Visual defects in the uninjured eye of patients with unilateral eye injury

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Abstract. We have examined the electroretinographic responses, the psychophysically determined course of dark adaptation and/or the scotopic and photopic (static) perimetric profile of the uninjured eyes of 11 patients with unilateral intraocular foreign bodies. Most of the patients showed subnormal ERG amplitudes over a range of light intensities, and subnormal light sensitivity in isolated retinal areas. The data suggest that eyes not directly injured by a unilateral traumatic ocular episode may show visual defects.

Introduction

Intraocular foreign bodies (IOFB) have highly variable effects on the physiology and responsiveness of the injured eye. In addition to the damage incurred by the ocular media during penetration through the eye globe the foreign body may cause secondary complications. These complications may result in widespread impairment of the retina and other ocular tissue (Duke-Elder & Perkins, 1966). Electrophysiological and psychophysical tests on the injured eye may reveal reduced sensitivity and/or abnormal transmission of electrical signals within the retina or along central visual pathways (Karpe, 1948).

Disturbances in the contralateral eye as a result of unilateral eye injury are a rare complication (0.02% of patients with penetrating ocular wounds in the most recent report (Niiranen, 1978)). It was, therefore, surprising to find in a retrospective survey that about 70% of patients with unilateral intraocular foreign bodies (N = 85) showed during routine clinical examination, abnormal electrophysiological responses from the uninjured eye. The abnormal responses resembled cases of Riggs-type congenital nyctalopia. In corroboration, patients often complained of difficulty with night vision and in the few cases tested psychophysically, dark adaptation was found to be deficient (Auerbach, 1977). Recent publications support the findings of abnormal electroretinograms evoked from the uninjured eyes of patients with unilateral IOFBs (Abraham, 1977; Knighton and Lewis, 1979).

To further investigate the effect of unilateral eye injury on the fellow eye, we re-examined some of these patients in detail by electrophysiological and

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psychophysical techniques. The results suggest that patients with unilateral eye trauma may show elevated ERG and psychophysically determined thresholds in the eye not affected directly by the injury.

Subjects and methods

Subjects

Of a total of 85 patients suffering from unilateral IOFBs examined in our laboratory between 1961 and 1978, 20 were invited to participate in the experiment. All subjects were selected by their apparent normal health prior to and post injury and by our judgement of their readiness and ability to cooperate. Of these 20 patients, only 11 responded positively and are the subjects of the present report.

It should be emphasized that in general we have not examined the ophthalmological or physiological status of the injured eye. Details of the accident and the description of the injured eye immediately following the trauma were scanty and in many cases deemed unreliable. We therefore do not report on the present state of the uninjured eye nor do we attempt to correlate the present status of the injured and uninjured eyes. We report only results from the *uninjured* eyes which appeared normal ophthalmologically during a recent examination and were reported to have been unharmed by the traumatic episode (see clinical data in Table 1).

ERG

The electroretinographic procedure has been described in detail elsewhere (Nawratzki, Auerbach & Rowe, 1966). Briefly, following 30 minutes in darkness, patients (1–8 in Table 1) were fitted with contact lens electrode while in a reclining position. A photostimulator, Grass PS22, was used at highest intensity (I16) to deliver 'white' test flashes of 10 usec duration. The light source was positioned at a distance of 20 cm from the subject's face. The intensity of the light stimuli was controlled over a range of at least 5 log units in steps of .1–.5 log units by interposing 'neutral' density filters into the light beam. The ERG responses of each eye evoked by the test flashes were recorded separately while the fellow eye was covered by a black eye patch. ERG responses were amplified, monitored on an oscilloscope and photographed for later analysis. Response amplitude was defined as the distance from the trough of the a-wave to the peak of the b-wave. Threshold was taken to be that light intensity, expressed as a density of the neutral filter, which evoked a 50 uv response.

Dark adaptation

For eight subjects (1–8 in Table 1) threshold changes during 40 min of dark adaptation were measured. The apparatus and procedure of measurement have been previously described (Auerbach & Kripke, 1974; Auerbach, Godel & Rowe, 1969). Patients were seated in a light-proof chamber, positioned on a chinrest.

