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DELPHI TECHNIQUE USED IN LASER INCIDENT SURVEILLANCE

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ABSTRACT

There are several data sources for collecting laser incidents. All reviewed sources collect information differently for varying purposes. An effort was undertaken to combine laser exposure reporting data into a single database so that trends in laser incidents could be identified. A review of available datasets revealed significant disparities in laser exposure reporting. As a result, utilizing the existing database to predict personnel at increased risk for laser exposure and injury is challenging if not impossible. For example, many of the data sources do not contain information about physical examinations, diagnosis, or medical follow-up, which are important for studying laser injury outcomes. This study proposes using the Delphi Technique to identify relevant fields that should be collected for a laser incident database based on the experiences of three groups of United States Air Force (USAF) professionals: (1) Engineers (Bioenvironmental Engineers), (2) Health Physicists, and (3) Physicians (Ophthalmologists and Flight Surgeons). In broad terms, these three professional groups coordinate laser incident analyses and investigations. Knowing what information is most important for studying laser incidents is the first step in establishing an effective database that will assist in identifying occupations that are at high-risk for laser injury. Robust data sets obtained for analysis by these healthcare professionals can be an effective tool for laser injury prevention and management.

Keywords: Laser injury, laser safety, laser incident, laser surveillance, Delphi Technique

1. INTRODUCTION

To date, no known scientific study has been performed to identify what medical or environmental exposure information should be collected for laser incidents. The goal of this study is to establish baseline data collection requirements for laser data sets in exposed USAF personnel. Because of the unique and dynamic operational environments that USAF personnel are frequently exposed to, surveillance of laser incidents on a rapidly changing battlefield and training ground is especially important. Although military laser injuries are rare, risk of injury due to laser systems has increased in the USAF between the years of 1965 and 2002 compared to other military branches [1]. This could be due to better detection of a constant number of injuries or an actual increase in the number of injuries secondary to the proliferation of laser systems. There is no consistent tracking process in the USAF to identify trends in laser incidents. Without trend information, only speculation can be used to determine who may be at risk of injury or why injuries are occurring. In the absence of validated data, it may not be possible to accurately determine the relationship between exposure, prevention, and treatment of laser related injuries.

The greatest limitations to laser implementation in field conditions has been power, size, weight, and heat output [2]. However, progress in laser research aids in the development of new ways to overcome these technical limitations resulting in smaller, more powerful, portable laser weapon systems, which are currently being used in USAF combat operations [3]. New uses for current laser systems and more powerful systems are on the horizon. There has also been an increased interest in non-lethal laser systems that can be used against personnel and more powerful systems that can be used against equipment. [3]. Non-operational laser use in USAF Medical Treatment facilities is another source of potential exposures

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and injury. Currently, lasers are used in many medical applications to include laser vision correction and other dermal (skin) procedures. Operational military uses of laser systems include target illumination, designators, communication systems, antiaircraft, antimissile, range finding, radar and warning systems, and electro-optical sensor destruction [2, 4-6]. Of the fourteen reported Army incidents from the unified database, nine of them were from target designators or range finders that happened during field training [4].

In both peacetime and during conflict, the human eyes and skin are at significant risk for laser injury. The major structure in the eye at greatest risk to laser injury is the retina. Retinal cells are particularly sensitive to collimated light between 400nm and 1400 nm. Further, the cornea and lens of the normal eye is very efficient at focusing laser light on the retina. [5]. Although there was a ban placed on them in Oct. 29, 1995 under the Geneva Convention Protocol on Blinding Laser Weapons (Protocol IV), anti-personnel lasers have been designed to intentionally cause retinal damage and blindness in large numbers of individuals [5]. Loss of vision due to a laser exposure could have devastating effects on the military mission. In addition, engineering controls and personal protective equipment are less effective when laser systems are used outdoors or in the field [4]. Unlike training scenarios, operational combatant environments are less predictable, putting personnel at greater risk for unintentional laser exposure. [7]. Because operational environments are more dynamic and unstable than training conditions, unintended reflection, operator error, and technical use limitations are all possible. When magnifying optics, such as binoculars, are used by ground personnel, the risk of severe eye injury becomes significantly greater. When laser eye injuries occur, they can cause significant disability and can be quite expensive (both in cost and combat effectiveness) for the DoD. [8]. Further, at lower levels and in the absence of a significant retinal burn, less severe exposures may go unreported because they may not be attributed to laser exposure [8]. An example of an exposure not resulting in injury was reported while the crew of an EC-130 was flashed with a ground-based laser from a light show system at a casino in Nevada, causing temporary flashblindness in the flight engineer. [4].

