An Assessment of the Occupational Hazards Related to Medical Lasers

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Objective: Occupational hazards associated with medical laser applications remain poorly understood and uncharacterized. **Methods:** A literature search was performed using PubMed, and all articles relevant to beam and nonbeam medical laser hazards were reviewed. The Rockwell Laser Industries Laser Accident Database was searched for medical laser injuries and abstracted. **Results:** Eye injuries, skin burns, injuries related to the onset of fires, and electric shock have been reported in relation to medical laser use. It is probable that both acute and chronic health effects have been experienced by medical personnel as the result of exposure to laser generated air contaminants. **Conclusions:** Because of the clinical benefits they provide, the growth of laser technologies and applications are anticipated to result in an increase in the number and type of medical personnel with future exposure to laser hazards.

The clinical use of lasers began in the early 1960s with applications of the carbon dioxide laser in otolaryngology, and today lasers are routinely used in most medical specialties.[1] According to the American National Standards Institute, the four principal health care laser systems are the Argon, Nd:YAG, Holmium:YAG, and CO_2 lasers.[2] Table 1 presents a list of laser devices commonly used in various medical specialties.[3–23] There are other health care laser systems currently in use but either are not approved by the US Food and Drug Administration or have yet to gain widespread acceptance.

The advantages of laser use in medicine are extensive and include reduction of trauma to surrounding tissue due to the precision with which they operate, decreased wound healing times, and drier operative sites due to the coagulating effects on small blood vessels. Nevertheless, the use of medical lasers may present unforeseen occupational hazards to operators and ancillary personnel. Two general types of occupational hazards exist and are broadly classified as beam and nonbeam hazards. Beam hazards are confined to the direct effects of laser exposure to the eyes and the skin. Nonbeam hazards experienced in the clinical setting include exposure to laser-generated air contaminants (LGAC), fires, electrical shock, and noise.

The purpose of this analysis was to summarize and present all of the seminal published literature pertaining to medical laser hazards and their control to understand the types and extent to which these hazards exist, to inform the medical and occupational health and safety community about these hazards, and to prioritize future areas of occupational health and safety research.

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METHODS

A literature search was performed for medical laser hazards in the US National Library of Medicine and the National Institutes of Health's PubMed database with combinations of search terms that included, but were not limited to, laser, medical, surgery, therapy, burn, injury, skin, eye, fire, plume, smoke, noise, electrical, electrocution, and hazard. To locate additional studies, the reference lists of all publications identified by our search, as well as key laser safety review articles, were systematically evaluated. Manuscripts relevant to beam and nonbeam hazards, including clinical case reports, were identified and reviewed. This review was limited in scope to laser-related occupational hazards for health care professionals; manuscripts specifically addressing patient safety were not included.

In addition, Rockwell Laser Industries (RLI) have maintained a laser accident database since 1964 that contains reports of laser-related injuries and incidents. The reporting is on a voluntary basis and the incident information is recorded on the RLI Web site directly. This database was filtered by "environment" to only include events that occurred in the medical setting, and the resulting incident reports were abstracted and summarized. The type of information abstracted for each incident included a description of the injury or incident and its severity, the date, location, type of laser, operational parameters; a description of the subject, the application or activity performed; and the use of personal protective equipment (PPE). The database encourages incident evaluation through a guided response reporting system; because reporting is voluntary, how representative it is remains unclear.

The Manufacturer and User Facility Device Experience online database hosted by the US Food and Drug Administration is a voluntary reporting system for incidents involving medical devices. Although this database may contain relevant medical laser-related occupational injury reports, these data were not accessed for this publication.

RESULTS

More than 500 articles were identified and reviewed as the result of our literature search, most of which were found by searching the reference lists of key review articles and clinical case reports.

