LASER-INDUCED RETINAL INJURY FOLLOWING A RECREATIONAL LASER SHOW: TWO CASE REPORTS AND A CLINICOPATHOLOGICAL STUDY

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ABSTRACT

Background: Two patients who attended a dance festival with an audience-scanning laser show presented in our department with a decrease in visual acuity from a direct laser hit in one eye. Ophthalmoscopy showed a similarly sized retinochoroidal coagulation spot, which had led to a retinal hemorrhage in both patients. Because the organizers of the show concluded that the retinal injury was caused by powerful, handheld laser pointers in the crowd, we were interested in determining if these laser pointers could cause this kind of acute retinopathy.

Methods: A 44-year-old man with an extrafoveal, temporal choroidal melanoma was scheduled for enucleation. The eye (visual acuity 20/20) had a healthy-appearing macula. Prior to enucleation, the retina was exposed to eight different durations (0.5-64 seconds) of laser beam from a commercially available, handheld, class 3B green laser pointer (500 mW).

Results: Histologic analysis was unable to identify any abnormalities in the choriocapillaris, the photoreceptors or the retinal pigment epithelium (RPE).

Conclusion: The use of powerful laser appliances (class 4 lasers) directed into the audience (audience-scanning laser show) can cause significant retinal injuries with lifelong visual consequences. It is unlikely that laser pointers, even those of class 3B, can cause these ocular injuries.

KEYWORDS

Laser pointer, Laser show, Retinal injury

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INTRODUCTION

Laser shows are increasingly popular during dance festivals. Audience scanning with lasers creates a visually impressive spectacle, but the lasers are very powerful, and there are no warnings explaining the risk of exposure to the eyes; however, there had been several cases in the literature describing eye damage after exposure to such shows (1,2,3). In addition, the misuse of powerful handheld lasers by audience members during such festivals is increasingly common.

On July 25, 2009, a laser show took place during the dance festival "Tomorrowland" in Boom, Belgium. Two patients presented in our department after experiencing a direct laser hit in one eye originating from the festival podium, followed by a prompt decrease of visual acuity.

CASE REPORTS

Case 1

A 21-year-old woman presented at our department for an eye examination, complaining of blurred vision since a laser beam hit her in the right eye one week prior, during the laser show. Her best corrected visual acuity (BCVA) was 20/20 in the right eye. Biomicroscopy was unremarkable, and intraocular pressure was normal. Ophthalmoscopy revealed a round, extrafoveal chorioretinal hemorrhage (Figure 1A, middle) and a small vitreous hemorrhage. Humphrey perimetry showed a superonasal scotoma corresponding to the site of coagulation (Figure 1A, right). Optical coherence tomography (OCT) showed a normal foveal depression (Figure 1A, left). Twelve weeks later, BCVA was