Table 1. Case report and data on visual performance of the uninjured eye of patients with unilateral IOFB

Patient No. [1]	Date of exam.	Date of penetrating injury	Age (years) at time of injury	Most recent data from uninjured eye			
				Acuity[2]	EOG(%)[3] (uV)	ERG b-wave[4]	Color vision[5]
1	Dec 26 1978	Nov 19 1978	53	4/9 + P.H.	not done	250	not done
2	Dec 26 1978	Oct 7 1973	21	6/4.5 p	273	430	normal
3	Jan 17 1979	Jan 1 1976	21	6/4.5 p	230	380	normal
4	Jan 24 1979	Oct 1973	22	6/6c gl	207	500	normal
5	Feb 7 1979	1948	21	6/6	210	340	normal
6	Feb 15 1979	1975	21	6/6c gl	–	380	normal
7	Feb 20 1979	Apr 30 1975	34	6/6	235	450	normal
8	Mar 1 1979	Jan 1 1972	18	6/4.5 p	220	550	normal
9	Feb 26 1981	1967	20	not done	210	360	normal
10	May 3 1981	Oct 1973	34	6/6 p	284	380	normal
11	May 14 1981	1972	21	6/6 p	not done	450	normal

[1] All patients were male
[2] Key: c gl – measured with glasses
P.H.– measured with pin hole
p – one mistake
[3] Average EOG for normals : 240%
lowest limit : 185%
[4] Range of ERG b-wave amplitude for normals: 420–540 uV
[5] Color vision: measured with Ishihara and Farnsworth D-15

Immediately prior to testing, subjects were light adapted by viewing a 500 watt bulb for 3 min. from a distance of 20 cm thus bleaching about 90% of the visual pigment. Patients were then instructed to observe with the eye to be tested a small fixation spot located 7° above the test light and 53 cm from the eyes. At the same time, the non-tested eye fixated a small annulus so that when properly aligned, the patient saw the fixation spot within the annulus. This fixation configuration allowed the patient to rest between stimulus presentations and to return precisely to the properly aligned position during trials. The fixation spot was continually dimmed at the subject's discretion during the dark adaptation process.

Tests of visual threshold were administered at regular intervals. During a trial a 1° flashing stimulus (1 cycle/sec) of 500 nm was presented. The stimulus, initially below threshold, was gradually increased in intensity in steps of less than .1 log units until the patient indicated by pressing a buzzer that the stimulus was seen. This intensity value was taken as threshold.

Static perimetry

Two patients (2, 5 in Table 1) were tested in a modified Goldmann perimeter to evaluate their scotopic light sensitivity at different retinal loci. The test light (500 nm, 1°) which flickered at a rate of 2 cyles/sec, was positioned in the center of a blackened field. The intensity of the test light was increased in intensity during trials by means of a neutral density circular wedge. During testing, each patient fixated a small red spot (0.2°) which varied in position from 5° or 10° to 40° from the macula across the horizontal (nasal to temporal) or vertical (superior to inferior) meridians of the field. At each retinal locus, threshold for seeing the test stimulus was calculated in a manner similar to that used during measurement of dark adaptation.

Patients 9–11 (Table 1) were also tested by static perimetry, however the ganzfeld background measured 74.0 candles and the test light was 620 nm.

Results

Figure 1 shows representative ERGs of one subject (3 in Table 1) evoked by light stimuli over a log unit range. The top row of responses were obtained from one eye of a normal subject (N). Responses from the injured (I) and noninjured (NI) eyes of a patient with a unilateral IOFB are shown in the middle and bottom rows respectively. Clearly, the responses evoked from the the normal eye are larger in amplitude than the ERGs obtained from either of the patient's eyes. Both, the patient's injured eye and uninjured eye showed ERGs of smaller amplitude than that of the normal eye.

