Dark adaptation in diabetes mellitus

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SUMMARY The effect of diabetes mellitus on the normal dark adaptation curve is investigated. It has been found that diabetic patients take longer to adapt and that their absolute thresholds are raised. The degree of elevation in the final threshold correlates with the duration of diabetes.

Many systemic conditions are known to have side effects that affect vision. One of these is diabetes mellitus. Besides the rapid fluctuations in refraction that frequently occur during the initial stages of this condition, which are related to fluctuations in the blood glucose level, the majority of visual effects are related to the frequently encountered retinopathy. While considerable research has been undertaken towards understanding the retinal changes that occur in this retinopathy, relatively little research has been directed towards documenting the type of visual loss that is concurrent with it, Roth (1969) and Bloom *et al.* (1972) being notable exceptions.

In this paper we report on the effects of diabetes mellitus on the normal dark adaptation curve. While it has previously been mentioned (François *et al.*, 1978) that light thresholds are often raised in diabetes, we have been unable to find any report on the quantitative measure of this effect.

Materials and methods

Measurements of the dark adaptation curve were taken with an H-A Dark Adaptometer (Henson and Allen, 1977). This adaptometer measures the time taken for subjects to be able to see each of 12 discrete levels of gradually decreasing intensity. The adaptometer is initially set at its brightest intensity level of 16.6 cd/m². Once the subject has reported that he can see this, the intensity is reduced to the next lowest discrete level, the subject again being asked to report as soon as he can see the light. The experimenter records the time taken for each of the intensity levels to be seen. To assist the subject in being able to recognise when they can see the light it is made to flash at approximately 0.5 Hz.

The dark adaptation measurements were taken monocularly on the right eye with the exception of 2

subjects in whom the vision in that eye was so poor that reliable results could only be obtained with the left eye. Subjects were preadapted for 1 minute by seating them with their faces against a large opal screen whose intensity was 17.4×10^2 cd/m². At the end of this period the adapting light was turned off and the subject's attention directed towards the adaptometer. The test continued until the subject had seen all the intensity levels or until he had been in the dark for a total of 1400 s (23 min 20 s).

Fixation was controlled during adaptation by asking the subject to direct his attention towards a small dim red light attached to the adaptometer which positioned the flashing patch 20 degrees from the fovea. The patch itself subtended 12 degrees at the eye.

After measurement of the dark adaptation curve the subject's visual acuities were recorded. If they were below 6/9 a retinoscopic refraction was performed to establish whether the lowered VA was a result of a refractive error. The subject's pupil was then dilated and a careful direct ophthalmoscopy performed. The results from this were supported by a fundus photograph taken with a Kowa camera.

Details about the duration of diabetes, age of the subject, and type of medication were also recorded.

Subjects were asked specifically if they had any visual problems and if they had noticed any increased difficulty either in seeing in the dark or in getting used to the dark.

Results

A total of 35 diabetics were tested. Their ages ranged from 11 to 73 years and their duration of diabetes from 3 months to 51 years. Six of the subjects were excluded from the analysis of the data because they had visual problems other than those

Fig. 1 Typical dark adaptation curves. $\blacktriangle$ Case 1. $\bullet$ Case 2. $\blacksquare$ Case 3

commonly encountered in diabetes. Three of them suffered from high blood pressure with related retinal changes, 2 had cataracts, and the final 1 had macular degeneration.

Typical dark adaptation curves for 3 of the subjects are shown in Fig. 1. The first of these, case 1, is essentially normal in both its time course and its final threshold. The second curve, case 2, shows an elevation in the final threshold of a little over 0.6 log units and an increase in the time taken to see each of the stimuli. The third curve, case 3, is grossly abnormal, showing both a marked rise in final threshold and a much delayed response.

From the ophthalmoscopic findings subjects were divided into 4 groups: (1) Those showing no fundus abnormalities. (2) Those showing only 1 or 2 dot haemorrhages. (3) Those showing several clusters of haemorrhages and exudates. (4) Those showing fairly extensive bleeding and exudates. Groups 2, 3, and 4 all fell within the intraretinal category of diabetic retinopathy as described by Cogan (1974).

The final thresholds reached by the 29 subjects are shown, plotted against the age of the subject, in Fig. 2. (The final threshold for each subject was taken as the intensity of the patch at the last switch position which was seen prior to the end of the test.) The bold line on this graph shows the normal rise in threshold known to occur with age. This line has been computed from the data of McFarland and Fisher (1955), which show a rise in threshold of 0.003 log units/year. The starting point for this line has been obtained from a series of 10 normal subjects all between the ages of 20 and 22 who were tested with this adaptometer prior to the present study.