Beam Hazards

The absorption of laser radiation by living tissue can be characterized as producing a thermal, mechanical (photoacoustic), or photochemical effect. Thermal damage occurs when the laser radiation increases the temperature of the living tissue. It has been shown that protein denaturation ensues when tissue is heated to roughly 60°C.[24,25] Thermal effects can occur at generally all laser wavelengths, for nearly all exposure durations.[26] Mechanical or photoacoustic effects occur as the result of the absorption of high-power and short pulses ($<50\ \mu s$).[25,27] Because of the rapid deposition of energy, heat dissipation cannot occur. Therefore, the temperature of the tissue is elevated by thousands of degrees, resulting in the formation of plasma.[25,27] As the plasma expands, acoustic shock waves are created, which disrupts adjacent tissue membranes. Photochemical damage occurs when the absorbed laser radiation provides the energy necessary to induce chemical reactions in the tissue. These effects

TABLE 1. Laser Devices Commonly Used in Various Medical Specialties and Applications

Specialty	Application	Laser Systems
Dermatology	Vascular lesion treatment	Argon (350–530 nm)[11]
		KTP (532 nm)[11]
		Pulsed dye (577, 585, and 595 nm)[11]
		Pulsed diode (800–900 nm)[11]
	Tattoo removal	Alexandrite (755 nm)[23]
		Nd:YAG (532 and 1064 nm)[23]
		Ruby (694 nm) [23]
	Skin resurfacing/treatment of acne scars	Erbium (1550 nm)[19]
		Er:YAG (2940 nm)[14]
		CO_2 (10,600 nm)[10]
	Treatment of pigment disorders and lesions	Excimer (308 nm)[18]
		Nd:YAG (532 nm)[16]
		Ruby (694 nm)[21]
	Skin tightening	Erbium (1550 nm)[17]
		Nd:YAG (1440 nm)[17]
		CO_2 (10,600 nm)[17]
Gynecology	Treatment of intraepithelial neoplasias	CO_2 (10,600 nm)[12,22]
Neurosurgery	Tumor removal	CO_2 (10,600 nm)[4]
		Nd:YAG (1320 nm)[6]
Otolaryngology	Treatment of tracheobronchial lesions, tumors, and stenosis	Nd:YAG (1064 nm)[3]
		CO_2 (10,600 nm)[9]
Gastrointestinal surgery	Removal of polyps and lesions	Argon (350–530 nm)[4]
		Nd:YAG (1064 nm)[4]
Cardiovascular surgery	Angioplasty	Excimer (308 nm)[20]
		Argon (350–530 nm)[5]
Ophthalmology	Refractive eye surgeries	Excimer (308 nm)[15]
		CO_2 (10,600 nm)[4]
		Krypton ion (400–670 nm)[4]
		Nd: YAG (1064 nm)[4]
	Blepharoplasty	CO_2 (10,600 nm)[8]
	Photocoagulation of polyps and resolution of hemorrhagic pigment epithelial detachment	Argon (350–530 nm)[13]
	Ablation of the lens capsule	Nd:YAG (1064)[7]
	Peripheral retinal coagulation	Krypton (647 nm)[7]
		Diode (630–650 nm)[7]
Urology	Ablation of invasive and in situ carcinomas	CO_2 (10,600 nm)[4]
		Nd:YAG (1064 nm)[4]

KTP, potassium titanyl phosphate; Nd:YAG, neodymium-doped yttrium aluminum garnet.

are wavelength dependent and are usually limited to low-power lasers with pulse durations of more than a few seconds.[27,28]

The eye is widely regarded as the most sensitive organ to laser radiation, and nearly all of the structures of the eye are susceptible to laser-induced injuries. Several factors determine the degree of eye injury: wavelength, exposure duration and intensity, the location of the injury, pupil size, and the degree of retinal pigmentation. Wavelength and power affect the amount of skin absorption, thus the severity of injury, and the penetration depth of laser light. Furthermore, absorption is dependent on the amount of absorptive materials in the skin, such as the chromophores melanin, hemoglobin, and water. A summary of the wavelength-specific biologic effects in the eye and skin is presented in Table 2.[25,29,30]

Summary of Clinical Case Reports

Several researchers have reported acute and chronic decreased color sensitivity in ophthalmologists performing laser procedures.[31–36] Additional eye injuries have been attributed to dermatologic laser use and include two cases of vitreous floaters in laser surgery fellows,[37] and a traumatic macular hole in a physician assistant during routine maintenance of a 755-nm Q-switched laser.[38]

Despite an extensive search, no cases of occupational-related skin injuries were found in the published literature.

Summary of Incident Report Data

There were 87 incident reports in the RLI database that met our inclusion criteria, of which 37 described injuries that occurred in health care workers (HCW), 39 detailed injuries in patients, 10 involved equipment failure (and no injury), and 1 was incorrectly coded as to the environment in which it occurred.