Previous researchers compiled information from available sources of laser incidents into a single, unified laser injury database [9]. Three primary sources were used to make the combined database: Rockwell Laser Industries' (RLI) Laser Accident Database, United States Army Medical Research Detachment (USAMRD) of the Walter Reed Army Institute of Research's Laser Accident and Incident Registry (LAIR), and the Food and Drug Administration's (FDA) Center for Devices and Radiological Health (CDRH) [10]. Other databases were consulted but did not contribute events not already reported in at least one of the three main databases. The combined database contains information about sources of reporting, accident descriptions, type of industry, location, wavelength, and other incident information. Each database had different objectives for collecting laser incident reports such as training (RLI), reporting equipment problems (CDRH), or for research and accident prevention (LAIR). Recognizing the need for a general guidance for laser incident reporting within the DoD, the Laser System Safety Working Group, which includes laser experts from all services, drafted a new DoD Instruction for Protection of DoD Personnel from Exposure to Laser Radiation and Military Exempt Lasers [1]. Currently, this regulation is in a draft form in circulation for approval. This instruction directs all services to report suspected laser exposures to the tri-service laser hotline at Brooks AFB. Information from this proposed study could be integrated into the LAIR database, greatly enhancing DoD-wide laser incident collection

Within the individual services there are significant discrepancies in data reporting. For example, exposure risks of Air Force Personnel have not been scientifically evaluated nor has there been any means to characterize them. To date, studies on laser eye injuries discuss military injuries as a whole or involve case series reports on incidents from the Army through the LAIR [4]. The number of unreported or improperly reported laser incidents is unknown whether it is because there are few injuries recorded in known databases or because specific reports regarding Air Force members had not been published [1]. Of 29 military laser injury reports in the unified database from 1965 to 2002, there were 6 Air Force, 15 Army and 8 Navy/Marine injuries [4]. A conclusion of their study is that it is doubtful that these encompass all laser incidents and the low numbers give no power to do a sufficient analysis of trends. There are several reasons attributed to the lack of laser incident data. A laser user may not be given ample direction for what to do in the event of an incident [11]. It has been speculated that some personnel may not report due to fear of consequences; for example, a pilot not reporting an exposure for fear of being grounded [1]. The military has exposure potentials that are unique compared to industry that makes protecting personnel a continuous challenge.

On the battlefield, anti-personnel lasers capable of blinding aviators and ground personnel are major threats to operations, despite current prohibitions against their use under International law, as promulgated by the Geneva Convention [8]. The issue of intentional blinding is a growing concern for future warfare, and carries a great psychological effect to people that may potentially be harmed [8]. It is widely known that a laser does not have to cause direct injury to be effective. When used at the opportune moment, glare, dazzle, or flash-blinding from a laser, such as a common laser pointer, can result in personal injury or loss of life from secondary hazards during operation of an automobile or aircraft [7]. Other countries have developed weapons against enemy troops that can be designed for blinding or dazzling adversaries during critical operations. Some systems employ tunable lasers or concurrently may emit multiple wavelengths [2]. Aircrews and special operations forces are at risk from enemy lasers on the battlefield, as anti-personnel and anti-material lasers become more common weapons. Unexpected laser exposure from unidentified systems makes training and personnel protection extremely difficult. Results could be devastating, leading to permanent blindness or death to a large number of troops. An analysis of military and non-military laser incidents from the unified database reported eye incidents making up 598 of the 1325 (45%) of reports collected [9].

There are three primary ways laser energy can damage a human eye: thermal damage, mechanical damage, or photochemical damage [6, 8]. Laser eye exposure may manifest itself in several ways including the blink reflex, glare, afterimages, and temporary vision impairment [1]. Corneal burns are more serious effects; however, retinal burns are considered the most severe type of laser injury because they may lead to permanent loss of vision [5, 6]. Because laser exposures may often not present with eye pain, many personnel may not know that an exposure has occurred [1]. Non-injury or near-miss data is valuable, in addition to objective injury data, for studying common exposure events. While there is a threat of anti-personnel laser weapons, it is essential that military leaders and medical personnel are aware of the adverse health effects of these weapons systems and must seek methods of identification, treatment, and prevention [5].

It is recommended for Air Force personnel working with lasers to have eye exams in accordance with ANSI Z136.1, but the reasons for this standard are unclear. It may be for legal purposes, to identify unreported exposures, or just to get a baseline. If only people working with lasers get exams, what provisions are in place to protect others who may have the potential for inadvertent exposures from laser systems and how are these individuals identified? Personnel not using the laser systems themselves are also at risk from entering the beam path potentially resulting in injury not just those operating the laser system. Besides friendly laser systems, enemy laser weapons in the battlefield or from acts of terrorism are a potential threat to personnel. Although there are many unanswered questions when it comes to the best methods of protecting military personnel from laser injuries a good surveillance system may help with this assessment.