Figure 2 illustrates the intensity-response curves of the ERG b-wave obtained from normal subjects and patients with IOFBs. The area between the two continuous lines describes the normal distribution of the b-wave amplitude obtained from 14 eyes of seven normal subjects. For each stimulus

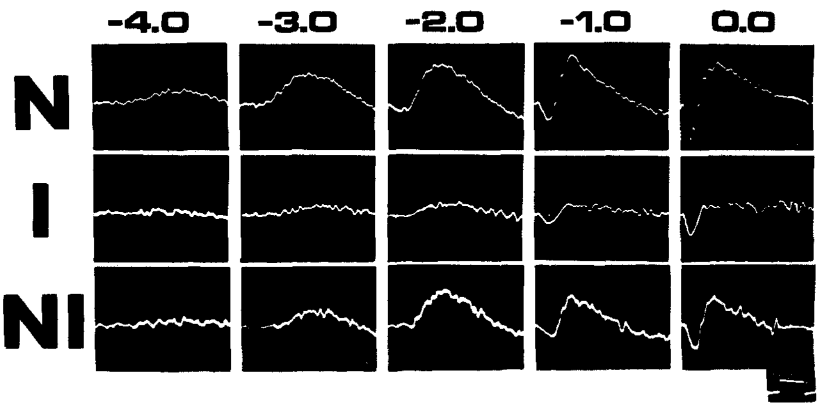

Figure 1. Representative ERG responses from a normal eye (N, top row) and injured and noninjured eyes of a patient with IOFB (middle (I) and bottom rows (NI) respectively). All responses were obtained after 30 min of dark adaptation. The light intensity used to evoke the responses are marked above each column of responses. The numbers describe the density of the neutral filter interposed in the light path during the trial in which the response was evoked.

intensity, the range described is from the mean ± 1 SD. Six patients with IOFB showed intensity-response curves of the uninjured eye which were significantly below normal. Only one patient (7, Table 1) showed threshold and suprathreshold ERG responses within the normal range, while the intensity-response curve of another patient (3, Table 1) fell within the normal range at medium stimulus intensities and below the normal range at either bright or dim stimuli.

The average log threshold of normal subjects expressed as the density of 'neutral' filter needed to evoke a 50 uv criterion response was − 4.41 ± 0.18 (SD). In contrast, the mean ERG threshold measured in the uninjured eye of eight patients was − 3.95 ± 0.27. In fact, at all stimulus intensities used, the ERGs from the patients' uninjured eyes were significantly smaller in amplitude than that from the eyes of control subjects (Figure 2, for all points $p < .005$).

In order to determine if the deficient ERG responses correlated with psychophysical dark adaptation as in cases of congenital nyctalopia (Auerbach et al., 1969), we measured thresholds during the dark adaptation process in the uninjured eye of these patients with unilateral IOFBs (Figure 3A–H). The area of the graph between the continuous lines in Figure 3 describes the range of thresholds measured in seven normal subjects. This normal dark adaptation curve deviates slightly from a previously described standard curve obtained with the same apparatus (Auerbach & Kripke, 1974). The course of dark adaptation as well as the final scotopic sensitivity of the uninjured eyes of seven of eight patients are shown to be within normal range (Figure 3B–H). Three patients, in fact, showed slightly faster than normal recovery probably due to poor fixation during the bleaching period. Only one patient (1, Table 1) showed an abnormally slow recovery with slightly elevated final scotopic threshold (Figure 3A).

