Photo-induced foveal injury after viewing a solar eclipse

Fredrik P. Källmark and Jan Ygge

St. Erik's Eye Hospital, Department of Clinical Neuroscience, Karolinska Institute, Stockholm, Sweden

ABSTRACT.

Purpose: **To study the injury to and possible recovery of the visual function and foveal morphology in patients with photo-induced foveal injury due to watching the solar eclipse of August 11th, 1999 in Stockholm, Sweden.**

Methods: **Fifteen patients, all of whom viewed the solar eclipse, were followed for 1 year, during which their visual symptoms were recorded and visual acuity (VA) was tested, and ophthalmoscopy and scanning laser ophthalmoscopy were performed.**

Results: **Photo-induced foveal injury gave rise to subjective visual disturbances, reduced VA and morphological changes in the fovea. Central scotomas could still be seen in all patients 1 year after the foveal injury.**

Conclusion: **Photo-induced foveal injury gave rise to subjective visual disturbances, reduced VA and morphological changes in the fovea. Scanning laser ophthalmoscopy offers the possibility of detailed examination of small retinal lesions, which can sometimes be difficult to localize with ophthalmoscopy.**

Key words: microperimetry – scanning laser ophthalmoscope – fixation – visual acuity

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Introduction

Solar retinopathy as a result of gazing towards the sun has been described previously (Wong et al. 2001; Chen & Lee 2004). The symptoms of this type of injury are possible visual disturbances such as metamorphopsia, decreased visual acuity (VA) or scotoma (Rai et al. 1998; Awan et al. 2002). Biophysical analysis has revealed retinal lesions and the minimum exposure to the sun that would produce such lesions (Sadun et al. 1984). A correlation between the funduscopic appearance and VA 2 weeks after solar injury has been shown (Atmaca et al. 1995), whereas other investigators have found no such correlation (Dhir et al. 1981). It has also been established with the use of the scanning laser ophthalmoscope (SLO) that solar-induced scotoma can dramatically reduce reading performance (Ehrt et al. 1999). Very few studies have described the relationship between functional loss after solar injury and the time required for possible recovery (Ehrt et al. 1999). Furthermore, it is not known to what extent solar-induced lesions can give rise to permanent damage to the photoreceptors (Atmaca et al. 1995). Because SLO is able to map the retinal function exactly, this technique could be useful for following retinal damage such as in solar retinopathy (Ehrt et al. 1999). The usefulness of the SLO technique has been demonstrated in studying fixational patterns in normal subjects (Källmark & Ygge, 'Fixation pattern in healthy subjects during microperimetry with the scanning laser ophthalmoscope'; unpublished observation). The aims of the present study were to assess patients' VA and the subjective disturbances resulting from solar-induced retinopathy and to perform ophthalmoscopic investigations of the fundus over a period of time. We also aimed to use the SLO to map solar-induced scotomas and evaluate the fixation pattern after such injury.

Methods

Subjects and clinical investigations

Fifteen patients (15 eyes; no patient had gazed towards the sun with both eyes) came to the emergency room at St. Erik's Eye Hospital in Stockholm, Sweden within 1 week of the partial solar eclipse on August 11th, 1999. Nine of the patients were female and six were male. Their mean age was 35.2 years (range 17–51 years). All the patients had visual disturbances such as reduced VA and central visual field loss. When asked, the patients estimated the time they had spent gazing at the sun to have been between 20 seconds and 5 mins. None of the patients reported any ongoing eye disease and none were using any medication. One patient had experienced solar retinopathy in the other eye several years

previously. Only the eyes with the above-mentioned symptoms are described here.

At the initial visit (visit 1) best corrected distance VA was measured using the traditional Snellen line chart, with rows of letters of decreasing size, and an ophthalmoscopic examination was performed. At the follow-up visits at 3 months (visit 2) and 12 months (visit 3), the patients' VA was tested and ophthalmoscopic (through a 90 D lens), and SLO examinations were performed while the pupil was dilated with one drop of 0.5% cyclopentolate. Any ophthalmoscopic findings of retinal oedema, lamellar macular hole and/or distinct retinal pigment epithelium (RPE) disturbances (referred to as lesions later in the text) were noted. During each visit the patients were also asked to subjectively describe the visual disturbance caused by the scotomas as severe, mild or no disturbance at all.