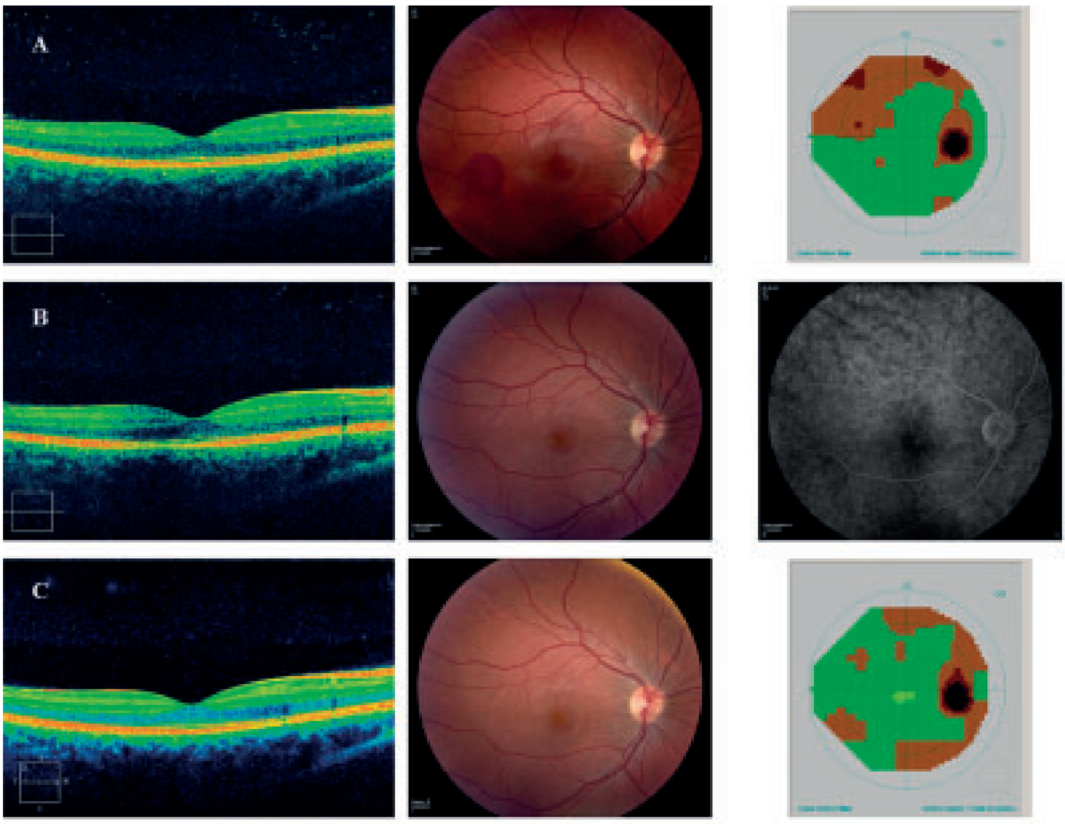

Fig. 1: OCT-images (left), fundus photographs (middle) and visual field examination / fluorescein angiogram (right) of first patient. A: one week after the laser injury, the OCT showed a retinal hemorrhage temporal from the fovea. B: 12 weeks after the laser injury. C: 9 months after the injury.

still 20/20 in the right eye, and ophthalmoscopy revealed a total regression of the subretinal hemorrhage and vitreous hemorrhage (Figure 1B, middle). OCT still showed a normal foveal depression. Fluorescein angiography (Figure 1B, right) demonstrated total resorption of the subretinal hemorrhage with no evidence of choroidal neovascularization, which is a known late complication in retinal laser injury (4,5). An examination nine months after the injury also showed no choroidal neovascularization and resolution of the scotoma on Humphrey perimetry (Figure 1C).

Nevertheless, because this patient was at a lifelong risk of developing extrafoveal choroidal neovascularization, she was instructed to report promptly if she experienced any changes in vision.

Case 2

A 26-year-old man, who also attended the same recreational laser show, presented at our department one week after the festival complaining of a sudden decrease of visual acuity and a central scotoma after a laser beam, also originating from the podium, hit his left eye. On examination, his BCVA was counting fingers in the left eye. Biomicroscopy was unremarkable, and intraocular pressure was normal. Ophthalmoscopy revealed a sub-internal limiting membrane (ILM) hemorrhage at the fovea (Figure 2A, middle and right). OCT showed a homogenous hyperreflectivity area at the surface on the retina with shadow effect on the whole retinal layers (Figure 2A, left), similar to lesions previously described (6). Six weeks later, his BCVA was 20/32 in the left eye, and ophthalmoscopy