Eye Injuries

Of the 37 reports involving HCW, 27 described eye injuries in technicians, service engineers, laser operators, and bystanders

TABLE 2. Wavelength-Specific Biologic Effects in the Eye and Skin

Spectral Region (Wavelength)	Biologic Effects in the Eye	Biologic Effects in the Skin
UV-C (200–280 nm)	Photokeratitis	Erythema Skin cancer
UV-B (280–315 nm)	Photokeratitis	Increased pigmentation Accelerated aging of the skin
UV-A (315–400 nm)	Photochemical cataract	Pigment darkening Skin burn
Visible (400–780 nm)	Photochemical and thermal retinal injury	Photosensitive reactions Skin burn
IR-A (780–1400 nm)	Cararact Retinal burn	Skin burn
IR-B (1400–3000 nm)	Cataract Corneal burn Aqueous flare	Skin burn
IR-C (3000 nm–1000 μm)	Corneal burn only	Skin burn

(other medical staff), all of which occurred between 1965 and 1997. Eleven injuries occurred during tasks such as servicing, alignment, and preparatory work (nonmedical procedures) and 14 occurred during medical procedures; the activities being performed at the time of injury for two cases were unknown. Of the eye injuries that occurred during nonmedical procedures, seven were permanent, three were temporary, and one was of unknown severity. Personal protective equipment was not worn in nine of the cases and the use of PPE was unknown in two of the cases (one temporary and one unknown severity). Of the permanent injury reports, five indicated retinal burns (one that resulted in a macular hole and one occurred on the fovea), one ocular burn (unknown location on the eye), and one indicated the presence of a "black spot," with no indication of the site of the injury. Of the temporary injuries, one indicated an ocular burn, one described a "burning sensation," and the details of one of the injuries were unknown. The report of the injury that occurred during a nonmedical procedure with unknown severity included no information on the location of injury.

Of the 14 injuries that occurred during medical procedures, three were permanent, seven were temporary, three were of unknown severity, and one indicated that although exposure occurred, no injury resulted (proper eyewear was noted). Personal protective equipment was not worn in two of the cases of permanent injury, one of the cases of temporary injury, and in one of the cases of unknown severity. Two of the temporary and two of the unknown severity injury reports indicated improper choice of eyewear; an additional case report of temporary injury indicated "eyewear failure." The use of PPE was unknown in one of the permanent injury cases, three of the temporary injury cases, and one of the unknown severity cases. Of the permanent injury reports, one indicated a retinal burn, one described a permanent blind spot occurring in one eye, and the location of one of the injuries was unknown. Of the temporary injuries, three indicated the presence of an afterimage, two indicated vision loss or blurring, one indicated optical distortion, and the location of one of the injuries was unknown. The reports of the injuries that occurred during medical procedures with unknown severity included no information on the location of injuries.

For the reports in which the activities being performed at the time of the injury were unknown, one resulted in permanent retinal damage and one in a temporary minor injury to the retina. Personal protective equipment was not worn in either of these instances.

Skin Injuries

There were nine reported skin burns, all of which were temporary, that occurred in HCW and technicians between 1980 and 1992. Three cases were due to shutter failure, one occurred during nonmedical beam alignment, and the remaining five occurred during surgical procedures. Personal protective equipment was noted in one case where laser penetration was prevented by gloves.

Control

Several authors have attributed the majority of laser-related accidents primarily to a lack of hazard recognition, disregard for laser safety procedures, and operator error, and have suggested that prevention strategies should focus mainly on education and training.[25,29] Nevertheless, although administrative controls such as these are important, ensuring safety through engineering design is considered to be a more effective solution. American National Standards Institute has defined the laser classification system and subsequent control strategy, which relies heavily on warning systems, signage, interlocks, and PPE guidance. Although the Occupational Safety and Health Administration (OSHA) do not specifically regulate these technologies, they recommend reliance on the General Duty Clause, which mandates that employers provide a work environment free of recognized hazards.