Instrumentation

Scanning laser ophthalmoscopy was performed with the Rodenstock SLO-101 using previously described methods (Iwas et al. 1986; Mainster et al. 1989; Timberlake et al. 1989; Van de Velde et al. 1990a, 1990b; Weber 1990). Visual stimuli were produced in the laser beam raster by means of a microcomputer and graphics board connected to an acousto-optic modulator in the SLO. Any pattern produced by the SLO computer and projected onto the patient's retina was displayed simultaneously on a monitor. The SLO provided a 32 × 22-degree image of the fundus with a minimum resolution of 3 minutes of arc (15 μm) for measurement and positioning of the targets. The SLO's graphics capabilities allowed the investigator to determine the retinal location of visual stimuli directly on the retinal image in real time. The SLO obtained retinal images continuously with an infrared laser (780 nm) and scanned stimuli on the retina with a modulated visible helium-neon laser (633 nm). The operator displayed the stimuli directly on the patient's retina. The helium-neon laser was used as the light source for background illumination, the fixation target and for generating the stimuli by acousto-optic modulation.

The variables used for manual static visual field testing with the SLO were those commonly used in conventional projection perimetry (i.e. background illumination: 10 Cd/m^2; incremental test stimuli [brighter than background] of 7 × 7 arc minutes [corresponding to a slightly larger diameter of 0.12 degree]), which approximates Goldman size I, with a stimulus duration of 200 ms. The patients looked into the SLO with the affected eye and an average of 38 stimuli were presented in a radial grid pattern (Fig. 1) within an area of approximately 5 degrees radius from the foveola. We chose to present the stimulus in a radial grid pattern because this allows for more precise mapping of the most central retinal areas. Three different light intensities were used: 0 dB (if not seen, considered as a dense scotoma); 10 dB (relative scotoma) and 20 dB (minimal suprathreshold scotoma; Fig. 1). A scotoma was defined as a negative response to a given stimulus presentation with the SLO.

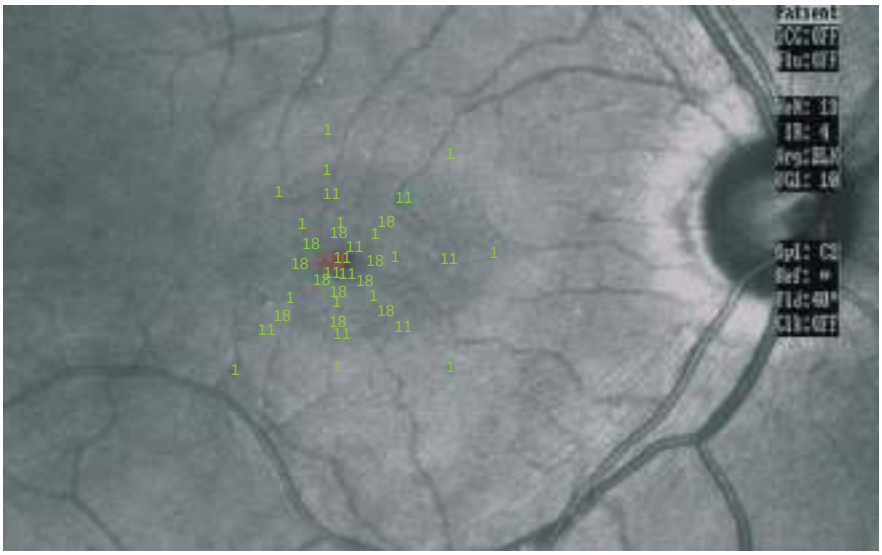

Fig. 1. Fundus photograph from a representative subject with a SLO/microperimetry overlay. In this 44-year-old patient, stimuli were presented within an area of approximately 5 degrees radius from the foveola. The different sensitivities are represented by 1–0 dB, 11–10 dB and 18–20 dB.

Data collection and analyses

The same examiner (FPK) performed all examinations, except during the initial visit to the emergency room where they were performed by the doctor on call. As the stimuli in the central part of the radial grid pattern were presented close to one another, it was presumed that the retinal areas between the stimulus and any possible overlap of the stimuli presented were very small and therefore the most peripheral and seen stimuli were regarded as representing the outer limit of the scotoma. During each stimulus presentation the location of the fixation was recorded (in x and y co-ordinates relative to the actual fixation cross-location). These fixation locations were used for estimating the fixation pattern in each subject. The mean of the x and y co-ordinates in each subject were used as a 'centre of gravity' (CG) for the fixation locations. The distance and angular location of each CG relative to the fixation cross-location was calculated in all patients. All calculations and plotting were performed using Origin Scientific Graphing and Analysis Software, Version 7 (Microcal Inc., Northampton, MA, USA). Visual acuity was evaluated with Friedman non-parametric repeated measures ANOVA test and fixation with Wilcoxon matched-pairs signed-ranks test. Statistical significance was set to the 95% confidence interval ($p < 0.05$).

Results

Subjective disturbances

The patients' subjective estimation of the disturbances from the scotoma showed that all patients (15) were experiencing severe disturbance on the initial visit. At 3 months (visit 2), eight were experiencing severe disturbance, five had mild disturbance and two had no disturbance at all. At 1 year (visit 3), six had mild disturbance and nine had no disturbance at all.

