Original Article

‘Dark Adaptation’ a Pitfall in Evaluation of Reliability of Visual Fields of Second Eye in Glaucoma Patients

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Purpose: To analyze that dark adaptation may be a pitfall in evaluation of reliability of visual fields of second eye of glaucoma patients.

Materials & Methods: The study was conducted in the Department of Ophthalmology, Abbasi Shaheed Hospital from January 2007-June 2008.

In this study evaluation of patients were randomly selected from the glaucoma clinic who went for routine perimetery for the first time. Patients were examined in detail, diagnosis was established and were sent for field examination to assess the extent of damage by glaucoma .Perimetery was done on Octopus 300 series perimeter after setting all the parameters and under constant supervision.

Results: A total of 117 patients were examined from January 2007- June 2008. A male preponderance was seen and majority of the patients belonged to 60-70 years age group making up to 37.4 %followed by 40-50 years age group i.e 25.6%. Maximum number of patients have percentage of false positives and false negatives between the range of 0-5 % which shows that a large number of patients(62% patients in false positives and 79% patients in false negatives in their right eyes and 68.4% patients in false positives and 74.6% patients in false negatives in their left eyes) had a reliable field, 96(82%) patients had reliability factor in acceptable normal range their right eyes and 104(89%) patients had reliability factor in acceptable normal range in left eyes. It shows that majority of patients had a reliable field test. It is obvious that fields of left eyes were more reliable as compared to right eyes.

Conclusion: It was concluded that the results of second eye of the patients were more reliable as compared to the reliability of the results of first eye. This could be due to the phenomenon of dark adaptation .The second eye gets dark adapted behind the occluder as the patient proceeds the test for first eye, and thus produces better results when examined. So dark adaptation may be a pitfall in interpretation of reliability of visual fields of second eye.

The eye operates over a large range of light levels. The sensitivity of our eye can be measured by determining the absolute intensity threshold, that is, the minimum luminance of a test spot required to produce a visual sensation. This can be measured by placing a subject in a dark room, and increasing the luminance of the test spot until the subject reports its presence. Consequently, dark adaptation refers to how the eye recovers its sensitivity in the dark following exposure to bright lights. Aubert (1865) was the first to estimate the threshold stimulus of the eye in the dark by measuring the electrical current required to render the glow on a platinum wire just visible. He found that the sensitivity had increased 35 times after time in the dark, and also introduce for the term "adaptation"[1].

Dark adaptation forms the basis of the Duplicity Theory which states that above a certain luminance level (about 0.03 cd/m^2), the cone mechanism is involved in mediating vision; photopic vision. Below this level, the rod mechanism comes into play providing scotopic (night) vision. The range where two mechanisms are working together is called the mesopic range, as there is not an abrupt transition between the two mechanism. The dark adaptation curve shown below depicts this duplex nature of our visual system (fig. 1). The first curve reflects the cone mechanism. The sensitivity of the rod pathway improves considerably after 5-10 minutes in the dark and is reflected by the second part of the dark adaptation curve. One way to demonstrate that the rod mechanism takes over at low luminance level, is to observe the colour of the stimuli. When the rod mechanism takes over, coloured test spots appear colourless, as only the cone pathways encode colour. This duplex nature of vision will affect the dark adaptation curve in different ways and is discussed below. To produce a dark adaptation curve, subjects gaze at a pre-adapting light for about five minutes, then absolute threshold is measured over time (Fig. 1). Pre-adaptation is important for normalisation and to ensure a bi-phasic curve is obtained.

From the above curve, it can be seen that initially there is a rapid decrease in threshold, then it declines slowly. After 5 to 8 minutes, a second mechanism of vision comes into play, where there is another rapid decrease in threshold, then an even slower decline. The curve asymptotes to a minimum (absolute threshold) at about 10^{-5} cd/m^2 after about forty minutes in the dark[1].

Factors Affecting Dark Adaptation

1. Intensity and duration of the pre-adapting light.
2. Size and position of the retina used in measuring dark adaptation.
3. Wavelength distribution of the light used.
4. Rhodopsin regeneration.

