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MODULE 18
NON-IONIZING RADIATION EXPOSURE

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Disclosure: Capt. Fajardo does not have any financial arrangements or affiliations with any corporate organizations that might constitute a conflict of interest with regard to this continuing education activity.

Goals:

1. Learn the principles of Non-Ionizing Radiation Exposure.
2. Know the effects of radiation on organ system function.
3. Understand the major classes of Non-ionizing Radiation.
4. Understand exposure prevention methods.
5. Learn the management of exposures to non ionizing radiation.
6. Learn about Laser Radiation Exposure

Note: The following material is a summary of information extracted from various sources dealing with this extensive subject matter. The presenter takes no authorship of this material. For more detailed information readers are referred to the reference material at the end of the section

RADIATION BASICS

Radiation is the emission or transmission of energy. Electromagnetic radiation (EMR), as such, defines the motion of oscillating electric (E) and magnetic (H) fields that characterize the emitted energy, while radar, an acronym for "radio detection and ranging", defines a system that locates and identifies objects through the reflection of electromagnetic energy beams. Electromagnetic radiation, ubiquitous in natural environments, has a number of wave motion characteristics, such as frequency, wavelength, and velocity, which define the range of the various types of radiation. These waves move through space at the speed of light and are classified according to wavelength and frequency, which operate in a direct inverse relationship.

Following is list of terms and mathematical calculations that are essential in the understanding of the clinical effects of electromagnetic radiation exposure.

WAVELENGTH (λ) - distance between two similar points on the wave.

Unit of measurement: meter (m); 1 millimeter (mm) = 10^{-3} m; 1μm = 10^{-6} m; 1 nm = 10^{-9} m.

FREQUENCY (v) - number of oscillations per unit of time.
Measurement unit: hertz (Hz); 1 kHz = 10^{-3} Hz; 1 MHz = 10^{-6} Hz; 1 GHz = 10^{-9} Hz.

VELOCITY (c) - speed at which electromagnetic radiation travels in a vacuum or in air. Velocity can be calculated by the following formula:

$$c = 3 \times 10^{8} \text{ meter/second (m/s)}$$

All the above characteristics of EMR relate by means of the following equation:

$$c = 3 \times 10^{8} \text{ meter/second (m/s)} = (\lambda)\ (v)$$

ENERGY (Q) can be calculated through the following formula:

$$Q = 1.26/\lambda\ (\mu m) \text{ electron volt (eV)}$$

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ joule (J)}$$

The latter formula is significant, for the purpose of this lecture, in understanding that Non-ionizing radiation is < 12.4 eV, while ionizing radiation is > 12.4 eV.

NON-IONIZING RADIATION

Ionization occurs when orbital electrons are entirely removed or added from the outer shells of atoms. Non-ionizing radiation refers to the various electromagnetic frequencies that lack the necessary energy to ionize the atoms in living cells. In other words, the electrons move to different orbitals (associated with different energy states), but new electrons are not removed or added from the atom. Non-ionizing radiation has only enough energy to vibrate molecules and in most cases, cause minor and most often reversible damage. It is important to note that in the health care field, exposure to non-ionizing radiation is more common than exposure to ionizing radiation. Non-ionizing radiation is made up of radio waves and microwaves as well as visible, ultraviolet and infrared light.

Some common sources of non-ionizing radiation include: (1) *Ultraviolet radiation* germicidal lamps, nursery incubators, and some air filters; (2) *Infrared radiation* heating and warming equipment; (3) *Radio and microwave sources*- diathermy, sterilizing and food preparation equipment, and (4) *Lasers*.

TABLE OF ELECTROMAGNETIC FREQUENCIES

The range of frequency and wavelength for some types of electromagnetic radiation are presented in the following table:

Type of Radiation	Frequency Range	Wavelength Range
Ionizing	> 3000 THz	< 100 nm
Non-Ionizing	< 3000 THz-< 0.3 kHz	> 100nm->1000km
Ultraviolet (UV) Far NEAR UV-C UV-B UV-A	3000-750 THz 1580-1000 1000-750 3000-1070 1070-952 952-750	100-400 nm 190-300 300-400 100-280 280-315 315-400
Visible Radiation	750-385 THz	400-780 nm
Infrared (IR) IR-A IR-B IR-C NEAR MIDDLE FAR	385-0.3 THz 385-214 214-100 100-0.3 385-100 100-10 10-0.3	0.78-1000 μm 0.78-1.4 1.4-3 3-1000 0.78-3 3-30 30-1000
Radiofrequency (RF) **MICROWAVES (MW)** Ext. high freq (EHF) Super high freq (SHF) Ultra high freq (UHF)	300 GHz-0.1 MHz 300-30 GHz 30-3 3-0.3	1 mm-3000 m 1-10 mm 10-100 100-1000
Radiofrequencies (cont) Very high freq (VHF) High freq (HF) Medium freq	300-30 MHz 30-3 3-0.3	1-10 m 10-100 100-1000
Low frequency (LF) Very low freq (VLF) -----------------------	300-30 kHz 30-3 3-0.3	1-10 km 10-100 100-1000
Extremely low freq (ELF)	<0.3 kHz	>1000 km