Visual acuity

At visit 1 the patients' VA ranged between 0.25 and 1.2 (median 0.8). At visits 2 and 3 VA was 0.4–1.6 (median 1.0) and 0.6–1.6 (median 1.0), respectively. Between visits 1 and 2, the average increase in VA was 0.25 (range 0–0.6, $p < 0.001$); between visits 2 and 3 the average increase was 0.09 (range 0–0.3, $p < 0.221$). All patients but one showed an increased VA over the entire study period (Fig. 2).

A significant difference in VA ($p < 0.001$) could be seen between the initial visit and visit 2, and between the initial visit and visit 3 ($p < 0.05$), but not between visits 2 and 3 ($p = 0.221$).

Large individual differences could be seen over time in the restoration of VA.

Funduscopic findings

Foveal lesions such as oedemas, lamellar macula holes and distinct RPE disturbance were seen in only seven patients (47%) at the initial visit. The corresponding figures were four (27%) and two (13%) at visits 2 and 3, respectively.

Scanning laser ophthalmoscopy

Scotomas

Scotomas were detected in all patients at every SLO examination. At visit 2 the size of the scotomas varied between one and four neighbouring stimulus presentations (corresponding to roughly 0.12–0.48 degree), while at visit 3 the scotomas had a size of 1–3 stimulus presentations (corresponding to approximately 0.12–0.36 degree) (Fig. 3). At visit 2, 11 patients showed a minimal suprathreshold (20 dB) and four showed a relative (10 dB) scotoma. At visit 3 a minimal suprathreshold scotoma was seen in all patients, but no deeper defects were found. As the radiation from the sun was focused through the optical system of the eye onto the centre of the fovea, all scotomas also included the central fovea, which corresponds to the fixation mark.

Fixation

Due to data failure, fixation analyses could only be performed for 11 patients at visits 2 and 3. Between 31 and 46 (average 38) fixation positions were calculated and CGs obtained. The fixation pattern varied between patients.

The mean distance of the CGs in relation to the fixation cross was found to be 0.27 degree (SD 0.10, range 0.13–0.46 degree) at visit 2 and 0.36 degree at visit 3 (SD 0.12, range 0.18–0.62 degree), not significantly different ($p = 0.174$). The fixation position in relation to the central scotoma was, at visit 2, predominately maintained inferior to the fovea, or inferior and nasal, or shifting around the scotoma. At visit 3 fixation was predominately maintained inferior, nasal or temporal to the scotoma.

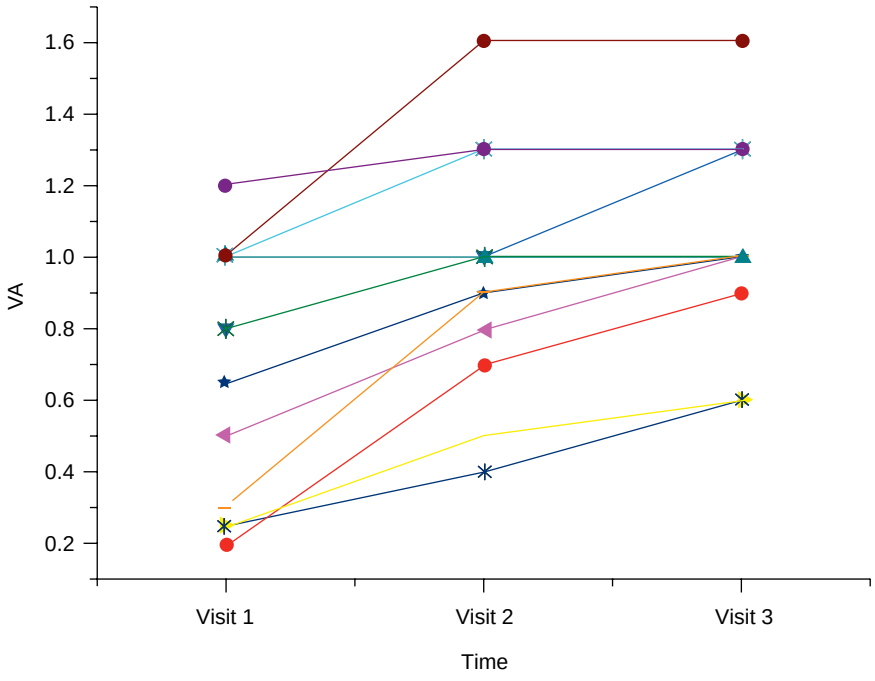

Fig. 2. Visual acuity over time in all subjects. Note that VA increased from visit 1 to visit 3 in all patients except one