Intensity and duration of pre-adapting light: Different intensities and duration of the pre-adapting light will affect dark adaptation curve in a number of areas. With increasing levels of pre-adapting luminances, the cone branch becomes longer while the rod branch becomes more delayed. Absolute threshold also takes longer to reach. At low levels of pre-adapting luminances, rod threshold drops quickly to reach absolute threshold (Fig. 2)[2].

The shorter the duration of the pre-adapting light, the more rapid the decrease in dark adaptation (fig. 3). For extremely short pre-adaptation periods, a single rod curve is obtained. It is only after long pre-adaptation that a bi-phasic, cone and rod branches are obtained.

Size and location of the retina used: The retinal location used to register the test spot during dark adaptation will affect the dark adaptation curve due to the distribution of the rod and cones in the retinal (Fig. 4).

When a small test spot is located at the fovea (eccentricity of 0^o), only one branch is seen with a higher threshold compared to the rod branch. When the same size test spot is used in the peripheral retina during dark adaptation, the typical break appears in the curve representing the cone branch and the rod branch (Fig. 5-6).

A similar principle applies when different size of the test spot is used. When a small test spot is used during dark adaptation, a single branch is found as only cones are present at the fovea. When a larger test spot is used during dark adaptation, a rod-cone break would be present since the test spot stimulates both cones and rods. As the test spot becomes even larger, incorporating more rods, the sensitivity of the eye in the dark is even greater.

Wavelength of the threshold light: When stimuli of different wavelengths are used, the dark adaptation curve is affected. From (Fig. 7) below, a rod-cone break is not seen when using light of long wavelengths such as extreme red. This occurs due to rods and cones having similar sensitivities to light of long wavelengths (Fig. 8). Figure 8 depicts the photopic and scotopic spectral sensitivity functions to illustrate the point that the rod and cone sensitivity difference is dependent upon test wavelength (although normalization of spatial, temporal and equivalent adaptation level for the rod and cones is not present in this figure). On the other hand, when light of short wavelength is used, the rod-cone break is most prominent as the rods are much more sensitive than the cones to short wavelengths once the rods have dark adapted[2].

Subjects were pre-adapted to 2000mL for 5 minutes. A 3 degree test stimuli was presented 7 degrees on the nasal retina. The colours were: RI (extreme red)=680 nm; RII (red)=635 nm; Y (yellow)=573 nm; G (green)=520 nm; V (violet)=485nm and W white).

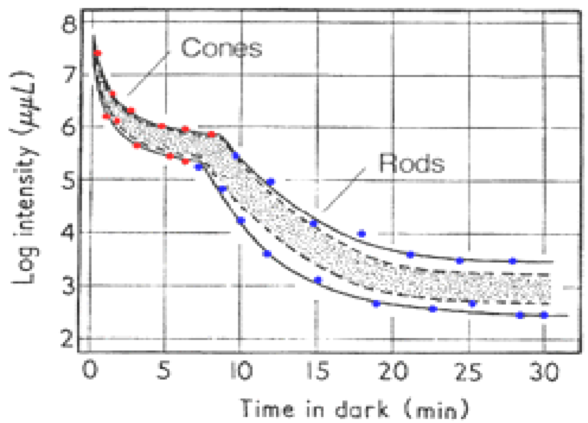


Fig. 1. Dark adaptation curve. The shaded area represents 80% of the group of subjects.

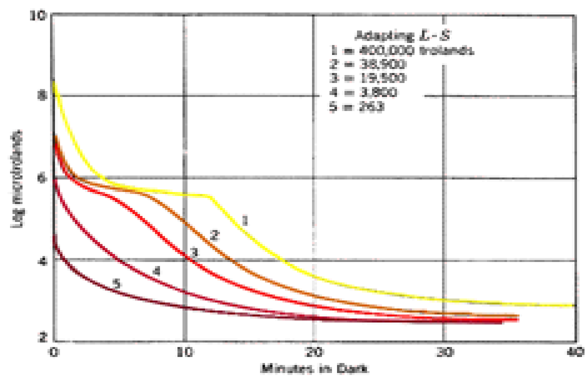


Fig. 2. Dark adaptation curves following different levels of pre-adapting luminances.

