measurement with the Goldmann and Proview instruments. (Figure 1)

![IOP Measures before and after dark room](image)

Figure 1. Mean IOP for two pre- and post-test measures. Median, max and minimum readings indicated. GAT = Goldmann applanation tonometry. Pro = Proview tonometer.

Measurements taken with the Tonopen in the dark room indicated no change in pressure while in the dark. Out of fifteen subjects, only one subject showed an overall decrease in intraocular pressure readings in the dark room using Proview. The decrease in the Proview readings in this patient could have been due to the subject's fatigue or lack of motivation. After the experiment was completed, the subject confessed that he did not
perform the test according to protocol. Instead he handed back the Proview to the examiner before seeing the phosphene, due to lack of interest and fatigue. The remaining fourteen subjects showed an increase in both the mean and the range of measured intraocular pressure in the dark room using Proview, but no change using the Tonopen. Figure 2 illustrates the stable Tonopen measurements as well as the increase in the Proview measures with time. At no point was the Tonopen measurement different from the baseline measures.

Figure 2 displays change in measured pressure with time in dark. Fisher's LSD (Protected t-tests) was applied. Table 1 indicates significant differences between the various time intervals.

![Change in Measured IOP with Time in the Dark](image)

Figure 2. Mean change (delta) in IOP in darkness with respect to baseline.
Table 1: Results from Fisher's LSD (Protected t-Tests) comparing all combinations of group means.

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Discussion

These results indicate a nearly linear increase in Proview readings in the dark room, with no actual change noted in intraocular pressure based on the Tonopen and Goldmann readings. Furthermore, the results indicate that more force was needed in order for the subjects to perceive the phosphene after a period of time in the dark. One possible interpretation of the results could be related to contrast sensitivity.

Since phosphenes can be perceived as a dark circle surrounded by a yellow halo, it is possible that contrast may play a role in the way a phosphene is perceived. Light illumination provides the best contrast for perceiving the phosphene. This is because a dark phosphene in contrast with the light surround creates a high contrast situation. As we move to dark illumination, the dark background along with the dark phosphene, leads to a reduction of contrast. Therefore, after dark adaptation, the subject tends to exert more pressure in order to initially perceive the phosphene resulting in spurious Proview readings. This supports Brindley's idea that "the threshold force for producing a deformation phosphene is about four times higher in darkness than in bright light." [10]
The following question still remains: why does more pressure needs to be exerted by the subjects over time in the dark room in order to perceive the phosphene?

Research has shown "at least 50% of individuals will have a peak IOP outside normal office hours. [11] Based on numerous studies report by Zeimer, intraocular pressure follows a diurnal curve that peaks in early morning hours but fluctuates and progressively decreases throughout the day. These studies were conducted by measuring a series of intraocular pressures in glaucoma and normal patients throughout a 24 hour period. [12] In lieu of in-office serial tonometry, clinicians may offer the use of Proview for home monitoring, so it would be a benefit to have a home monitoring device. Sehi and Flanagan have shown that the Proview is a repeatable and reliable measure of intraocular pressure as compared to Goldmann [4]. Home monitoring of intraocular pressure with the Proview tonometer is a simple procedure with a relatively inexpensive, portable, and easily maintained instrument that requires no power source. It is the clinicians' responsibility to educate the patient on the proper use of the device.

In conducting this research we came to the conclusion that dim ambient lighting, and in particular the time in the dark, can influence intraocular pressure readings as measured by Proview. Therefore, it is recommended that patients refrain from using Proview after prolonged periods in the dark. For instance, when the patient first wakes up in the morning, they should delay Proview readings until in the light for several minutes. This is one of the potential shortcomings of the Proview device. More studies dealing with the effect of ambient lighting in conjunction with Proview need to be conducted to determine how long the effect lasts. Another shortcoming of the Proview device lies in the fact that the Proview measurements rely on the patient's ability to see
the phosphene. Based on our experiment, regardless of how much pressure was applied to the eyelid, some subjects were unable to perceive a phosphene at all. The inability to see the phosphene was based on the subject's description.

Previous research suggested that phosphene perception is due to mechanical deformation of photoreceptor cells. If this were true, our results would have been expected to follow the dark adaptation curve, but our results did not support this. More research would need to be done in order to determine the underlying cause for the variation in force needed to perceive the phosphene after a period of time in the dark.

As follow up to this experiment, a longer period in the dark is necessary to determine if and when the Proview reading levels off. In this experiment, total time in the dark was twenty-five minutes. This length of time was chosen based on our original idea that the curve generated would follow the dark adaptation curve. On the contrary, the twenty-five minute period in the dark was not sufficient time to allow the Proview pressure readings to plateau, though the lack of significant difference between the 20 and 25 minute intervals does indicate that this may have begun.
Acknowledgements

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