

# Retinopathy From a Green Laser Pointer

## A Clinicopathologic Study

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**Objective:** To report retinopathy following exposure to light from a commercially available class 3A green laser pointer.

**Methods:** A 55-year-old woman with a ring melanoma was scheduled for enucleation. The eye (visual acuity 20/20) had a healthy-appearing macular retina. The retina was exposed to light from a commercially available class 3A green laser: 60 seconds to the fovea, 5 minutes to a site 5° below the fovea, and 15 minutes to a site 5° superior to the fovea. Color photographs were obtained before and after exposure. The eye was enucleated 20 days after exposure.

**Results:** Laser power measurements averaged less than

5 mW. Retinopathy was observed 24 hours after laser exposure. This was characterized by a yellowish discoloration at the level of the retinal pigment epithelium (RPE) in the subfoveal region and at the site superior to the macula where the retina received 15 minutes of laser exposure. Each site developed granular changes at the level of the RPE within 5 days of exposure. Histologic study showed RPE damage in the exposed subfoveal and parafoveal regions.

**Conclusion:** A class 3A green laser pointer caused visible retinopathy in the human eye with exposures as short as 60 seconds.

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**W**E REPORT THE DEVELOPMENT of clinically recognizable retinopathy following exposure of the human eye to light from a commercially available class 3A green laser pointer. A 55-year-old woman with a ring melanoma that involved the ciliary body was scheduled for enucleation. The eye had a healthy-appearing macular retina and good visual function (visual acuity 20/20). The patient agreed to have her retina exposed to laser light from the green laser pointer before enucleation. Continuous exposure was directed to the fovea for 1 minute, to the retina 5° below fixation for 5 minutes, and to the retina 5° above fixation for 15 minutes. The retina was evaluated ophthalmoscopically and the fundus was documented by color photography before, 24 hours after, and 6 and 20 days after laser exposure. Transient pink afterimages were observed by the patient for approximately 4 minutes after the laser exposure. The patient's visual acuity was recorded as 20/20 the day after exposure and 20/20 at 6 and 20 days after exposure. The

patient was unable to discern any visual abnormality and could not discern a scotoma on tangent screen or Amsler grid testing 6 and 20 days after exposure. Twenty-four hours after exposure, fundus examination revealed a distinct yellowish discoloration in the subfoveal region at the level of the retinal pigment epithelium (RPE). An area of yellowish discoloration was also recognized at the retinal site exposed to the laser for 15 minutes. A delicate granular irregularity developed in each site at the level of the pigment epithelium and was recognizable at the 6- and 20-day follow-ups. Histologic study of the enucleated eye showed a choroidal melanoma in the ciliary body, and thick sections revealed apical displacement of the nuclei of some RPE cells in the subfoveal region. The pigment granules were also displaced into the outer receptor layer, and many intracytoplasmic granules displayed irregular shapes and density characteristics of melanofuscin. Displacement of some of the pigment epithelial cells into the subretinal space was also observed at the exposed site. Although in this experiment a class 3A

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green laser pointer caused retinopathy with exposures as short as 60 seconds, the recognized ophthalmoscopic and histologic abnormalities were unaccompanied by visually perceptible abnormalities.

In a previous study,<sup>1</sup> we reported the absence of retinal injury following retinal exposures of laser light from commercially available class 3A red laser pointers with powers of 1, 2, and 5 mW. Three human eyes were exposed to light from these laser pointers for 1, 5, and 15 minutes. We documented no functional, ophthalmoscopic, histologic, or ultrastructural abnormalities that could be attributed to the laser exposures. We concluded that the risk to the adult human eye from transient exposure to light from these red laser sources was negligible, although 2 credible reports<sup>2,3</sup> have been published of visible retinal abnormalities after exposure to red laser pointers in 2 young patients, one 11 years old and the other 19 years old. Green laser pointers have been used interchangeably with red laser pointers by some lecturers, and green laser pointers are increasingly being used by amateur astronomers as pointers to deep sky objects. Unlike the beam of the red laser, which cannot be seen well in ordinary night atmosphere, the beam from the green laser can be easily seen in the deep night sky, where it can point to a single star. Additionally, since the green laser is visible in the daytime, when directed to outdoor objects of interest, the green laser pointer has proved useful to some instructors of outdoor painting, landscape design, architecture, and construction. Since the retina is increasingly more sensitive to shorter wavelengths, we were interested in learning if the green laser pointer could cause retinopathy in the human eye.