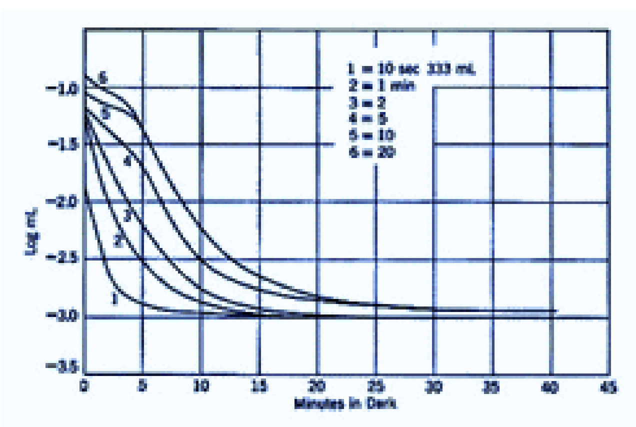


Fig. 3. Dark adaptation curves following different duration of a pre-adapting luminance.

Rhodopsin regeneration

Dark adaptation also depends upon photopigment bleaching. Retinal (or reflection) densitometry, which is a procedure based on measuring the light reflected from the fundus of the eye, can be used to determine

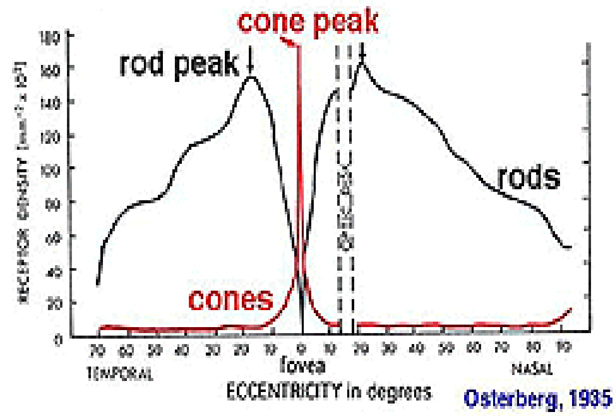
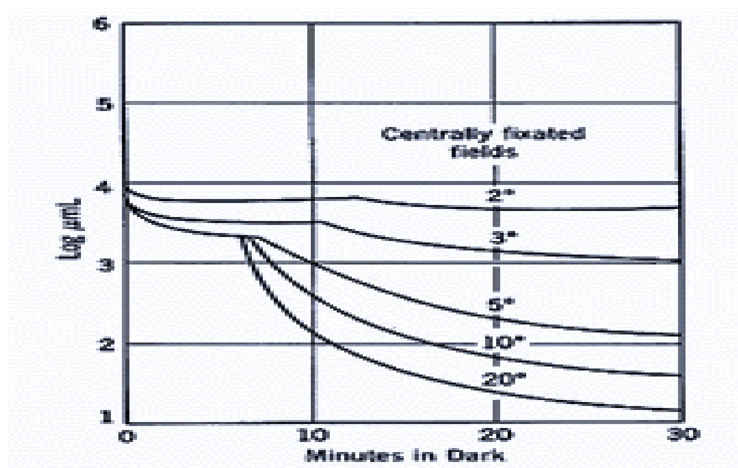


Fig. 4. Distribution of rod and cones in the retina.



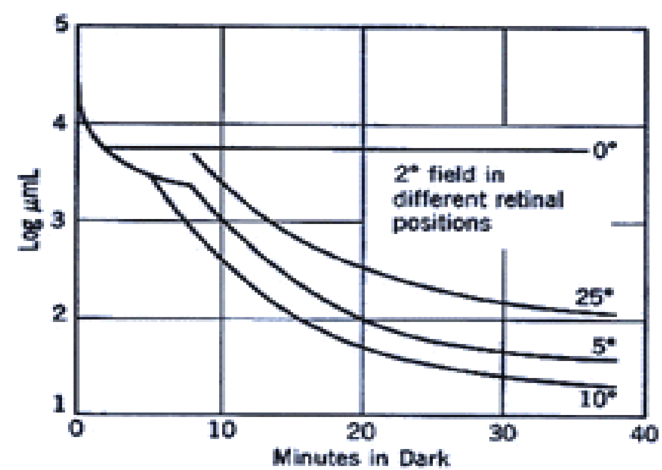


Fig. 5,6: Dark adaptation measured with a 2° test spot at different angular distances from fixation.

