Aircrew and Handheld Laser Exposure

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BACKGROUND: Laser devices are ubiquitous in everyday operations. These devices pose a hazard to the eye and numerous injuries have been documented. However, there lies a misunderstanding in the propensity to damage aircrews' eyes during an exposure. Patient encounters and article review is presented in hopes to raise awareness that aircrew laser exposure at altitude, outside of critical phases of flight, is a distraction and not a threat. Also, to propose a change to Air Force policy regarding such exposures and further educating flight surgeons.

METHODS: An electronic medical record (EMR) search at a deployed clinic was performed from July 2016 through Jan 2017. The "reason for visit" column was perused for any reference to the eye and laser exposure. Subsequently, the patient encounters were scrutinized specifically for eye injury, optometry visit, color of laser, and suspension of flight duties. All members were military aircrew spanning loadmasters, boom operators, and pilots. No protective lenses or other forms of optics were employed at time of exposure.

RESULTS: There were 21 encounters reviewed; 1 patient was seen twice due to 2 separate instances. Of the encounters, 14 were green lasers, 6 did not comment, and 1 indicated white. Zero acute injuries were discovered.

DISCUSSION: Patients were needlessly sent for further examination and prohibited from performing their duties. Following military patient encounters and civilian literature regarding laser injury, the evidence highly supports the hypothesis that hand-held laser exposure in flight from a ground base does not engender eye injury. More emphasis should be placed on recognizing the laser threat as a distraction or disruption to critical phases of flight, and a policy change may be in order for the USAF laser exposure guide.

KEYWORDS: laser, eye injury, aircrew, military.

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Lasers are ubiquitous implements that are regularly employed in daily life. Their applications range from the mundane presentation pointers to military target acquisition and beyond. The inherent properties of lasers place users and bystanders at risk for nonionizing radiation exposure. The most forefront risk would be exposure to the eye. It comes as no surprise that some unscrupulous individuals find these effective instruments to harass, disrupt, and injure. This is evidenced by news articles regarding lasers used to distract civilian pilots. Military pilots are not an exception. Consequently, these events have birthed fear and led to unnecessary occupational disruption. Using data gathered from patient encounters and literature, I aim to elucidate laser exposure is more apt to disrupt flight and not directly injure aircrew vision while flying at altitude.

Laser is an acronym for light amplification by stimulated emission of radiation. The light emitted from a laser is monochromatic, coherent, and directional.[16] These very characteristics allow for a focused beam of electromagnetic radiation, or light, to be directed at an object. Depending on the power, irradiance, and divergence, this could yield injuries to skin and eyes. Laser devices are classified by their ability to cause biological damage. The federal laser product performance standard (FLPPS) designates four classes.[10] The summarizations come from OSHA.[10]

Class I: No known hazard level. Continuous wave 0.4 μW at visible wavelengths.
Class IA: Emission does not exceed the Class I limit for estimated 1000 s.
Class II: Low power lasers. Emit above Class I levels, but radiant power not above 1 mW.

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Class IIIA: Intermediate power lasers. Continuous wave 1–5 mW. Intrabeam viewing is hazardous.
Class IIIB: Moderate power lasers. Continuous wave 5–500 mW, pulsed: $\leq 10\ J \cdot cm^{-2}$. Not a fire hazard, not capable of hazardous diffuse reflection.
Class IV: High power lasers. Continuous wave 500 mW, pulsed $>10\ J \cdot cm^{-2}$. Hazardous under all conditions, directly or scattered. Potential fire hazard and skin hazard.

METHODS

An electronic medical record (EMR) search at a deployed clinic was performed from July 2016 through January 2017. The "reason for visit" column was perused for any reference to the eye and laser exposure. Subsequently, the patient encounters were scrutinized specifically for eye injury, optometry visit, color of laser, and suspension of flight duties. A total of 6 mo worth of documented laser exposures were reviewed. The incident locations varied; however, all patients were examined in the same clinic. Locations and clinic cannot be disclosed secondary to the sensitive nature of operations. Patients were examined within 24 h of exposure.

RESULTS

All members were military aircrew, spanning loadmasters, boom operators, and pilots. There were 21 encounters found and, of those, 1 individual sustained 2 separate exposures. Of the encounters, 12 led to dilated funduscopic exams (DFE); consequently those 12 encounters yielded grounding of exposed aircrew. No protective lenses or other forms of optics were employed at time of exposure. Green was the most common laser color at 14, 6 encounters did not report the color, and 1 indicated white. Zero acute injuries were discovered in the 21 encounters. One patient had an incidental nevus. Secondary to DFE, 12 were grounded for 24 h. All exposures were presumed to be at greater than 10,000 ft above ground level (AGL) because they happened during refueling or normal operations. All exposures were ground-to-air lasers.