## REPORT OF A CASE

A 55-year-old woman with a ring melanoma of the ciliary body was 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 a green laser pointer would expose her retina to light for intervals of up to 15 minutes. The study was approved by our institutional review board before the experiment, and our patient was fully informed of the nature of the experiment and gave verbal and written informed consent to participate.

## METHODS

An apparatus was designed to direct the laser beam from a class 3A green laser pointer through a hole (5 mm in diameter created with a simple paper punch) in the center of a black Amsler grid and then into the patient's pupil to target the retina. This device was similar to that used by Robertson et al<sup>1</sup> (as shown in their Figure 1). The apparatus was arranged on a slitlamp so the patient's head could be positioned comfortably during the exposure. A paper clip and a rubber band held the switch of the laser on continuously. The front aperture of the laser pointer was fixed 15 cm from the estimated location of the posterior pole of the eye (macular retina). Two 1-mm white fixation targets were placed on the Amsler grid, one 2½ squares above and one 2½ squares below the center of the Amsler grid, thereby subtending angles approximately 5° above and 5° be-

low the center of the Amsler grid. The pupil of the eye that contained the tumor was dilated to 8 mm with 2% cyclopentolate hydrochloride and 10% phenylephrine hydrochloride. The other eye was doubly patched. The eye that contained the melanoma was subjected to 3 durations of exposure from the laser pointer.

The retina was exposed to light from a handheld green laser marketed as a laser pointer (LightVision Technologies Corp, Kaoyuan, Taiwan). Light output was continuous (not pulsed) and specified by the manufacturer as less than 5 mW at 532 nm. The beam power was measured with a radiometer (IL 700, SEE-100 probe; International Light Inc, Newburyport, Mass). From information relating to the retinal hazards of intrabeam viewing of lasers specified by the American National Standard for the Safe Use of Lasers,<sup>4</sup> we calculated maximum permissible exposure at various exposure times.