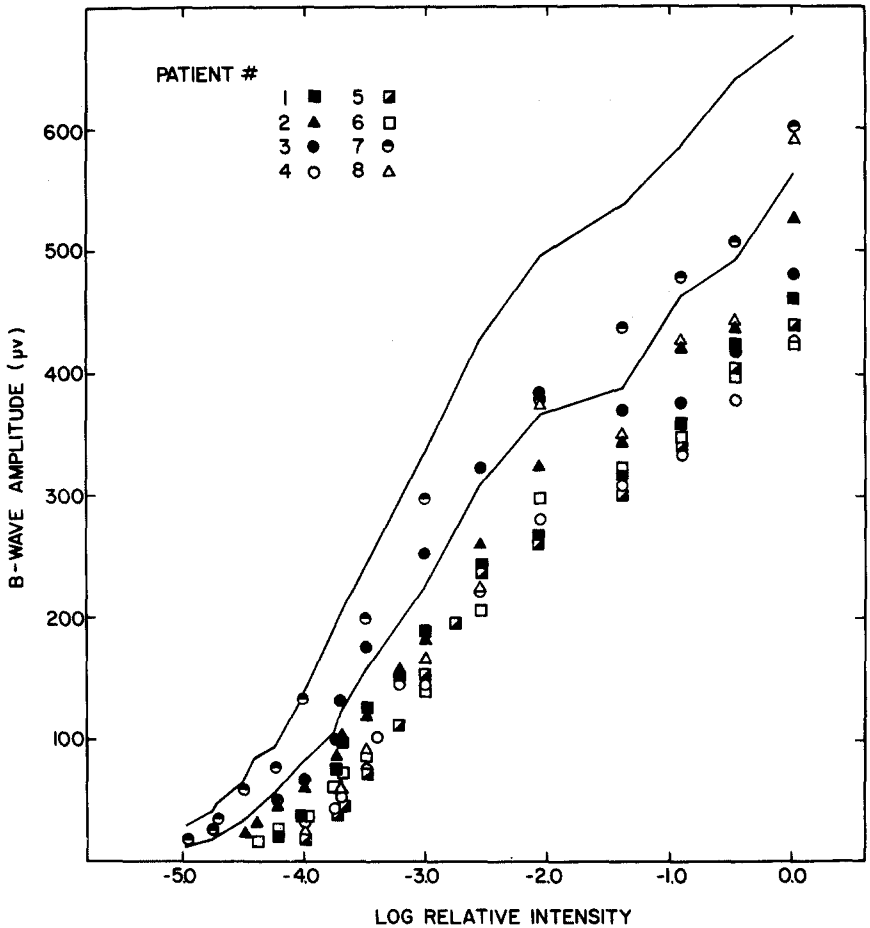

Figure 2. Intensity-response curves of the uninjured eyes of eight patients who suffered from unilateral penetrating eye injury. The data points represent the amplitude of the ERG b-wave, measured from the trough of the a-wave to the peak of the b-wave, as a function of the test flash relative intensity. The area between the two continuous lines depicts the range of amplitudes from mean ± 1 SD obtained from 14 eyes of seven normal subjects.

To account for the apparent discrepancy between the subnormal retinal responses obtained electrophysiologically and the normal psychophysical data, we hypothesized that the retina of the uninjured eye was not uniformly defective. Thus, certain areas of the retina may retain normal functional integrity while other areas show some visual deficit. This hypothesis is based on the assumption that while the ERG as measured in the present experiment recorded from the dark-adapted retina is a function of the whole retina, the psychophysical measurements are determined by the local integrity of the area stimulated. In order to verify the above hypothesis, we measured the scotopic visual sensitivity at different retinal loci of the uninjured eye of two patients (2 and