All medical personnel, including operators and ancillary staff, should wear protective eyewear (inserts or goggles) when aligning, repairing, and operating laser devices within the nominal hazard zone; that is, anywhere a laser-beam exposure could exceed the maximum permissible exposure. The maximum permissible exposure is a function of wavelength, beam diameter, pulse duration, and intensity of the laser. Not only is the eyewear essential in preventing direct beam exposure, but it also prevents indirect exposure to laser beams that may occur as the result of reflection off metallic surfaces of medical instruments and other reflective surfaces.[39] Protective eyewear must be specific to the laser wavelength used and must have side shields.[40] Protective eyewear is rated by optical density, that is a log-based scale and ranges from 2 to an optical density of more than 10. The minimum required optical density to be protective for a specific laser is the base-10 log ratio of the irradiance or radiant energy of the laser to the maximum permissible exposure.

In addition, all areas of the skin that may be incidentally exposed to laser radiation should be covered when lasers of intermediate or high powers that create potential skin hazards using materials such as laboratory coats, gloves, and face shields.

Exposure to Laser-Generated Air Contaminants

According to OSHA, each year an estimated 500,000 HCW are exposed to laser or electrosurgical smoke.[41] The laser surgical plume is generated as the result of target cells being heated to the point of boiling, causing the membranes to rupture in addition to pyrolysis. This cellular vaporization and combustion release steam, cell contents, combustion by-products[42,43] and the quantity and characteristics of the cellular matter are determined by the type of laser being used, the irradiance, and the type of tissue being treated.[43–46]

To date, researchers have identified roughly 150 chemical constituents of plume, a subset presented in Table 3[42,44,46–61]; however, it has been estimated that there are more than 600 compounds yet to be identified.[58] In addition, the laser plume consists of particulate matter that has been shown to include viable cellular matter,[59] viruses, and viral DNA or RNA (including human papillomavirus, human immunodeficiency virus, and polio vaccine virus),[60–68] and