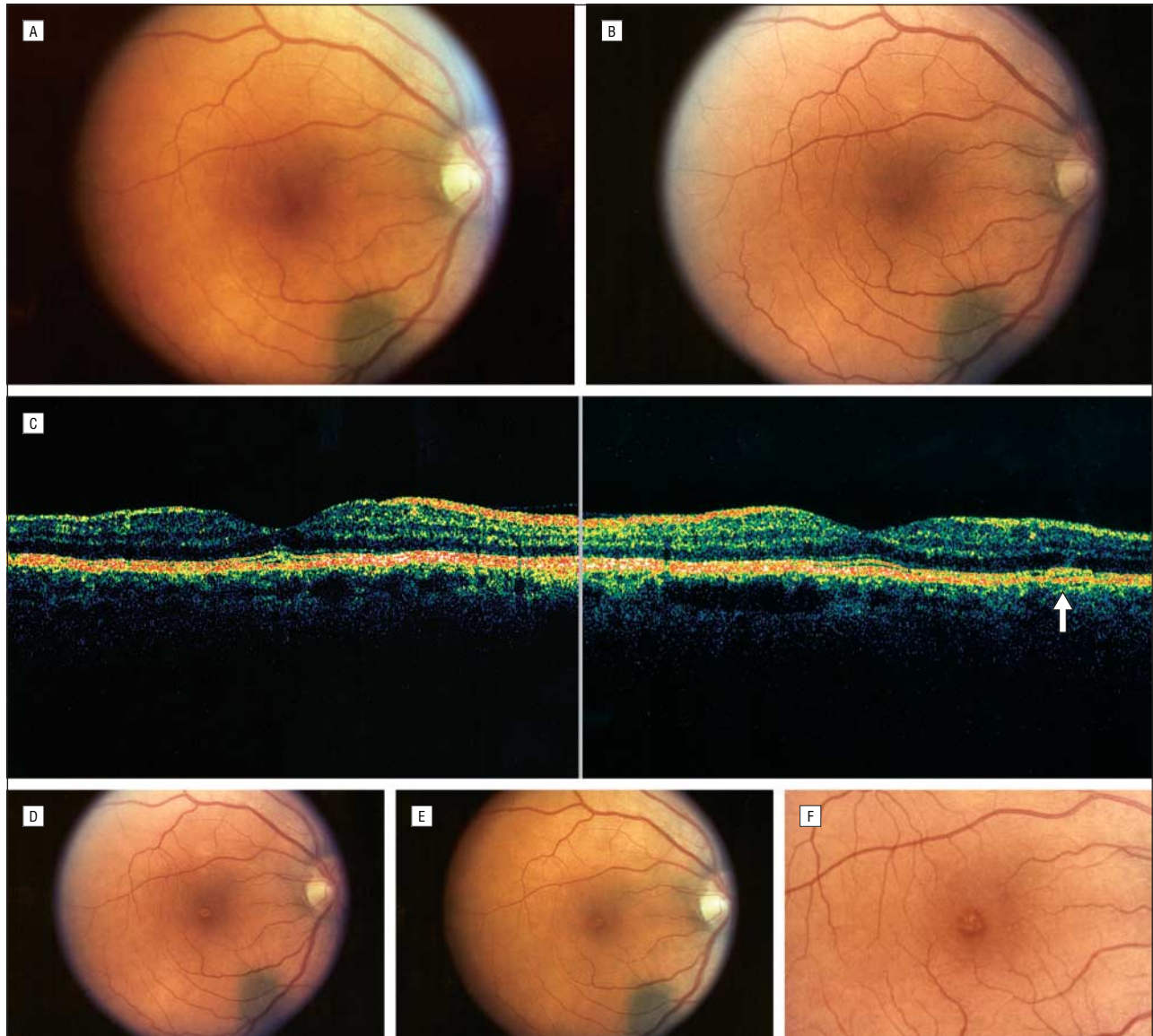
Exposures were administered as follows. The patient fixated her gaze for 60 seconds directly at the laser beam as it passed through the center of the aperture in the Amsler grid. Then the patient fixated her gaze for 5 minutes on the fixation target 2½ squares below the aperture and the laser beam. The last exposure was a 15-minute fixated gaze on the fixation target 2½ squares above the aperture and the laser beam. Normal blinking was allowed during the exposures. During each exposure, the patient's fixation was confirmed by one of us (D.M.R.), and the laser beam was maintained in the central 2 mm of the patient's widely dilated pupil. After each exposure the patient was asked to report any recognized afterimages or photopsias. Immediately after responding to this request, the patient was instructed to gaze at the center of a standard Amsler grid and report any defects in the grid. The patient wore corrective eyewear for this last assessment.

The patient returned the following day, 6 days after exposure, and again 20 days after exposure for measurement of the Snellen visual acuity, ophthalmoscopic examination with slit-lamp biomicroscopy aided by a Hruby lens and the 90-diopter (D) and 60-D fundus viewing lenses, and color photographic documentation of the fundus. The retina was examined by ocular coherence tomography (OCT) 24 hours after laser exposure. The central visual field was studied 24 hours and 20 days after laser exposure with the Amsler grid and tangent screen evaluations with a 1-mm white target. Sites in the fundus that were exposed to the laser light were carefully inspected for abnormalities. These sites included the fovea and the RPE complex 5° superior and 5° inferior to the fovea.