the amount of photopigment bleached. Using retinal densitometry, it was found that the time course for dark adaptation and rhodopsin regeneration was the

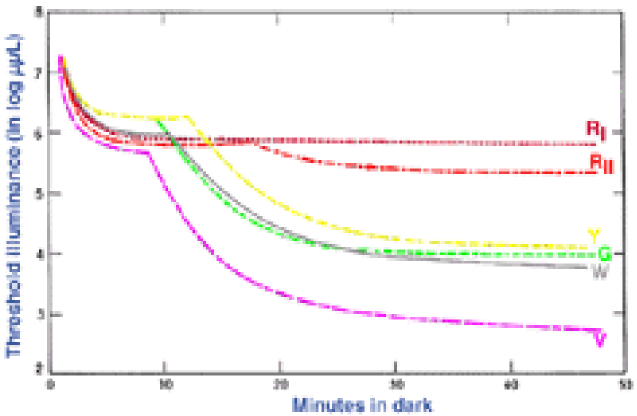


Fig. 7. Dark adaptation curve using different test stimuli of different wavelengths

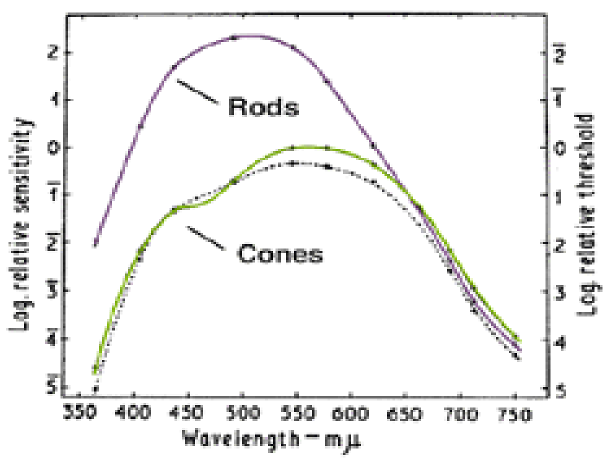


Fig. 8. Scotopic (rods) and photopic (cones) spectral sensitivity functions. (3)

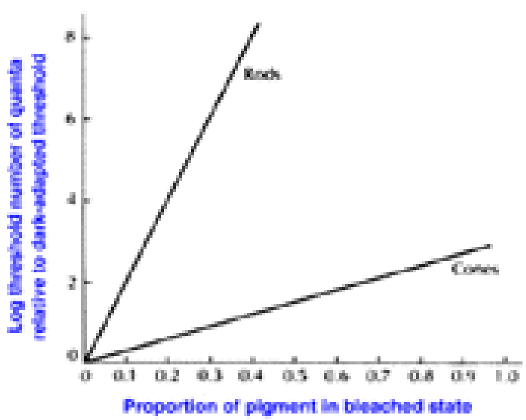


Fig. 9. Log relative threshold as a function of the percentage of photopigment bleached.

same. However, this does not fully explain the large increase in sensitivity with time. Bleaching rhodopsin by 1% raises threshold by 10 (decreases sensitivity by 10). In (Fig. 9), it can be seen that, bleaching 50% of rhodopsin in rods raises threshold by 10 log units while the bleaching 50% of cone photopigment raises threshold by about one and a half log units. Therefore, rod sensitivity is not fully accounted for at the receptor level and may be explained by further retinal processing on cone thresholds.

With dark adaptation, we noticed that there is progressive decrease in threshold (increase in sensitivity) with time in the dark. As the threshold decreases and sensitivity increases the results of visual fields of second eye which has got dark adapted by this time may be much better or reliable as compared to the results of first eye[3].

