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Laser Pointers Revisited Editorial

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Retina specialists are now seeing increased number of cases with hand-held lasers induced retinal damages in particularly outside of the US, where these dangerous devices are sold as toys for children. The low price of these lasers has also led to their widespread use by the public and there are increasing complaints by airline pilots about lasers directed at their planes as well. Although there has been only one report about an alleged laser induced injury in a pilot during landing operation ¹, there have been many case reports with a vision disturbances or vision loss (up to counting finger level) in children or in the adult population when such lasers are directed into the eye. In the U.S., the FDA has imposed strict guidelines for the sale of laser pointers, which considers an output power of less than 5 mW to be safe. Devices with higher power are considered hand-held lasers. However, a quick survey of the laser pointers used in lectures at our own institution revealed output powers of over 5 mW in 3 of 4 devices (range from 20 to 160 mW). Recent technologic advances have made high-power green lasers available with a wavelength of 540 nm, very close to the peak of photopic sensitivity (555 nm) with power outputs in excess of 2,000 mW [<http://www.wickedlasers.com>], 400 times the maximum power of class 3R lasers (5 mW maximum power between 400 and 700 nm) which is considered to be safe if handled carefully, i.e. without direct eye exposure. Some blue laser diodes (445 nm) have output powers of 6,000 mW [<https://goo.gl/dDV1cU>]. These high-power laser diodes have been developed for the digital projection devices. However, a quick review of popular websites finds over 20,000 videos describing high-power laser uses including videos where 8 laser diodes with 5W each were assembled into a 40W laser diode array used to set various items on fire [<https://goo.gl/ZzwPzJ>]. Even though federal regulations prohibit the sale of these high-power lasers, these lasers are readily available from oversea vendors who ship them to the U.S. without any apparently effective regulation. Many high powered lasers are available as hand held, battery operated devices which look like ‘laser pointers’. Most lasers are classified as Class 1, Class 2 or Class 3R devices, according to their laser power and wavelength. The American National Standard Institute (ANSI) publishes the ANSI standard on the safe use of lasers ². They present a complex guideline for determining safety limits, establishing safety rules and conditions, and other aspects of laser use. The previous classifications of class 1, 2, 3a, 3b and 4 has been replaced by a system with classes 1, 1M, 2, 2M, 3R, 3B and 4. Class 1 lasers are safe under all conditions and include CD players, DVD players, laser printers and ophthalmic scanning laser ophthalmoscopes. Class 2 lasers are visible wavelength (400-700 nm) products that are safe due to the blink reflex that limits exposure to no more than 0.25 seconds. These lasers have an output power of 1 mW or less for continuous wave (cw). Class 2M lasers are similar to Class 2 lasers with the addition that they not be viewed through optical instruments. Typically these lasers have either a large diameter or a large divergence and would be unsafe if used with lenses that can refocus the energy. Class 3R laser pointers or devices are considered safe if handled carefully with

restricted beam viewing. In the visible spectrum cw lasers are limited to 5 mW at wavelengths between 400 and 700 nm. Class 3B lasers are hazardous if the eye is directly exposed, but diffusion reflections are not harmful. Class 3B cw lasers in the visible spectrum are limited to 500 mW. Class 4 lasers are the highest and most dangerous types of lasers. ANSI guidelines recommend that the use of Class 3R lasers in situations involving the general public should be supervised by a trained operator or used in such a fashion that direct or specularly reflected exposure is impossible. The ANSI guidelines recommend that safety and training programs should be required for Class 3R lasers. Clearly, these conditions are not met in the present situation where laser pointers are sold to the general public without any training or supervision. Safety warnings on the laser warn the user to avoid direct eye exposure but fail to offer a threshold for eye injury or damage. In addition, some lasers have warning labels with a letter size of 3/100th of an inch (0.75 mm font size).

Researchers have presented studies that document eye injury due to the misuse of lasers ³⁻⁵. Robertson and colleagues ⁶ performed a study with a laser pointer with power output between 3 and 7 mW (532 nm) that was measured with a laser power meter. They illuminated the retina of a patient scheduled for enucleation to 60 seconds, 5 minute, and 15-minute exposures. On clinical examination they observed retinopathy within 24 hours and RPE damage was seen with all exposures on the histology. While Mainster et al. ⁷ showed that a 0.12 mW yellow-green laser operating at 555 nm has the same apparent photopic brightness as a 4 mW, 670 nm red diode laser, manufacturers have instead opted to sell overly bright 3 - 5 mW, 542 nm, frequency-doubled YAG lasers or more recently InGaN (indium-gallium-nitride, 380-405 nm blue) laser diodes. Most authors agree that the general public is unaware of the risks associated with the abuse of these devices ^{8, 9}.