## RESULTS

The beam power of our green laser was variable and between 3 and 7 mW, although the manufacturer stated that the light output was less than 5 mW. The maximum permissible exposure is 0.39 mW for exposures between 1 and 15 minutes, assuming a 7-mm limiting aperture (pupil diameter).<sup>4</sup> Retinal exposure from our laser exceeded this limit by 8 to 18 times.

Pretreatment evaluation of the fundus of our patient revealed the presence of a small choroidal nevus beneath the inferior retinal vascular arcade. The central macula appeared normal (**Figure 1A**). The visual acuity was 20/20 uncorrected. After exposures to the laser pointer, the patient observed pink discoloration within her central visual field, which faded within 4 minutes of each laser exposure. The visual acuity was 20/25 within 3 minutes of exposure. No functional disturbance in visual acuity or the central visual field could be discerned



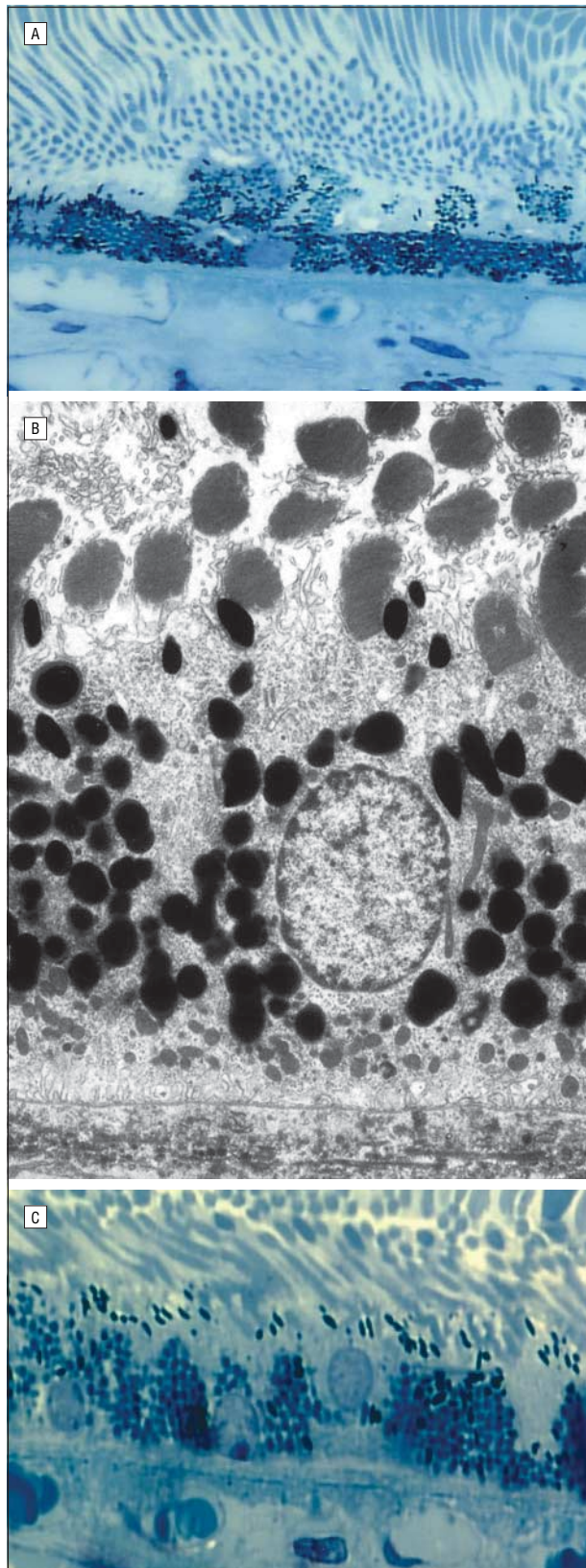
**Figure 1.** Composite showing the fundus photographs and optical coherence tomographic images before and after exposure to the green laser pointer. A, Normal-appearing macula. An incidental choroidal nevus is visible inferior to the disc. B, Twenty-four hours after exposure to the green laser pointer, subtle yellowish discoloration at the level of the retinal pigment epithelium (site of 60-second exposure to the laser pointer) is apparent; abnormal yellowish discoloration superior to the fovea where the site was continuously exposed for 15 minutes to the laser beam is also apparent. C, Ocular coherence tomogram that shows tissue thickening at the level of the retinal pigment epithelium in the subfoveal region (top) and the area of the fundus superior to the fovea where the retina was exposed to the laser for 15 minutes (bottom, arrow). D, Six days after exposure to the green laser pointer, the 2 sites identified in panel B now exhibit a delicate granular irregularity at the level of the retinal pigment epithelium. E, Twenty days following exposure. The 2 sites identified in panels B and D are less evident. The abnormality in the foveal region shows a light creamy discoloration. F, Foveal region shows irregular discoloration (original magnification  $\times 2$ ).