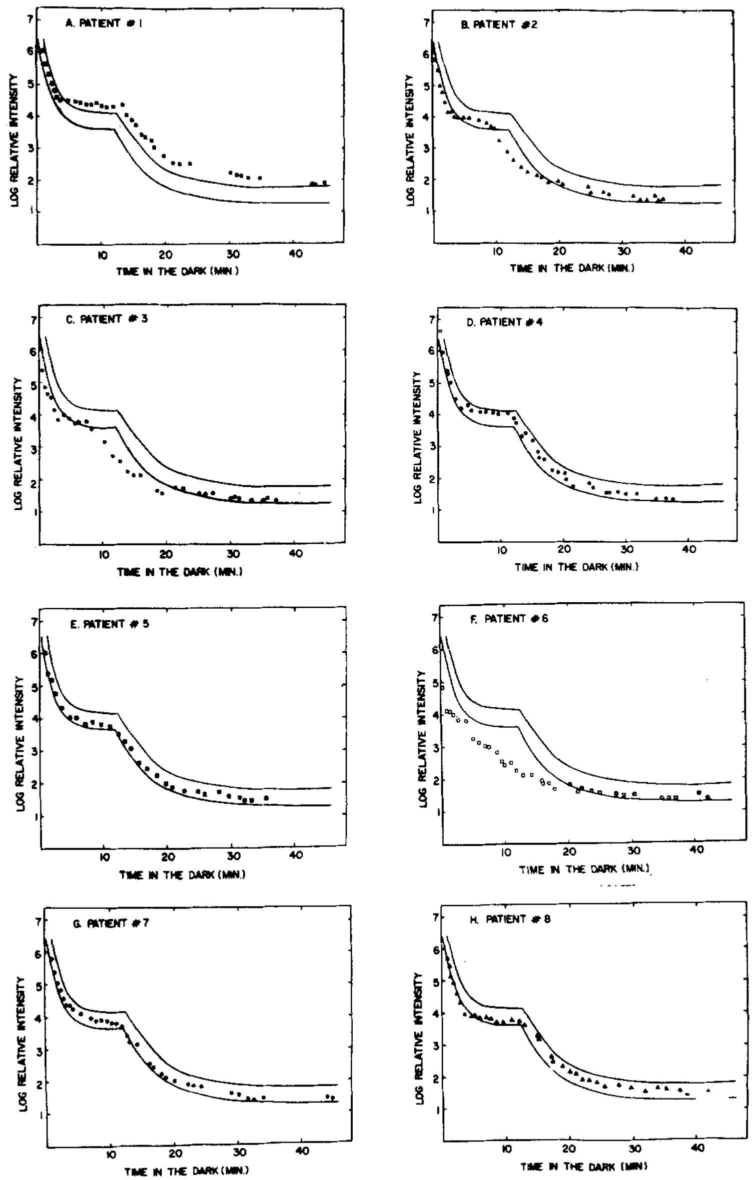

Figure 3. A-H. Psychophysically determined dark adaptation curves obtained from the uninjured eyes of the patient with unilateral intraocular foreign body (IOFB). During testing, a 1° circular test field of 500 nm was presented 7° above fovea. The area bordered by the 2 continuous curves in each figure represents the range measured from 7 normal subjects. Patients symbols remain as in Figure 1. Most patients data fell within the normal range (D, E, G, H). One patient displayed an abnormal slow dark adaptation with elevated scotopic threshold (A). The other three patients (B, F, C) displayed normal final thresholds but abnormally fast recovery possibly due to poor fixation during the bleaching period.

5 in Table 1) who had previously shown normal dark adaptation curves (Figures 3B and E), but deficient ERG responses (Figure 2).

Figure 4 shows the scotopic sensitivity profile obtained from the left eye of two normal subjects (Figure 4A, B) and from the uninjured eye of two patients (Figure 4C, D) measured at retinal loci across the horizontal and vertical meridians (from 5° to 40° in temporal, nasal, inferior and superior parts of the retina). The data are presented as the difference in log threshold at any retinal locus and that measured at the most sensitive locus of the same eye. In normals, the maximum threshold elevation across the retina did not exceed 0.3 log units (Figure 4A, B). This is in agreement with findings of Sloan (1971), but slightly lower than those of Cabello and Stiles (1976). Difference in subjects or in experimental procedures may account for the discrepancy. The patients with IOFBs, on the other hand, showed threshold variation of more than one log unit across the visual field of the uninjured eye (Figure 4C, D).

Figure 5 illustrates the average photopic sensitivity profiles obtained from both eyes of 9 control subjects. Data is again plotted in terms of threshold differences between all retinal loci and the most sensitive retinal area (0°, in all cases). Maximum threshold differences was 1.56 ± 0.3 as measured 40° from the fovea in the nasal direction. Two patients (9, 10) both of whom showed subnormal ERG amplitudes to suprathreshold light intensities also showed thresholds outside the normal range in the periphery (40°) of the uninjured eye (Figure 5B, C). Patient 11 showed a normal threshold profile and normal ERG amplitude. (The electrophysiological data of subjects 9–11 (Table 1) were obtained from past files and therefore not included in the amplitude-intensity curve, Figure 1). The static perimetric data may suggest then that the electrophysiological deficit is a result of subnormal performance of restricted peripheral areas rather than of diffuse retinal damage.

Discussion

The data presented in this study show that in some cases of unilateral IOFB the uninjured eye may exhibit some visual deficits. This deficit is expressed in a subnormal scotopic ERG, which is probably the result of a reduced performance of the scotopic visual mechanism in the peripheral retina.