TABLE 3. Health Effects of Chemicals Found in the Laser Plume

Chemical	Health Effects
Acetaldehyde	Irritation to the eyes, skin, and nose; eye and skin burns; dermatitis; conjunctivitis; cough; CNS depression; delayed pulmonary edema; and carcinogen (nasal cancer)[46,59]
Acetonitrile	Irritation to the eyes, skin, and nose; cyanosis; and cardiac and respiratory arrest[42,48,57,58,59]
Acetylene	CNS, cardiac and respiratory symptoms related to oxygen deficiency, explosive/flammable [42,48,57,58,61]
Acrolein	Irritation to the eyes, skin, and nose; decreased pulmonary function; delayed pulmonary edema; chronic respiratory disease[42,46,48,57,58,59]
Acrylonitrile	Irritation to the eyes and skin; asphyxia; headache; sneezing; nausea, vomiting; lassitude, dizziness; skin vesiculation; scaling dermatitis; CNS impairment, potential carcinogen (brain tumors, lung and bowel cancer)[42,48,57,58,59]
Anthracene	Can cause skin damage, burning, itching, and edema; headaches, nausea, loss of appetite, swelling of the stomach and intestines; slowed reaction time and weakness; reduced serum immunoglobulins[44,61]
Benzaldehyde	Acutely causes eye and skin irritation and redness [42,54,57]
Benzene	Irritation to the eyes, skin, nose, and respiratory system; dizziness; headache, nausea, staggered gait; anorexia, lassitude; dermatitis; bone marrow depression; potential carcinogen (leukemia) [42,46,48,57,58,59]
Benzonitrile	Irritation to the eyes and skin[42,51,57]
Butadiene (1,3 Butadiene)	Irritation to the eyes, nose, and throat; drowsiness, dizziness; carcinogen (leukemia and lymphoma) [42,47,48,57,58,61]
Carbon monoxide	Headache, tachypnea, nausea, lassitude, dizziness, confusion, hallucinations; cyanosis; depressed S-T segment of electrocardiogram, angina, and syncope[42,48,57,58,59]
Creosol	Irritation to the respiratory system, skin, and eyes; cytotoxic; corrosive [42,48,57,58,61]
Cyanide	Coma, death; breathing difficulties, chest pain, vomiting, headaches, and enlarged thyroid; shortness of breath, loss of consciousness, possible hearing loss[44,60,61]
1-Decene (hydrocarbon)	Vapors produce eye irritation and respiratory tract irritation; may be a slight anesthetic at high concentrations[42,53,57]
Ethane	Simple asphyxiant[42,48,52,57,58]
Ethanol	Irritation to the eyes, skin, and nose; headache, drowsiness, lassitude, narcosis; cough; liver damage; anemia; reproductive, teratogenic effects[44,59]
Ethene (reported as ethylene)	Headache, muscular weakness, drowsiness, dizziness, and unconsciousness[42,48,56,57,58]
Ethyl benzene	Irritation to the eyes, throat, skin and mucous membrane; dizziness; dermatitis; narcosis, coma[42,57,59]
Formaldehyde	Irritation to the eyes, nose, throat, and respiratory system; lacrimation; cough; wheezing; potential carcinogen (nasal cancer)[42,44,46,48,57,58,59]
Furfural (aldehyde)	Irritation to the eyes, skin, and upper respiratory system; headache; dermatitis[42,57,59]
Hexadecanoic acid (palmitic acid)	Irritation to the respiratory tract[42,50,57]
Hydrogen cyanide	Asphyxiant; lassitude, headache, confusion; nausea, vomiting; increased rate and depth of respiration or respiration slow and gasping; thyroid, blood changes [42,48,57,58,59]
Isobutene	Dizziness, drowsiness, dullness, nausea, unconsciousness, and vomiting [42,48,55,57]
Isopropanol	Irritation to the eyes, nose, throat; drowsiness, dizziness, headache; narcosis in animals[44,59]
Methane	CNS depression; cardiac sensitization[42,48,57,58,59]
4-Methyl phenol (*p*-cresol)	Irritation to the eyes, skin, and mucous membranes; CNS effects: confusion, depression, respiratory failure; dyspnea, irregular rapid respiration, weak pulse; eye and skin burns; dermatitis; lung, liver, kidney, and pancreas damage[42,57,59]
2-Methyl propanol	Irritation to the eyes, skin, and throat; headaches, drowsiness[42,57,59]
Phenol	Irritation to the eyes, nose, and throat; anorexia, weight loss; lassitude; muscle ache, pain; dark urine; cyanosis; liver, kidney damage; skin burns; dermatitis; ochronosis; tremor, convulsions, twitching[42,48,57,58]
Polycyclic aromatic hydrocarbons	Dermatitis; conjunctivitis; increased risk of certain cancers[42,48,57,58,61]
Propylene	Drowsiness, dizziness, and unconsciousness[42,48,49,57,58]
Pyridine	Irritation to the eyes; headache, anxiety, dizziness, insomnia; nausea, anorexia; dermatitis; liver, kidney damage[42,48,57,58,59]
Styrene	Irritation to the eyes, nose, and respiratory system; headache, lassitude, dizziness, confusion, malaise; drowsiness, unsteady gait; narcosis; defatting dermatitis; possible liver injury; reproductive effects[42,46,48,57,58,59]
Toluene	Irritation to the eyes and nose; lassitude; confusion, euphoria, dizziness, headache; dilated pupils, lacrimation; anxiety, muscle fatigue, insomnia; paresthesia; dermatitis; liver, kidney damage[42,46,48,57,58,59]
Xylene	Irritation to the eyes, skin, nose, and throat; dizziness, excitement, drowsiness, incoordination, staggering gait; corneal vacuolization; anorexia, nausea, vomiting, abdominal pain; dermatitis[42,46,48,57,58,59]

CNS, central nervous system.

bacteria.[69–72] Two case reports have suggested the occurrence of viral transmission as the result of medical laser use, both of which describe laryngeal papillomatosis in HCWs who performed laser therapy on patients with anogenital condylomas.[73,74] In both cases, virologic analyses confirmed or suggested a causative link between occupational exposure to human papillomavirus DNA in the laser plume and the laryngeal papillomatosis.

Many of the chemicals contained in the plume are acutely toxic and others are known carcinogens, and little has been reported in the literature regarding measured concentrations of these contaminants. The particulate fraction of the plume has been shown to be cytotoxic, genotoxic, clastogenic, and mutagenic.[75] The mutagenic potency of the plume has been compared with that of cigarette smoke, and it has been noted that CO_2 laser irradiation of 1 g of tissue had the same hazard potential as smoking three unfiltered cigarettes.[76] The potential health effects identified in the literature resulting from exposure to the laser plume include the following: acute and chronic inflammatory respiratory changes (eg, emphysema, asthma, and chronic bronchitis), hypoxia/dizziness, eye and throat irritation, nausea/vomiting, headache, weakness, dermatitis, cardiovascular dysfunction, nasopharyngeal lesions, viral infections, and cancer.[77] Whether occupational exposure to LGACs leads to the development of respiratory disease has not be studied.