Table 1: Gender Distribution

Gender	No: of patients n (%)
Male	77 (65.8)
Female	40 (34.2)

Table 2: Age Distribution

Age in years	No of patients n (%)
10-20	3 (2.7)
20-30	6 (5.1)
30-40	9 (7.8)
40-50	30 (25.6)
50-60	18 (15.4)
60-70	44 (37.4)
70-80	7 (6)

Table 3: False Positives in Right & Left Eye

Range of false positives	Right Eye	Left Eye
	No of patients n (%)	No of patients n (%)
0-5	72 (62)	80 (68.4)
5-10	0 (0)	1 (0.8)
10-15	28(2.4)	21 (17.9)
15-20	1 (0.8)	2 (18)
20 and above	16 (13.2)	13 (11.1)

Table 4: False negative in Right & Left Eye

Range of false negative	Right Eye	Left Eye
	No of patients n (%)	No of patients n (%)
0-5	92 (79)	87 (74.6)
5-10	1 (0.8)	4 (3.4)
10-15	11 (9.2)	11 (9.2)
15-20	3 (2.5)	1 (0.8)
20 and above	10 (8.5)	14 (12)

Table 5: Reliability Factor

Reliability factor	Right Eye	Left Eye
	No of patients n (%)	No of patients n (%)
0-5	57 (48.8)	67 (57.3)
5-10	29 (24.8)	28 (24)
10-15	10 (8.5)	9 (7.7)
15-20	6 (5.1)	5 (4.3)
20 and above	15 (12.8)	8 (6.75)

Light Adaptation

With dark adaptation, we noticed that there is progressive decrease in threshold (increase in sensitivity) with time in the dark. With light adaptation, the eye has to quickly adapt to the background illumination to be able to distinguish objects in this background. Light adaptation can be explored by determining increment thresholds. In an increment threshold experiment, a test stimulus is presented on a background of a certain luminance. The stimulus is increased in luminance until detection threshold is reached against the background Therefore, the independent variable is the luminance of the background and the dependent variable is the threshold intensity or luminance of the incremental test required for detection. Such an approach is used when visual fields are measured in clinical practice[4].

MATERIALS NAD METHODS

The patients were randomly selected from the Glaucoma clinic when they were registered and were sent for routine perimetric examination for the first time. Before sending for field test these patients were thoroughly examined. The examination included detailed slit lamp examination, measurement of intra-ocular pressure by applanation tonometery, detailed fundoscopy to access the status of optic disc and gonioscopy where required. The type of glaucoma was diagnosed and patients were sent for routine perimetry.

The inclusion criteria were new referral, no previous threshold visual field tests, absence of hearing or cognitive impairment, understanding language, and best corrected visual acuity of 6/36 or better in both eyes.

The exclusion criteria were patients who had alraedy undergone the examination once, patients with hearing problems and patients with dense cataracts and corneal opacities.

The perimetry was carried out on Octopus 300 series perimeter using standard glaucoma G1 dynamic white on white programme, after instructing the patient properly. Patient data regarding name, ID, gender, visual acuity and intraocular pressure was fed in the computerized perimeter. The patients were seated comfortably and their spectacle number placed in the given socket. The pupil size was noted The patients were supervised throughout the test by well trained examiners and fixation was maintained by the electronic eye fixation control system in the perimeter through out the test as the reliability of visual fields depends largely upon quality of eye fixation. Test duration, positive catch trials, negative catch trials and reliability factor were noted. The reliability of the results was accessed after a thorough review of reliability indices.

RESULTS

A total of 117 patients were examined from January 2007- June 2008.The results are tabulated as follows:

A male preponderance was seen and majority of the patients belonged to 60-70 years age group making up to 37.4 %followed by 40-50 years age group i.e 25.6%.The size of pupil noted in almost all the patients was in range of 3-7 mm which is a reliable range for normality.

Almost 90% of the patients completed the test in 6-9 minutes 8 % completed in 10-15 minutes and only2% took time more than 15 minutes.