at subsequent visits 24 hours, 6 days, and 20 days after laser exposure. The uncorrected visual acuity was 20/20 at each of these follow-up visits.

Twenty-four hours after laser exposure, an ophthalmoscopically distinct yellowish discoloration appeared in the subfoveal region at the level of the RPE (site of 60-second exposure) (Figure 1B). No abnormality was visible in the fundus at the site of the 5-minute exposure, but a distinct abnormal yellowish discoloration was apparent superior to the fovea where the retina had been exposed to the laser beam for 15 minutes (Figure 1B). An OCT examination 24 hours after exposure suggested tissue thickening at the level of the RPE in both the subfoveal location and the area of the fundus supe-

rior to the fovea where the retina was exposed to the laser for 15 minutes (Figure 1C). Each of these 2 sites developed a delicate granular irregularity at the level of the pigment epithelium that was visible at the 6-day follow-up (Figure 1D). Some of this granularity persisted at this follow-up, but by 20 days the abnormality at the fovea was characterized primarily by a more delicate creamy discoloration (Figure 1E and F). The eye was enucleated 20 days after laser exposure.

The eye was received fresh from the operating room. It was sectioned at the equator. The anterior segment was placed in 10% buffered formalin and fixed for 48 hours before gross examination. The posterior segment was examined and dissected immediately. A small choroidal ne-



**Figure 2.** Composite showing both light microscopic and electron microscopic findings in the retina 20 days after laser exposure. A, Epoxy resin (Epon)-embedded thick section shows focal displacement of the retinal pigment epithelial cells into the subretinal space. No abnormalities are seen in the photoreceptor cells (epoxy resin-embedded toluidine blue stain, original magnification  $\times 100$ ). B, Transmission electron microscopic study shows clumping of pigment granules within the retinal pigment epithelial cells and dispersed in the subretinal space. The cross-sectional area of the outer segments appears normal (lead citrate, original magnification  $\times 2500$ ). C, Transmission electron microscopic study shows apical displacement of the nuclei of some pigment epithelial cells. Some pigment granules are irregular in shape and show densities characteristic of melanofuscin (epoxy resin-embedded toluidine blue stain, original magnification  $\times 100$ ).

vea were placed in glutaraldehyde and examined by transmission electron microscopy.

Gross examination of the anterior segment showed clear cornea that measured  $12 \times 12$  mm. The iris contained a mass from 9- to 12-o'clock ( $5 \times 3 \times 2$  mm) that adhered to the posterior corneal surface and extended posteriorly to the ciliary body. The anterior segment was sectioned clockwise, and all sections were embedded for histologic examination. Microscopically, a malignant melanoma, mixed cell type (spindle and epithelioid), was forming a predominant mass in the iris root that invaded anteriorly the trabecular meshwork and extended posteriorly to invade the ciliary body muscle. However, isolated tumor cells were observed in the trabecular meshwork and angle structures at approximately  $360^\circ$ . This morphologic impression was confirmed by melan-A immunostain, a melanoma marker.