Control

Local smoke evacuation systems have been recommended by many consensus organizations (American Conference of Governmental Industrial Hygienists, Association of Operating Room Nurses, *American Society for Laser Medicine and Surgery*, Emergency Care Research Institute, and National Institute for Occupational Safety and Health) and may improve the quality of the operating field.[43,78] Nonetheless, smoke evacuation devices have not been used on a routine and consistent basis in many operating rooms.[79,80] Resistance to this simple engineering solution on the part of health care organizations, surgeons, and perioperative personnel has been attributed to the lack of knowledge about the potential health hazards associated with exposure to the plume, and desensitization to the offensive odor that accompanies laser procedures.[81,82] In addition, although OSHA does regulate a wide range of substances found within surgical plumes (eg, benzene, formaldehyde, and hydrogen cyanide), OSHA does not specifically require the use of smoke evacuation and filtering systems.[43,77,83]

It is generally accepted that standard surgical masks provide inadequate protection against exposure to the laser plume.[43,44,77,81,84] Although surgical masks are relatively efficient at capturing particles with diameters of 5 μm and larger, the laser plume consists of particulate matter that is on average over an order of magnitude smaller, making them highly penetrable. High-filtration masks, also known as laser or submicron masks, are often recommended; however, they too have been shown to be penetrable by the plume.[43,81,85,86]

Fires

It is reported that on average 550 to 650 surgical fires occur annually; however, because of the lack of a centralized reporting network, it has been estimated that only 1 in 10 to 1 in 100 fires are documented.[86,87] The circumstances that lead to the onset of fires vary, but three elements are required to initiate and maintain a fire: an oxidizer, a fuel, and an ignition source.[88] Within the operating room, the most frequent sources of ignition are electrosurgery units (68%) and laser equipment (13%),[89] but unlike electrosurgery units, lasers do not need to be in direct contact with a material to cause its ignition.[90]

The most common oxidizers are supplemental oxygen and nitrous oxide when mixed with oxygen.[91] Because of the leakage of oxygen from delivery systems, local concentrations of 80% to 90% have been measured around the mouth of patients, and ambient concentrations of oxygen as high as 32% have been reported in the operating room.[92–94] Several cases of remote flash fires resulting from the ignition of oxygen pools distant from the site of laser pulsing have been reported in the literature.[93]

There are numerous materials that are ubiquitous within the medical setting that can serve as fuels. These supplies include, but are not limited to, endotracheal tubes, gauze, drapes, sheets, towels, sponges, adhesive tape, eye shields, and gowns.[85,87,95] In addition, skin antiseptics, preparation solutions, and ointments are often combustible.[89,96] There are also various patient-related fuel sources, such as visible hair, lanugo, gastrointestinal tract gases, and desiccated tissue.[97–99] Alarmingly, it has been established that in an oxygen-enriched environment, even fire-resistant materials can serve as fuels.[89,99]

Control

Educating all surgical staff members with respect to the fire triangle and encouraging communication within and between surgical teams are fundamental steps for preventing laser-induced fires. In addition, the following precautionary measures have been recommended in the published literature:

1. Administering supplemental oxygen at the lowest concentration possible, and when possible, concurrently administer helium to increase the ignition threshold.[39,85,86,93,97]
2. Substituting less-flammable equipment and materials (phenol polymer drape, water-based prepping agents, red rubber endotracheal tubes [when using a CO_2 laser]) for more flammable equipment and materials (cotton/polyester drape, alcohol-based prepping agents, polyvinylchloride endotracheal tubes).[85,100–103]
3. Soaking any gauze or towels in a saline solution that will be in proximity to the treatment site.[97]
4. Applying prepping agents in thin coats and allowing sufficient time to dry before beginning a laser procedure.[88]
5. Ensuring that water and fire extinguishers are readily available.