How can a unilateral intraocular foreign body cause physiological changes in the contralateral uninjured eye? We shall consider three hypotheses. The first assumes that the damaged eye can affect the visual functions of the uninjured eye via interactions at the cortical level and efferent pathways from the brain to the retina. This hypothesis has been used to explain the differences found in the course of dark adaptation after monocular or binocular bleaching (Paris & Prestrude, 1975; Makous, Teller & Boothe, 1976). The explanation, however, must be viewed with caution as the perceptual thresholds measured during dark adaptation can be explained by cortical interactions alone without efferent processing. However, for an intraocular foreign body to effect the

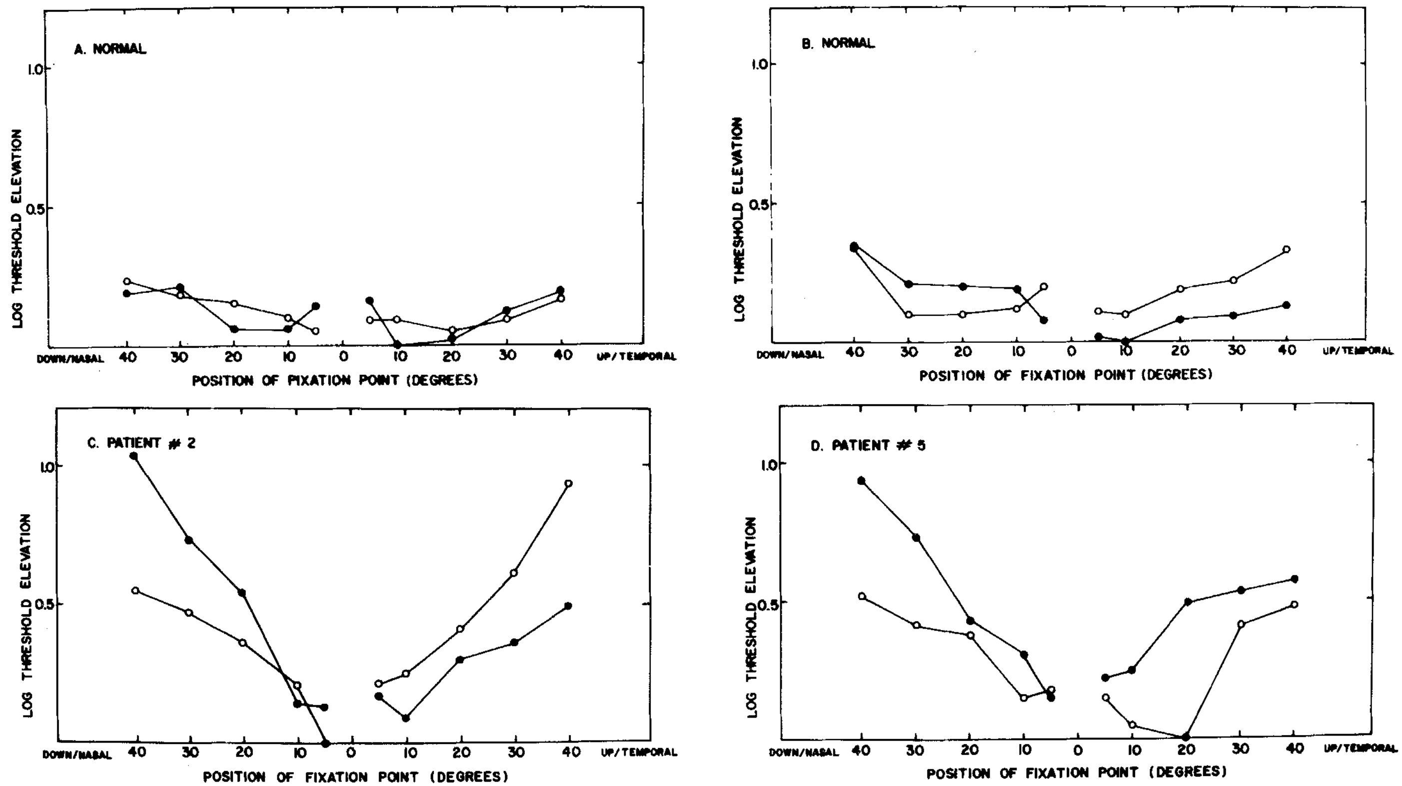

Figure 4. Retinal profile of scotopic sensitivity from two normal subjects (A and B) and two patients with unilateral IOFBs (C and D). Each data point represents the difference in log threshold measured from the retinal eccentricity denoted in the abcissa and the minimum log threshold measured in the same eye. Measurements were obtained from retinal loci from 5–40° on either side of the fovea along either the vertical (solid circles) or horizontal (open circles) meridians.