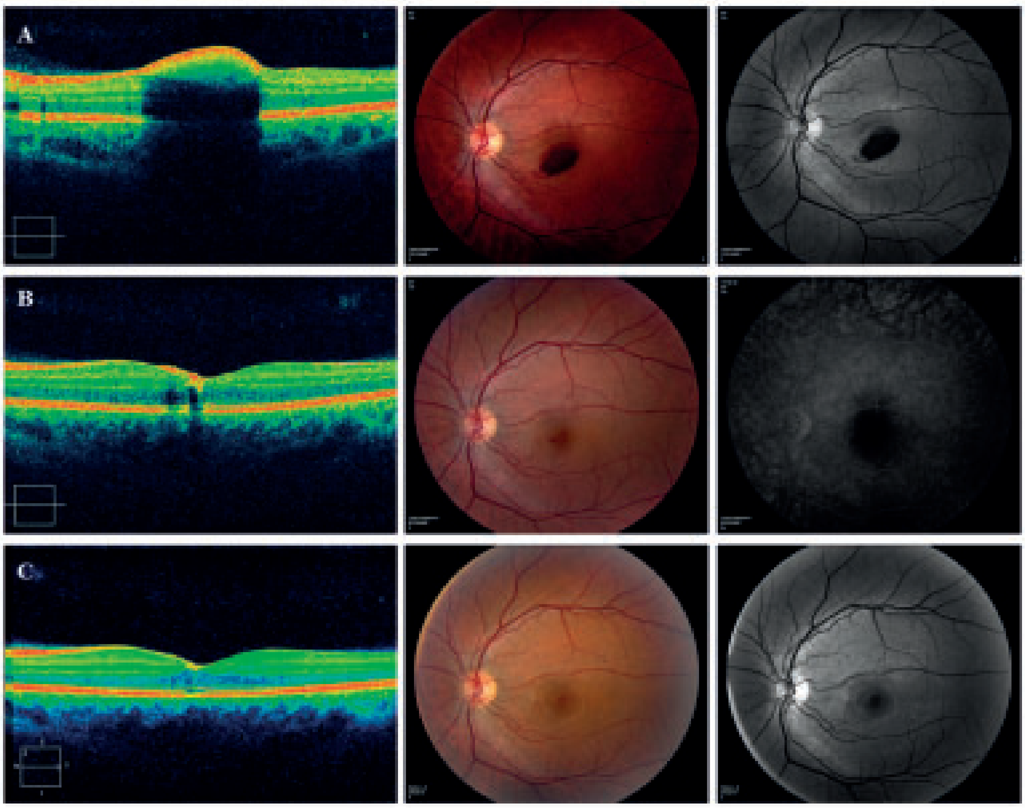

Fig. 2: OCT-images (left), fundus photographs (middle) and fluorescein angiogram / red free fundus photograph (right) of the second patient. A: one week after the laser injury, the OCT showed a retinal hemorrhage in the fovea. B: 6 weeks after the laser injury, demonstrating resorption of the hemorrhage and recovery of foveal anatomy on OCT. C: 7 months after the injury, with persistent focal RPE damage.

showed regression of the retinal hemorrhage (Figure 2B, middle). OCT showed normalisation of the foveal contour but persistence of a small hyperreflective area in the internal retinal layer with a shadow defect on the underlying retinal layers parafoveally at the side of the original laser injury (Figure 2B, left). Fluorescein angiography showed absence of choroidal neovascularization (Figure 2B, right). On follow-up seven months after the incident (Figure 2C), his BCVA was 20/20 in the left eye. Ophthalmoscopy showed a small parafoveal scar whereas OCT showed a residual foveal disturbance under the ILM and outer segment/inner segment (OS/IS) band and persistence of vertically hyperreflective band in the whole foveal thickness. Fluorescein angiography could not document any choroidal neovascularization. Because this patient has a lifelong risk of foveal choroidal neovascularization at the site of the laser impact, the self-assessment of macular vision with an Amsler grid was explained to the patient to whom it was recommended to consult in the eventually of any metamorphopsias.

Because the organizers of the show concluded that the retinal injury in both patients was caused by powerful, handheld laser pointers in the crowd, we aimed to determine if such laser pointers could cause this kind of acute retinopathy in the human eye. Furthermore, the two patients independently reported that the laser beam that hit them in the eye originated from the festival stage and not from audience members.

There are four categories of lasers, and at present, there are numerous publications about the safety of class 2 and 3A laser pointers (7,8). However, little is known about the possible risk of exposure of the eye to class 3B laser pointers (5,8,9-14,15-19). These powerful class 3B pointers are illegal in many countries but can be easily purchased on the internet.

METHODS

This study was performed on a 44-year-old man with an extrafoveal, temporal choroidal melanoma scheduled for enucleation. The eye was normotensive and had an uncorrected visual acuity of 20/20. The patient consented to participate in an experiment during which his macula (with a broad margin from the ocular tumor) would be exposed to a class 3B green diode laser pointer for intervals of up to 64 seconds. The study was approved by our institutional review board (Ethics Committee of the University Hospitals Leuven). The patient was fully informed of the nature of the experiment, and written informed consent was obtained.

For this experiment, the most powerful handheld laser pointer, a class 3B 500-mW green 532-nm model, was obtained from the Chinese internet site *www.yotang.com* (item code YT28152). Under general anesthesia, the eye that contained the melanoma was subjected to eight different durations of exposure from the laser pointer (0.5-64 seconds, doubling the exposure duration in each shot) from 1 m away. The site of each exposure spot was drawn on a retinal map, permitting exact localization by the pathologist. It should be noted that even at the longest exposure duration (64 seconds), no retinal coagulation could be seen with ophthalmoscopy at the end of the experiment.

After the completion of the laser experiment, the eye was enucleated and fixed immediately in buffered 4% formalin. After fixation overnight, it was sectioned circumferentially at the level of the ora serrata centered on the tumor and the posterior pole. The eye was further lamellated through the tumor, and sections were routinely processed. The posterior pole was separately sectioned and embedded. Serial sections were performed and stained with hematoxylin and eosin.

RESULTS

Microscopy revealed a classic malignant melanoma composed of pigmented epithelioid cells and confined to the choroid and a small, flat retinal detachment adjacent to the tumor. In the region of the laser spots, no abnormalities were detected. The pigment epithelium was regular, with evenly spaced nuclei positioned on the exterior side. The photoreceptor outer segments were interdigitated between the outer pigmented parts of the RPE layer (Figure 3). No abnormalities could be identified in the sites exposed to the laser.