Discussion

Central visual field and fixation mapping

Traditionally, the mapping of visual field defects has been performed using computerized perimetry such as the Humphrey field analyser (Henson et al. 1999), or high-pass resolution perimetry (HRP) (Frisén 1993). However, the SLO microperimetry technique is the only perimetry method that allows real-time simultaneous perimetry and mapping of the fixation position. Therefore, the results from an SLO microperimetry session could be very useful for detecting central scotomas and mapping the central visual field (VF); SLO can thus be considered an interesting complementary tool to conventional perimetry methods. Further, the results from an SLO microperimetry session with fixational mapping are useful in patients with unstable and/or extrafoveal fixation, which is a common situation in patients with a foveal lesion/injury. As the accuracy of conventional VF techniques relies on the assumption that the subject's fixation remains foveal and stable during the examination (Whittaker et al. 1988; White & Bedell 1990; Schuchard & Raasch 1992; Fletcher et al. 1994), the VF will still be mapped as though fixation is in the centre of the field, and all tested points will be shifted relative to their true retinal location if the fixation is not foveal (Timberlake et al. 1982; Enoch et al. 1984; Guez et al. 1993; Schuchard 1993). At visit 2, the mean distance of the CGs in relation to the fixation cross was 0.27 degree, which closely corresponds to the 0.27 degree found for normal subjects (Källmark & Ygge, 'Fixation pattern in healthy subjects during microperimetry with the scanning laser ophthalmoscope'; unpublished observation).

Funduscopic appearance and visual acuity

The results from our study are consistent with the work of Dhir et al. (1981), who found no correlation between funduscopic appearance and VA. On the other hand, with SLO microperimetry, a clear correlation of this kind could be seen in all cases.

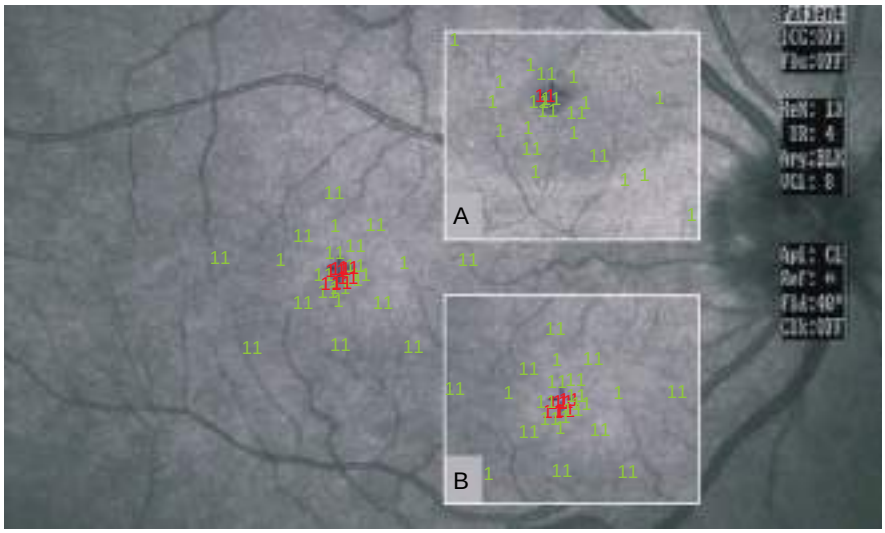

Fig. 3. Fundus photograph from a representative subject showing the results of SLO investigation (large picture) with a microperimetry overlay showing non-response stimuli indicative of a scotoma (in red) surrounded by normal retinal response (green). The blue cross represents the fixation cross. (A) Enlargement of a central portion of the retina in a patient with a central scotoma, representing a retinal area with an approximate diameter of 0.12 degree. (B) Enlargement of a central retinal area (same enlargement as in A) in a patient with a large central scotoma corresponding to a retinal area with an approximate diameter of 0.36 degree.

Most of the improvement in VA was observed to occur between visits 1 and 2. Between visits 2 and 3, no statistically significant improvement was noted, which also correlates well with the findings of other studies (Atmaca et al. 1995; Awan et al. 2002). However, a number of eyes showed an improvement in VA between visits 2 and 3 and the lack of significance was probably due to the small sample size. Subjectively, a decrease in the degree of visual disturbance occurred over the whole period, but 40% of the patients experienced a mild disturbance after 1 year. Further, the SLO results revealed the presence of scotomas at visit 3, even when the patients did not experience any visual disturbance. The good visual prognosis in most cases can probably be attributed to the resistance of the foveal cone cells to photochemical damage (Hope-Ross et al. 1993).

The results of the present study also give a clear indication of the hazards of looking into the sun and the importance of providing adequate safety information to the public before an impending eclipse. Prevention remains the mainstay of therapy.

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Correspondence:
Dr Fredrik P. Källmark
St Erik's Eye Hospital
Polhemsgatan 50
S-112 82 Stockholm
Sweden
Tel: + 46 8 672 3660
Fax: + 46 8 672 3330
Email: fredrik.kallmark@ste.ki.se