Because it is difficult to determine the overall number of people at risk, personnel from the Optical Radiation Branch of the Air Force Research Laboratory (AFRL) are undergoing data collection on the number of laser systems in the Air Force, which will provide additional scientific data for evaluation. There is a likely chance that a correlation exists between the number of systems in the Air Force and the number of injuries. A letter was distributed in the fall of 2003 to the entire Air Force requesting Bioenvironmental Engineering offices at each base to submit laser information about local laser systems for assessing the number and types of laser systems in the Air Force. This information will be used with a central database populated the AFRL that contains information on all Air Force laser systems. As discussed earlier, complications arise when attempting to apply safety controls to the battlefield. Lack of training has been identified as a potential factor in increasing the chance of injury. Harris et al, conclude "it is extremely difficult to get denominator data (how many people are at risk) for laser eye injuries since theoretically everyone in uniform (and many civilians) is at some (albeit minimal) risk." [8]

2. METHODS

This study proposes to use the Delphi Technique and cognitive interviews to develop an Air Force laser incident reporting form. Using interviews and the Delphi process, feedback will be obtained about laser exposure health and environmental screening from field health and safety professionals. A reproducible, universally available laser incident exposure format, based on medical, engineering, and safety professional input, could be incorporated in DoD Instructions or service specific regulations on laser exposure management.

2.1 Incident definitions

A laser incident can fit one of several definitions from the earlier unified laser incident database study [9]. An *injury* is physical harm or damage to a human, physiological dysfunction, adverse surgical outcome based on the laser energy or system that otherwise would not have resulted in injury had the laser not been used, or a second procedure undertaken to correct a laser procedure. *No injury* is defined as the malfunction of equipment not resulting in an exposure (near miss). *Side effects* are primarily generated by medical procedures where the procedure was properly performed, but had undesirable effects (i.e. visual halos or skin hyper-pigmentation). Finally, an *exposure (without injury)* is when laser light being visualized, but not above the threshold of injury.

2.2 Delphi Technique

As defined by hyperdictionary.com, the Delphi Technique is, "A group forecasting technique, generally used for future events such as technological developments, that uses estimates from experts and feedback summaries of these estimates for additional estimates by these experts until reasonable consensus occurs". The first step in the Delphi process is to identify professionals in the topic of interest. The next series of steps involves having the professionals submit information for 1-2 general questions to identify information they deem pertinent to the selected topic. Their first round of answers is pooled together and returned to the professionals asking them to rank by order of importance the items they submitted. The process continues until a consensus is reached. These items will be used for creating a form in this study.

Medical and safety professionals who have direct experience with the investigation or evaluation of a laser incident were selected for this study. Experienced healthcare providers, engineers and safety professionals are the primary source for the most relevant information that should be collected for laser incident reporting. For purposes of this study, Physicians (flight surgeons and ophthalmologists), bioenvironmental engineers, and health physicists were identified as the most pertinent expert groups for the Air Force. Fifteen subjects from each group will be selected.

Professional Expert Groups for Delphi Technique	Desired number of groups	Minimum desired responses
Flight Surgeons	15	10
Bioenvironmental Engineers	15	10
Health Physicists	15	10
Ophthalmologists	15	10
Total	**60**	**40**

Questions administered for this study will be based on background information and references reviewed during the literature search. Next, based on the Delphi Technique, a questionnaire will be e-mailed to each group to identify what information should be collected in the event of a laser incident [12]. Responses will be given on an opinion basis about what information should be collected in a laser event for purposes of future study. After the first round of results, the responses will be collected and organized into one document without personal identifiers. The second questionnaire is a compilation of all the initial responses. It is returned to the original participants asking them to rank, by order of importance, results submitted by the whole group. A third or fourth round may be needed if additional clarification is necessary.

2.3 Laser Incident Form

Finally, a form will be created based entirely on information supplied during the Delphi Technique. Upon completion of a draft form, cognitive interviews will be conducted for feedback regarding the functionality of the form and clarity of desired information. At least one professional from each of the four identified professional groups (minimum of 4 total) meeting the same qualifications but not used during the Delphi Technique will be contacted to ensure proper interpretation of the form created from the Delphi group responses. This last step will help validate the laser incident exposure form as the consensus tool for documenting laser events.

3. RESULTS

Based on the evaluation of the unified database by Johnson, et al., trends of increased eye and skin injuries were reported over time [9]. An increasing trend line of laser related injuries suggest better detection, a proliferation of systems, poor training, a misunderstanding of laser systems or all of the above. Standardizing an incident documentation process is an important tool to ensuring objective data for future safety and health analysis.