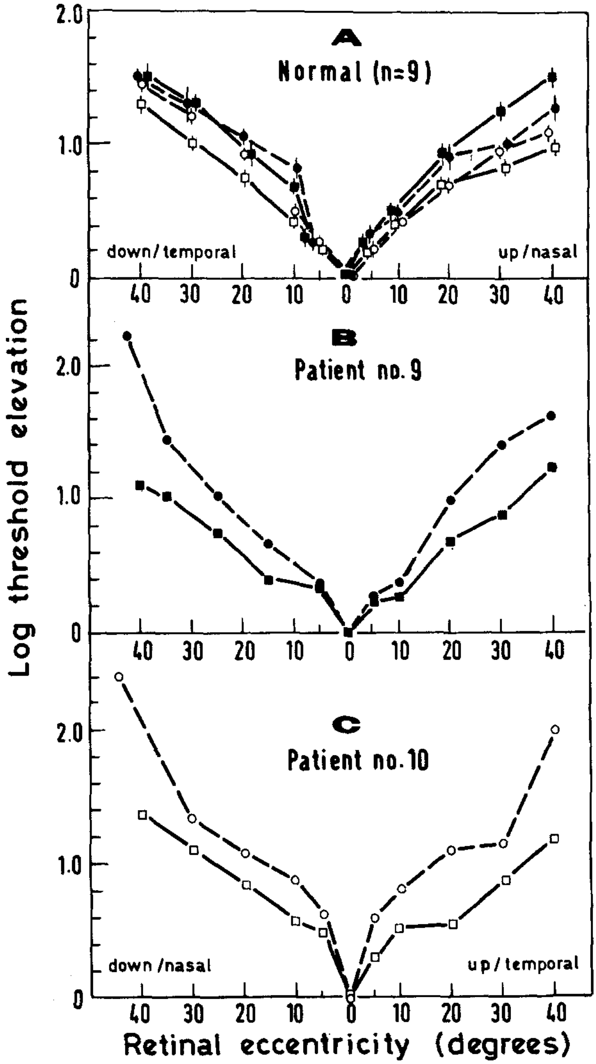

Figure 5. Retinal profile of average (± 1 SD) photopic sensitivity from 9 normal subjects (A) and two patients with IOFBs (B and C). Thresholds from both the right eye (open symbols) and left eye (closed symbols) were measured from 0–40° on either side of the fovea along the vertical (circles) or horizontal (squares) meridians. Only the uninjured eyes of patients were measured. For both groups, each data point represents the difference in log threshold measured from the retinal eccentricity denoted in the abcissa and the minimum log threshold measured in the same eye.

ERG of the uninjured eye, centrifugal fibers must be postulated. Such fibers have been noted in lower vertebrates (for example, see Cowan & Powell, 1963; Witkovsky, 1971), but their existence in mammals is unclear (see Honrubia & Elliott, 1968; 1970; Brindley & Hamaski, 1962). With these limitations, we regard this hypothesis as unlikely in explaining the observed visual deficits in the uninjured eye of patients with unilateral foreign body penetration.

It is also possible that post-traumatic inflammation in the uninjured eye could affect its functioning (sympathetic ophthalmia). This has been noted on occasion in patients with penetrating ocular injuries (review in Duke-Elder & Perkins, 1966). However, in these cases, the injured eye was persistently painful and irritated. Moreover, the injured eye also showed signs of severe intraocular inflammation. As these symptoms were not seen in the patients of this study, infection or inflammation is thought to be unlikely as the cause for the observed deficit in the uninjured eye.

A third possibility supposes that the head movement at the time of impact caused a dislocation of cerebral and/or retinal tissue which may have caused the visual defects. While possible, we deem this explanation unlikely due to the small size of most IOFBs and their minimal shearing force.

While the basis for the defects are unclear, it has been suggested that the injurous effects may not be permanent (Abraham, 1977). We corroborate this finding since the one patient showing slow dark adaptation was the most recently injured.

The nature of the pathology of the uninjured eye in patients with unilateral eye injury must await further study particularly on animal models. Our results do suggest, however, that testing of patients with such injuries should include eyes not directly affected by the injury.

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