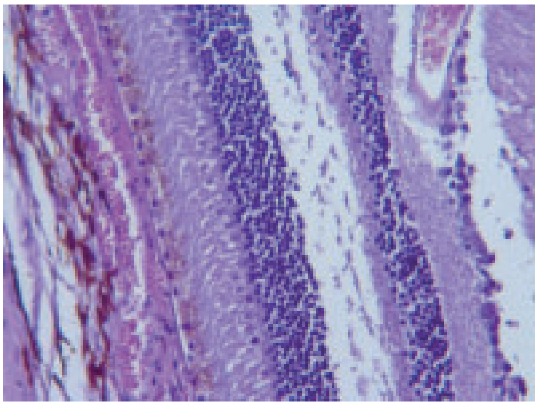

Fig. 3: Histology of the retina and the pigment epithelium in the treated area (magnification X100, hematoxylin and eosin stain staining). No abnormalities were found.

DISCUSSION

Laser shows use very powerful class 4 lasers. According to the organizers of the show, "beam attenuation map" software was in use, which should lower the laser power when beams are directed downwards into the crowd. In addition, the laser beams were kept moving throughout the entire show, which would increase safety. According to the organizers, the entire show was uneventful, with no equipment failures or other concerns, and light levels were below International Laser Display Association (ILDA) recommendations (*www.laserist.org*). According to the ILDA, calculations based on laser beam power, divergence, and diameter, in addition to the software beam attenuation map settings, showed that irradiance was at most 50 mW/cm^2 at the closest audience distance (30 meters from the laser projector). At a distance of 50 m, the irradiance would be about 10 mW/cm^2. These levels are below the 100 mW/cm^2 maximum level recommended by the ILDA for "level 2 shows" such as discos, nightclubs and festivals. The ILDA recommends two levels. A level of 10 mW/cm^2 for a static beam indicates that the exposure is safe for any audience as long as the beam is kept moving, as it should be in an audience-scanning show. Because shows at 10 mW/cm^2 are subjectively perceived as "dim" and because there have been "close to zero" incidents over 30 years of audience scanning with levels well over 100 mW/cm^2, ILDA analysis indicates that lasers up to a maximum of 100 mW/cm^2 are reasonable for nightclubs, discos, festivals and other more extreme environments. The ILDA supports the use of additional safety measures for shows at this level. Further, the ILDA does not believe that shows with an irradiance above 100 mW/cm^2 should be allowed.

However, these recommendations of a maximum of 100 mW/cm^2 for a "level 2 show" are 10 times the maximum permissible exposure (MPE) limits used in international safety standards. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has published guidelines for human exposure, which are available at no cost from the ICNIRP website (*www.icnirp.org*). MPE is the level of laser radiation to which a person may be exposed without hazardous effects or biological changes in the eye. MPE levels are a function of laser wavelength, exposure time and pulse repetition. MPE is usually expressed either in terms of radiant exposure in joules per centimeter squared or as irradiance in watts per centimeter squared for a given wavelength and exposure duration. For this type of show, the MPE is 0.001 seconds for a beam irradiance of 10 mW/cm^2.

Both patients noticed a sudden visual decrease in one eye immediately following a short (<1 second) hit by a laser beam coming from the stage. The organizers of the show claim that there were many people in the crowd flashing very powerful handheld laser pointers, which caused these injuries. These pointers are illegal in many countries but can be easily purchased on the internet. Because the organizers of the show concluded that the acute retinal injury in both patients was caused by these illegal handheld laser pointers in the crowd, we investigated whether such handheld laser pointers could cause this kind of retinopathy in the human eye. In this experiment, we could not document any acute retinopathy in a human eye even after a long-duration exposure (64 seconds) to a 500-mW handheld green laser pointer from a short (1 m) distance.

It must be noted that there were several mirrorballs consisting of several flat mirror pieces, hanging from the ceiling in the festival tent where our two patients were hit by a laser beam (several video recording showing the lasers in the show hitting the mirror balls can be found on *www.youtube.com*, searching for "Kozzmozz Area Tomorrowland 2009"). When the lasers beams are directed into the sky, the "beam attenuation map" software will allow a much higher laser power compared to the setting when the beams are directed downwards into the crowd. The reflection of the high laser power beams on the mirrorballs deviated to the people in the crowd can be a possible explanation of the laser injury in our two patients. It can also be a possible explanation of the extramacular location of the laser injury in the first patient, when the reflected beam hit the eye with an oblique angle.

In conclusion, this article indicates that the use of powerful laser appliances directed into the audience during dance festivals can cause significant retinal injury. Therefore, we think that level 2 shows exceeding the MPE levels require additional cautionary announcements to inform the audience of the visual risks. Moreover, the supervision of such shows by trained and certified personnel is necessary but is presently not mandatory by law in many countries.

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