Although natural protective mechanisms such as the blink reflex and aversion response limit the duration of laser exposure, those mechanisms may fail to protect the eye against the high power laser, subsequently mild to severe retinal damage may occur. Using the ANSI standard ² we calculated that a 6W laser (Nichia NUBM44, 455 nm, currently the most powerful commercially available blue laser diode) directed at the eye will exceed the safety limit by over 20,000 fold and cause damage even if only exposed for 10 milliseconds, far less than the blink reflex. We conducted a review of case reports of laser eye injuries over the last five years. ^{3-5, 10-20} Most of the cases occurred as a result of intentional viewing into a laser's beam or use of lasers by poorly trained individuals in military activities. ^{5, 13, 18, 21, 22} However, with the high power now available in hand-held laser damage can be caused even by accidental exposure.

Most accidental laser injury victims in the literature have been children or young adults and the age of the patients ranged between 11 to 34 years of age. ^{10, 11, 17} Cases usually present with visual disturbances at 4 hours to 1 week following exposure to laser beam, however the interval between exposure and presentation may be prolonged, particularly in pediatric patients who may not be aware of ophthalmological symptoms. Most of the reported cases had asymmetric injury, most likely due the method of injury when the laser pointer is directed at one eye from a short distance to the head. The best-corrected visual acuity (BCVA) in those cases at presentation ranged from counting fingers to 20/20.

Laser pointer injuries may cause a variety of retinal changes including foveal granularity, perifoveal drusenoid like deposits/ pigment clumps, or ring-shaped hypopigmented lesions in fovea, vitreous hemorrhage and hemorrhages in different retinal levels. During the follow-up, complications may occur including epiretinal membrane (ERM), macular hole, choroidal neovascularization (CNV), and scars in the pigment epithelium. Although some of the cases showed spontaneous improvement in vision during the follow-up, late complications such as chorioretinal scarring may be responsible for delayed worsening of visual function after the initial improvement.^{10, 11, 13, 17} The spectra- domain optical coherence tomography (OCT) findings of laser injuries are characterized by vertical hyper-reflective bands, ellipsoid and external limiting membrane disruption, and hyporeflective cavities.¹⁹ The vertical bands typically originate from the retinal pigment epithelium and overlying photoreceptor outer segments and follow the remainder of the photoreceptor cell toward the outer plexiform layer.

The medical management of eyes without complications is limited to systemic steroids; however, there have been no properly established data showing the efficacy of corticosteroid administration.

Alsulaiman et al.,¹⁷ reported the largest case series of 14 patients with various maculopathies including subhyaloid hemorrhage (35.7%), sub-internal limiting membrane (ILM) hemorrhage (14.2%), schisis like cavity (7.1%), full-thickness macular hole (FTMH) (28.5%), ERM (7.1%), and outer retinal layer disruption caused by a high-power handheld blue laser device with a wavelength of 450 nm and a power of 1200 mW. In this case series, 5 eyes showed significant improvement in vision following pars plana vitrectomy for FTMH and ERM; 5 had Nd:YAG hyaloidotomy for subhyaloid hemorrhage, and the others demonstrated spontaneous resolution of lesions with complete restoration of foveal contour. Although Nd:YAG hyaloidotomy failed to allow the blood to drain into the vitreous cavity due to clotted blood in 2 eyes, vision significantly increased after 2 to 5 months in those eyes. The mechanism of macular hole (MH) formation following high power laser exposure is believed to be as a result of photodisruptive effect that leads to initial retinal dehiscence and subsequently enlarges secondary to tractional forces by the taut hyaloid.^{3, 10, 18} Spontaneous closure of macular holes may be anticipated in some cases; however, since those cases behave differently from idiopathic and traumatic holes, and high likelihood of MH enlargement, further early surgical intervention may be required.¹⁸ The largest study of FTMH secondary to laser pointer injuries was from Saudi Arabia,¹⁸ the study group reported the outcomes of 17 eyes with a mean of 20/210 (ranged from 20/30 to 2/200) baseline vision that had FTMH following handheld blue laser exposure with a wavelength of 450 nm and a power of up to 2000 mW. Eleven of 14 (78.6%) operated eyes following an observation period had complete closure of the macular hole and vision improved from 20/230 (range; 20/60-2/200) to 20/43 (range: 20/20- 20/200) in those cases. Of the 3 unoperated eyes, 1 eye with the smallest macular hole (minimum diameter 168 µm and base diameter 184 µm) closed spontaneously with a slight improvement in vision (from 20/400 to 20/300) following an observation period at month-9. Although the vision increased from 20/100 to 20/50 at month-5 in a patient who refused the surgery, the final vision is unknown in 1 eye because of not having a follow-up.

The abundance of recent case reports support the high risk of eye injury due to high power laser pointers/ hand held laser devices.^{3-5, 10-16} According to ANSI standard each laser pointer has a nominal ocular hazard distance (NOHD), the distance that a laser beam does not cause immediate or long-term damage based on a 0.25 second blink reflex. For the modern high-power 3.5 W blue (445 nm) laser pointer this NOHD is approximately 280 meters or over 900 feet. In contrast, a class 3R laser pointer does not pose any risk within the 0.25 second blink reflex.

Laser eye injury caused by laser pointers/ hand held laser devices is possible, however, it can be avoided by proper training and teaching. It may be necessary to restrict sale of laser pointers by imposing a minimum age and educate parents about the inherent danger of laser pointers.

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