DISCUSSION

The obvious limitation is the small pool of patients, subjective reporting, and nonstandardization of lasers aimed at aircraft. However, no encounters yielded any evidence of acute injury, which is to be expected given the flight level and the limitations of lasers. Nominal ocular hazard distance (NOHD) describes the safe distance from a laser source. At this distance, there is nearly no chance of injuring the eye. Cleverly, the NOHD has a degree of safety built into the value. At one-third of the NOHD, there is a 50% chance of retinal damage under ideal conditions. As a result, the additional two-thirds of NOHD provides a buffer, leaving virtually no risk of damage during exposure at or beyond the determined distance. Looking at an example of a 1-W laser that is available to the general public, the eye injury hazard is 437 ft. Clearly this is well below typical operational altitude, making any eye exposure to conventional laser pointer nonexistent.[8]

Patients were reflexively sent to optometry, where they defaulted to DFE, looking for affirmation of injury to the eye. This occurred without complaints or findings during initial presentation. This naturally led to a grounding period where aircrew were not permitted to perform flying duties. In peacetime operations, this would be of little consequence; however, in a deployed environment, a given mission may grind to a halt unnecessarily. Wherefore, this may reasonably lead to an underreporting of exposures because of fear of "grounding" and adverse mission impact. More effort should be placed on educating aircrew on recognizing and recovering from flash blindness and glare to thwart visual disruption in flight. There was another group of patients who were not referred to specialists for further workup. In part, some of the providers felt more comfortable personally examining the patient and letting the history and physical dictate the necessity of referral.

The critical phases of flight are the most sensitive to disruption due to laser exposure. Glare and/or flash blindness during these times could contribute to loss of visual acquisition of the airfield, leading to missed approaches or crashes. The propensity of retinal damage from exposure is greater during these phases, but flash blindness or glare does not indicate retinal damage. With commercial handheld lasers of any wavelength, the human blink reflex, 0.25 s, is sufficient enough to shield the eye from damage.[2]

Evaluating the physics of laser instrumentation used in ophthalmology further argues the negligible risk of retina or eye damage during flight. Photocoagulation is employed in retinal laser surgery. To coagulate tissue, 10 to 20°C above body temperature is needed. Photovaporization occurs when the water in cells and the extracellular areas reach 100°C. Hyperthermia ranges from 42 to 52°C and this temperature must be sustained for 20 s to 4 min for irreversible effects to occur.[16] None of these measurements can be achieved during a brief exposure while at altitude.

A review of case reports of laser exposure with ocular findings consistent with damage are all due to the close proximity of the light source.[3] A 15-yr-old boy suffered laser pointer induced maculopathy following bouts of self-inflicted green laser exposure off a mirror.[14] Anterior segment was unremarkable, and subsequent retinal damage was present. Prior to evaluation, the boy was complaining of distorted vision and dyschromatopsia. A 20-yr-old man with loss of central vision in the right eye sought care following a direct exposure from a short distance (not specified).[1] Exam revealed a normal anterior segment of the afflicted eye and macular edema with hemorrhage below the fovea. There has also been a report of a 24-yr-old woman, a 36-yr-old man, and a 16 yr old (sex not provided) with self-inflicted laser injuries resulting in iris atrophy and maculopathy.[5] A 9, 11, and 8 yr old in a retrospective case series all demonstrated maculopathy secondary to hand-held laser

exposure.[13] In separate cases, three male children sustained retinal disruptions following laser pointer misuse.[4,9] Uveal tissue damage was found in patients following inadvertent exposure during laser hair reduction of the eyebrows.[12,18] The cases are plentiful. The FAA published laser incidents for 2010–2014 and the number is staggering: 17,764. The data encompasses reported exposures from the United States and Puerto Rico. Of those exposed, zero injuries were reported.[6] In further support, 64 laser strike incidents of commercial airline pilots did not result in any definite cases of ocular damage.[11,15,19]

Patients are inclined to become hypervigilant of areas of perceived injury. They will naturally muse on any symptom and question its relationship to the exposure. Most of this fear can be dispelled with reassurance, education, and performing a simple eye exam checking visual acuity, Amsler grid, and fundoscopy. This naturally raises another issue: the flight surgeon must be comfortable enough examining the patient in order to avoid unnecessary referral.

For damage to occur, energy must be absorbed. This energy is readily absorbed at the retina and uvea secondary to melanin. Epitheliopathy is not possible with hand-held lasers because the energy passes through the cornea. Corneal damage found in case reports were attributed to significant eye rubbing.[2]

The U.S. Air Force (USAF) does have policies and flowcharts for suspected laser injuries; however, the tone and information presented is more pertinent to close proximity exposures. This is more apropos for ground troops than aircrew. The instructions for flight surgeon evaluation of exposed crewmembers provides guidance for obtaining a detailed history and physical for these encounters. Some of the sections are too detailed and recommend physical exams that are not practical or possible in a deployed setting. The average flight surgeon has had minimal experience evaluating and treating eye conditions, therefore anxiety ensues and patients are needlessly referred to ophthalmology or optometry. This is most likely the reason why patients in this paper were sent for DFE and slit lamp examination with optometry. As a result, I propose a truncated separate policy and guidance for exposed aircrew in an austere or limited resource environment. 1.) Require asymptomatic exposed aircrew to document the incident on existing approved forms within 24 h for safety surveillance. 2.) Require symptomatic patients to report directly to flight medicine as soon as possible for appropriate workup. 3.) If abnormalities are found on exam, resort to specialist evaluation. This would abate unnecessary use of resources and superfluous temporary loss of aircrew.[7,17] In addition, flight surgeons should be further educated and well versed with basic ophthalmological evaluation.

Following military patient encounters and civilian literature regarding laser injury, the evidence highly supports the hypothesis that handheld laser exposure in flight from a ground base does not engender eye injury. More emphasis should be placed on recognizing the laser threat as a distraction or disruption to critical phases of flight, and educating flight surgeons, while a policy change may be in order for the USAF laser exposure guide.

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