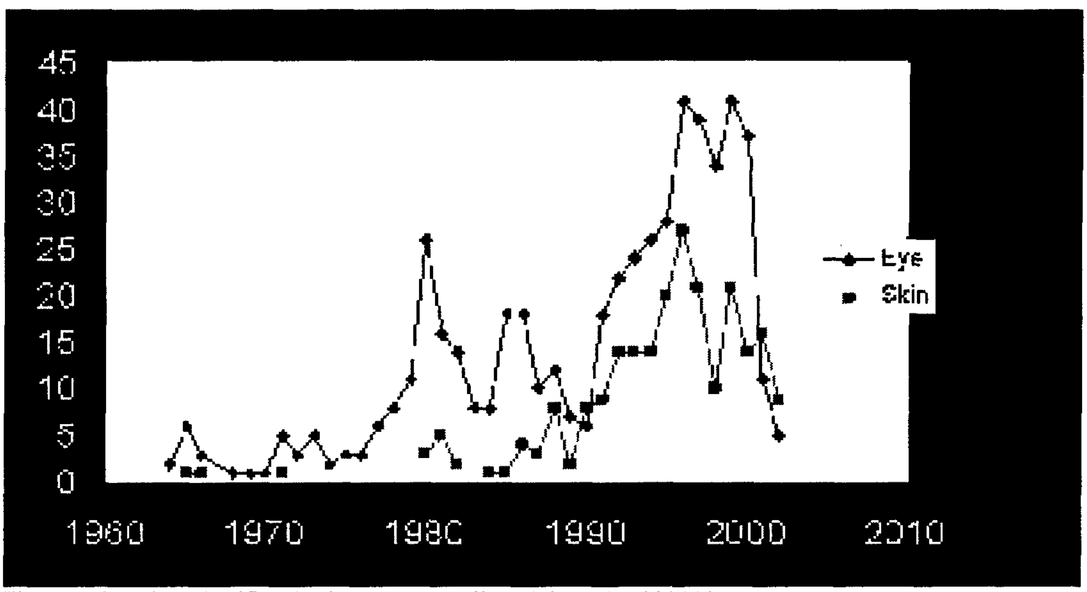

Figure 1. Number of unified database reports collected through mid 2000.

The response rate will be recorded for the Delphi Technique, as well as clarification changes to the final form that can be used to populate a database at a later time. A goal is to have 10 responses of the 15 individuals selected from each of the four groups for a minimum total of 40 Delphi respondents. The goal of the form is to be as streamlined as possible, but ensure all critical information is included as provided from the Delphi groups. Cutoffs will be determined based on responses of key variables and ranking of the provided variables by individuals contributing to the Delphi Technique portion of the study. General pertinent information, ultimately based on responses, will relate to the laser system involved in the incident, details of the incident, personal information and medical information. Like data will be grouped together for ease of use for the individual best qualified to supply the information i.e. medical information will be grouped together so that a medical professional can fill out that specific section. Room will be needed for future medical follow-up.

4. CONCLUSIONS

Conclusions will be based on information supplied during the study. Although there were many groups who could supply information about laser incident information, this study was limited due to the size of this study to groups most likely to be involved in debilitating field or training incidents rather than hospital surgery, cosmetic, or non-critical events that would not directly affect the military mission or add to battlefield casualties. However, these events also will be recommended for inclusion in the laser incidence surveillance system because these trends are still important for health outcomes and treatments.

The Delphi Technique is a useful tool to bring together geographically disparate laser safety and health experts to generate a standardized exposure form. Although these professionals are geographically separated, it may be advantageous in this situation that all ideas are independent thoughts avoiding any coercion that may overshadow others' thoughts if all individuals at the same location. However, a disadvantage is getting clarification on individual recommendations and interpretation of responses by investigators. Because designing the form alone will not add any value unless incorporated into an entire surveillance system that would include specific responsibilities for reporting incidents, some recommendations will be made in how this useful tool can be part of a surveillance program primarily based on Air Force Occupational Safety and Health Standard (AFOSH) Standard 48-139. Future studies are needed toward promoting the use of this tool but a better system for reporting incidents, as determined by this study, is necessary for the characterization and prevention of future laser incidents.

Tracking these trends is vital in the development of protection for individuals at risk of laser injuries. In a paper about using existing military databases for injury surveillance and research, it was mentioned that surveillance is considered to be the driving force of research and prevention efforts by using a mechanism to identify worker groups with high frequency and risk of injury [13]. Furthermore, the author says that without proper attention to surveillance, priority areas based on the magnitude of the problem, risk of injury and amenability to prevention will go unserved, and the ability to evaluate these efforts will be lost. In turn a comprehensive tracking system can assist decision makers in targeting personnel for training, physical exams, and personal protective equipment use. Finally, tracking injuries over time can help medical personnel assess the best methods for treatment of laser injuries in the field and over a course of time. The first step in developing such a system is to determine what information is most important to medical and safety professionals. From this information, a comprehensive form can be created for the collection of this valuable data, which later can be entered into a database where future studies will use this information to identify trends in laser incidents, research areas for protection measures, and medical treatment of injuries that will hopefully lead to injury minimization and prevention.

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