The number of false positive answers (positive response when no stimulus was presented) is expressed as a percentage of total positive trials. False negative answers (Negative response after presentation of brightest possible stimulus in an area where patient showed sensitivity on prior questions) are also expressed in percentage of total questions asked. False positives and negatives were calculated in both eyes and are tabulated.

It is quite obvious from the tables that maximum number of patients have percentage of false positives and false negatives between the range of 0-5 % which shows that a large number of patients (62% patients in false positives and 79% patients in false negatives in their right eyes and 68.4% patients in false positives and 74.6% patients in false negatives in their left eyes) had a reliable field. The reliable range of rate of false positives and false negatives in Octopus 300 series perimeter (the machine we used) is 10-15%.

Reliability factor RF indicates patients cooperation and is actually the percentage of sum of false positive and false negative answers divided by total number of catch trial questions. According to the settings of the perimeter we used value of RF should not be higher than 15%. A grade of 0 is excellent. It is evident from the table that 96(82%) patients had reliability factor in acceptable normal range their right eyes and 104(89%) patients had reliability factor in acceptable normal range in left eyes. It shows that majority of patients had a reliable field test. It is obvious that fields of left eyes were more reliable as compared to those of right eyes.

DISCUSSION

We conducted this study at eye department Abbasi Shaheed Hospital from January 2007 - June 2008 including 117 patients to analyze that dark adaptation may be a pitfall in evaluation of reliability of visual fields of second eye of glaucoma patients.

A male preponderance was seen and majority of the patients belonged to 60-70 years age group making up to 37.4 %followed by 40-50 years age group i.e 25.6%. The size of pupil noted in almost all the patients was in range of 3-7 mm which is a reliable range for normality. It was observed that maximum number of patients have percentage of false positives and false negatives between the range of 0-5 % which shows that a large number of patients (62% patients in false positives and 79% patients in false negatives in their right eyes and 68.4% patients in false positives and 74.6% patients in false negatives in their left eyes) had a reliable field. The reliable range of rate of false positives and false negatives in Octopus 300 series perimeter, the machine we used is 10-15%. According to the settings of the perimeter we used value of RF should not be higher than 15%. A grade of 0 is excellent. It was seen that 96(82%) patients had Reliability factor in acceptable normal range their right eyes and 104(89%) patients had reliability factor in acceptable normal range in left eyes. It shows that majority of patients had a reliable field test. It is very obvious that fields of left eyes were more reliable as compared to right eyes. Better reliability of second eye may be due to phenomenon of dark adaptation.

The second eye was continously behind opaque occluder and was dark adapted while first eye was being examined. Adams et al. found that the average sensitivity in the second eye tested was reduced by approximately 1.2 dB (0.06 log units) relative to the first[5].Although this was attributed to a dichoptic contrast adaptation effect, subsequent work has suggested that the sensitivity loss results from a delay in light adaptation of the second eye after its opaque ocluder is removed.Although such effects might be minimized with the use of a translucent occluder[6].

Humphrey Matrix perimeter (Carl Zeiss Meditec; Welch Allyn) has recently become available, with a smaller target size of 5° that allows the sensitivity of the visual field to be sampled at finer spatial intervals. Examination of the normative database for this instrument confirmed that sensitivity in the second eye was reduced (the "second-eye effect"). However, the improved spatial resolution of the test also showed that this second-eye effect was not equal across the visual field but was slightly greater in the temporal hemifield[6].

Previous authors have noted a loss in perimetric sensitivity over time, with any attributing this to subject fatigue[7-11] quanifying fatigue effect, however, have had limited temporal resolution. Although it has been demonstrated that the adaptational state of the eye is a critical determinant of the second-eye effect, the role of light adaptation in mediating any progressive loss of sensitivity in the first eye has not been assessed[6].

CONCLUSION

It was concluded that the results of second eye of the patients were more reliable as compared to the reliability of the results of first eye. This could be due to the phenomenon of dark adaptation. The second eye gets dark adapted behind the occluder as the patient proceeds the test for first eye, and thus produces better results when examined. So dark adaptation may be a pitfall in interpretation of reliability of visual fields of second eye.

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