Noise Exposure

Unlike high-speed medical and dental drills, little attention has been paid to occupational noise exposure resulting from laser applications. Nevertheless, potentially damaging peak sound levels have been reported specifically for the erbium laser.[104] Compounding this problem, based on an analysis of the National Health and Nutrition Examination Survey data from 1999 to 2004, is the reported widespread nonuse (98%) of hearing protective devices among noise-exposed health services workers.[105]

Electrical Hazards

Lasers contain high-voltage electrical circuits; thus, electrical shock and electrocution risks are commensurate with other electronic equipment of similar output levels.[39] In addition, some older models of medical lasers use an external water source for cooling, which increases this hazard.[42] Other contributing factors that may lead to electrical accidents include damaged electrical cords, faulty grounding, inadequate safeguards, and lack of compliance with training programs.[39,42]

Although electrocution and shock are well-known laser-related hazards and are some of the leading causes of laser-related injury and death within all industries, no clinical case reports describing such incidents in medical or dental personnel were found in the literature. Laser repair technicians have been reported to be at the highest risk among the medical community of electrical injury.[106]

Summary of Incident Report Data

Only one case report was found in the RLI database that pertained to an electrical injury. According to the report, a nurse was knocked unconscious for several seconds after turning on a Nd:YAG laser. The report indicated that water was present on the floor as the result of a recent mopping, and that the laser's plug was not adequately grounded.

Control

Numerous mechanisms to prevent electrical accidents have been suggested in the literature. First, issues of appropriate laser installation, grounding, automatic shut-off features, and other safeguards should be addressed by a biomedical engineer or laser technician.[39] Second, it is recommended that the laser, all accessory equipment, and the environment in which the laser is to be used, undergo visual inspection before use. Specifically, the integrity of the electrical cords, plugs, and foot pedals must be verified before the laser is plugged into the electrical source.[42] Moreover, personnel should avoid the use of extension cords; rather, the laser should be plugged directly into the wall outlet. Third, no unauthorized personnel should remove the outside protective cover of the laser, and no one should access a laser's internal components unless qualified and approved to do so.[42,106] Last, all staff members who are involved in laser operation or repair should be adequately trained with respect to electrical safety.

DISCUSSION

It is clear that the following injuries occur in HCWs consequent to the use of laser devices: eye injuries, skin burns, injuries related to the onset of fires, and electric shock. It is probable that both acute and chronic health effects have been experienced by medical personnel as the result of exposure to LGAC, which to date is largely not quantified, not regulated by OSHA, and oftentimes lacking of adequate control mechanisms. Despite their known occurrence, there is a dearth of literature describing these hazards and others, such as the resulting noise exposure, and their associated health outcomes. Nonetheless, because of the clinical benefits that laser technologies provide, it is expected that the number of applications in which lasers are used will continue to grow, which is anticipated to result in an increase in the number and type of personnel with future exposure to laser hazards.

Limitations

There is a paucity of recently published literature relevant to beam and nonbeam medical laser hazards; thus, many of the articles that were identified by our literature search were published over a decade ago. Nonetheless, although the laser technologies may have changed over time, the spectrum of occupational injuries and illnesses resulting from medical laser use today are not expected to differ from those previously reported.

The RLI incident database is a voluntary industry effort for the laser applications community. Abstraction and summary of the RLI incident database do not provide any epidemiologic evidence of these types of injuries but rather provides the medical and health and safety community some sense of the scope of hazards that exist within the medical setting. Because reporting incidents to the RLI database is not mandated, the frequency at which these injuries occur cannot be accurately determined. The most recently reported incident that met our search criteria occurred roughly 2 decades ago; thus, it is evident that the contribution to this database has lacked in the recent years. The RLI database also lacks detailed incident information reporting, which often includes numerous missing data fields per report. The absence of a centralized database and compulsory reporting requirements has also contributed to a lack of recognition of laser-associated hazards within the medical community.

CONCLUSIONS

The use of medical lasers likely poses a health and safety threat to the medical community, particularly with respect to the initiation of fires, and the inhalation of LGAC. To fully characterize laser-related risks, further research must be done to quantify the risks to HCW posed by medical lasers, with an emphasis on determining the impact of laser type, operational parameters, tissue treated, and application. Specific research is warranted in plume constituent characterization and determination of airborne level concentrations, characterization of noise levels generated during laser procedures, and determination of the adequacy of currently recommended engineering controls and PPE. Furthermore, to capture the extent and frequency of laser-related incidents, the development of a formal occupational injury and illness surveillance system that mandates reporting is required.

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