It can be seen from Fig. 2 that a good number of the subjects had final thresholds considerably above the mean for their age group. However, the scatter

of the results is so large that no general trend between threshold elevation and age can be seen. The data have been replotted in Fig. 3 as the degree of elevation above norm for their age versus the duration of diabetes. By plotting the data in this way the degree of scatter has been substantially reduced. The line drawn on this graph is the least squares fit of the degree of elevation on the duration of diabetes. It can be seen from this diagram that all 3 subjects who had had diabetes for more than

Fig. 2 Final threshold reached after 1400 s in the dark versus the age of the patient. The solid line represents the normal increase in threshold seen with age. The symbol $\triangle$ is for subjects with no retinal changes, $\blacktriangle$ for subjects with 1 or 2 dot haemorrhages, $\blacktriangle$ for subjects with several clusters of haemorrhages and some exudates, $\blacktriangle$ for subjects showing fairly extensive haemorrhages and exudates

Fig. 3 The elevation in final threshold above the norm for their age versus the duration of diabetes. The solid line is the least squares fit to the data. The meaning of the symbols $\triangle$, $\blacktriangle$, $\blacktriangle$, and $\blacktriangle$ is the same as that in Fig. 2

22 years had raised dark adaptation thresholds above the norm for their age.

The mean rise in final threshold of the 6 subjects not included in the data analysed was on average above that of the remaining 29 subjects.

Discussion

The data indicate that a large number of diabetics have final thresholds above the norm for their age. The amount of elevation is roughly correlated ($r=0.534$) with the duration of diabetes. There is, however, considerable spread in the data, some subjects showing considerable elevation after only a few years of diabetes while others who have had the condition for many years show no significant elevation.

The percentage of subjects above the norm for their age is approximately the same for those with and without retinal changes, though the former had on average a much larger increase in their final thresholds.

Cogan (1974) has shown that the retinal changes associated with diabetes often produce ischaemic areas with little, if any, capillary network. These areas could be expected to have a much larger loss in sensitivity than those in which the capillary network is still intact. If in the process of measuring dark adaptation the stimulus were to fall on one of these ischaemic areas, the elevation in final threshold would be expected to be greater than if it fell on some other area. This factor alone could account for a fairly large amount of variability in response seen in subjects with identical degrees of retinopathy as detected with the ophthalmoscope.

McFarland *et al.* (1946) have shown in normal persons that the differential threshold is increased during periods of hypoglycaemia and that the degree of elevation is maximal at the lower intensity levels. Thresholds measured on diabetics may fluctuate in an analogous manner according to the blood sugar level at the time of testing, creating even more variability in the responses.

The results showed that there was no correlation between the threshold elevation and the visual acuity of the subjects. All of them with the exception of 2 had corrected acuities of 6/9 or better in the tested eye. The 2 remaining had acuities of 6/12 and 6/18. The subject with the 6/12 acuity had a 1 degree convergent strabismus and the subject with the 6/18 acuity had one of the more advanced retinopathies.

Only 2 of the subjects of the 35 tested reported any increased difficulty in seeing at night or in getting used to the dark. Both of these subjects had retinal or media changes other than those commonly

found in diabetics, that is, they fell within the group of 6 subjects excluded from the analysis of the data. This failure to report any increased difficulty was despite the fact that 20% of them showed marked elevations in final thresholds (greater than 0.5 log units) and 20% took more than 3 times the normal time to see switch position number 10 (intensity 1.05 cd/m²). (Statistical analysis showed a correlation ($r=0.739$ between the final threshold and time taken to reach switch position number 10.) The average time for normal persons, taken from the beginning of the test (when the preadapting light had been turned off), to see this intensity was 100 s.

The fact that our subjects did not experience any increased difficulty in seeing in the dark is not surprising, since they would rarely have to perform any visual tasks at intensities anywhere near the lowest levels tested in this experiment. What is surprising is that they did not report any increased difficulty in getting used to the dark. Switch position number 10 was specifically chosen for analysis because the intensity of the light at that position falls above the alpha point in normal subjects and is in the range of intensities frequently encountered at night in the urban visual environment.

The driving performance of diabetics must thus be of considerable concern to their physicians. While many diabetics may be within normal limits, there is a substantial deficit in the visual ability of some diabetics to drive safely at night. Their recovery from glare from oncoming headlights must be considerably above the norm. This disability will not be detected by either ophthalmoscopy or measurement of visual acuity.

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