Examination by transmission electron microscopy of well-fixed tissue from the region of the fovea showed apical displacement of the nuclei in some of the RPE cells in addition to focal clumping of pigment granules within the RPE cell cytoplasm. Many of the pigment granules had irregular shapes and demonstrated densities characteristic of melanofuscin granules. Distinct displacement of RPE cells also occurred into the subretinal space in some sections (**Figure 2A-C**). We were unable to identify any abnormalities in the choriocapillaries. The outer segments of the photoreceptors appeared to be normal except for some minimal disruption of the lamellae attributed to prefixation autolysis (present both in the posterior pole and a control site nasal to the disc). We could not identify abnormalities in the other sites exposed to the laser.

#### COMMENT

In this experiment, we documented the development of retinopathy in a human eye after purposeful exposure to light from a green laser pointer. In previous studies with red laser pointers, we failed to produce any evidence of retinopathy despite exposures of the retina to continuous light for up to 15 minutes.<sup>1</sup> The fact that we were able to demonstrate green laser pointer-induced retinopathy with exposure times as short as 60 seconds may not be surprising, since the human retina is much more sensitive to shorter than longer wavelengths. Also, melanin in the pigment epithelium absorbs more energy at shorter wavelengths than longer wavelengths.<sup>5</sup>

The appearance of the lesion after 60 seconds of green laser exposure was similar to the clinical appearance of

vus (2 mm) was noted inferior to the fovea. No other gross abnormalities were noted. Small portions of the fovea, the macular region approximately 5 mm superior and inferior to the fovea, and the nasal retina opposite the fo-

solar retinopathy in patients who have stared at a solar eclipse. The yellowish discoloration that was visible ophthalmoscopically probably represented a change at the level of the RPE where the pigment epithelium had received a mild thermal injury. Clinically, the discoloration did not appear at the inner retina in the region of greatest concentration of xanthophyll; an OCT study demonstrated thickening at the level of the pigment epithelium, which suggests that the ophthalmoscopically visible abnormality was at the level of the pigment epithelium. Why retinopathy was not visible 5° below fixation where the retina was exposed for 5 minutes cannot be readily explained, but the presence of a relatively broad area of retinopathy superior to the fovea where the retina had been exposed for 15 minutes suggests that the patient may have had difficulty maintaining precise fixation on the larger white target in the mounted apparatus as opposed to the more precise foveal fixation when the eye was gazing directly at the center of the laser beam. Microsaccades, micronystagmus, and slow drifts in eye position during fixation of a small target for more than a few seconds can spread the area of retina exposed to a laser.<sup>6</sup> Perhaps the greater excursions of the eye during fixation on the white target distributed the laser exposure across a greater area on the retina and allowed heat dissipation so that the retina was not injured at 5 minutes but was injured over a relatively broad region of 500 to 700 μm after an exposure of 15 minutes.

Our patient was unable to recognize any defect in central vision despite attempted efforts to identify a scotoma with the tangent screen using 1-mm targets and the Amsler grid study. The inability of the patient to recognize functional changes in vision may reflect either a true absence of functional damage or simply our inability to detect subtle changes in the central visual field function with the testing methods used. The histologic study indicated some damage to the RPE represented by displacement of the nuclei away from the basement membrane, dispersion of pigment granules, the development of melanofuscin changes near the site of maximum exposure at the fovea, and displacement of RPE cells into the subretinal space. These findings are consistent with ther-

mal injury that affects primarily the RPE. Although it remains comforting that the patient did not experience any visual abnormalities up to 20 days following laser exposure, nevertheless the inducement of ophthalmoscopically visible photic damage along with the induced histologic abnormalities suggests the need for caution with the use of laser pointers and, more particularly, the green laser pointer. Fortunately, the risks to the human eye from transient exposure to light from laser pointers are minimized by the normal blink and aversion reflexes that occur within fractions of a second of exposure. Nevertheless, exposure of the retina to light from a commercially available green laser pointer carries a risk that is real; this risk appears to exceed the risk from commercially available red laser pointers.

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