A short list of commonly used devices and their respective frequencies is presented here:

Electric power (50-60 Hz)
VDT/TC circuits (17-31 kHz)
AM radio (535-1705 kHz)
FM Radio (54-88 MHz)
VHF television (174-216 MHz)
UHF television (470-890 MHz)
Microwave ovens (2.45 GHz)
Telephones (3.7-4.2 GHz)

The table of electromagnetic frequencies shown above, as well as the sample list of commonly used devices, clearly demonstrates that electromagnetic energy occurs in a continuum of frequencies or wavelengths or both, ranging from below radio frequencies (RF) to above ionizing radiation, and includes microwave, infrared, visible and ultraviolet radiation. There is no sharp delineation in any one part of the spectrum and often the wavelengths overlap. Exposure within the electromagnetic spectrum produces broad and diverse biological effects, and although non-ionizing radiation typically lacks the energy required to ionize atoms or molecules in tissue, ultraviolet and infrared radiation as well as radio frequency and microwave and radar radiation can produce damaging effects.

HEALTH EFFECTS

ULTRAVIOLET RADIATION (UV)

UV radiation is a form of radiant energy invisible to the human eye. It is naturally produced by the sun as well as by artificial sources, such as electric arcs when operating at high temperatures. UV light extends in a narrow band between 400-40 nm, with three subdivisions each of which has a distinct pattern of tissue penetration. UV-A (400-315 nm) is the closest to visible light; UV-B (315-280 nm); and UV-C (280-40 nm) is the farthest from visible light and closest to long wave x-rays. The spectral band > 320 nm consisting of long UV-C and UV-B is often referred to as the actinic band. UV radiation is common in the food processing industry, since mercury vapor lamps used for food sterilization can produce injurious amounts of UV light. As a result, welders and workers in food processing jobs can be exposed to significant UV radiation.

<u>UV-A</u>- also called “black light” is absorbed by the crystalline lens. The physiologic consequences of over exposure are not well defined but it is believed to potentiate the harmful effects of UV-B.

UV-B (ocular effects)- this band is responsible for most of the harmful effects associated with UV exposure. Since our eyes do not perceive UV-B rays and there is a significant latent period between clinical symptoms and exposure, ocular damage is done before we are aware that the harmful exposure has occurred. Ocular injuries from UV-B radiation are often acutely painful and are associated with photophobia, conjunctivitis, headaches, blepharitis, deep corneal ulcers and conjunctival burns. A sensation of “sand in the eyes” is often used to describe a “flash burn” injury- an acute, intense exposure to UV light-, which can be associated with partial loss of vision. More serious clinical effects, such as the development of cortical cataracts, can be seen after exposure to the middle of the UV-B spectrum (297 nm). There is also strong evidence supporting the association between solar radiation and lenticular opacifications, macular disease and possibly macular degeneration.

UV-B (skin effects)- subacute effects of UV-B exposure include solar erythema commonly appearing within 1-6 hours of the exposure and fading after 3 days. Long-term exposure can cause actinic damage, which leads to solar elastosis, manifested by sagging, leathery, and discolored skin. UV exposure can also induce a photochemical skin reaction making the skin more sensitive to other chemical agents, such as seen with the use of certain tanning oils, anti-aging creams, desquamating agents, certain classes of antibiotics and anticonvulsant medications. Most of these products carry warning labels to this effect. The most significant outcome of UV exposure is the development of skin cancer. The incident of skin cancer among caucasians in the U.S. increases approximately 15% per degree of south latitude. Risk factors of skin cancer include childhood freckling and blue eyes. Basal cell carcinomas (BCC), which are the most common type of skin cancer, are consistently associated with peak (acute sunburn) UV exposures in those patients who do not tan easily. It therefore comes as no surprise that BCC’s are typically found on areas of skin typically exposed to large amounts of sunlight, such as the head and neck. As with basal cell carcinomas, squamous cell carcinomas (SCC) and malignant melanoma are two other forms of skin cancers typically associated with outdoor activities and solar exposure. They also appear in the most cancer prone areas, such as the head and neck. Malignant melanomas, the most serious and lethal form of skin cancer, have seen a fourfold increase in the past three decades. It is highly associated with fair skin, sunburns and the number of pigmented nevi in childhood. Chronic low-level recreational exposure has been suggested as being protective, though a high incidence of truncal melanomas suggests otherwise.

Prevention- the damaging effects of UV exposure and the incidence of sun-induced skin cancers can be reduced by avoiding repetitive cycles of recreational sunburning, especially among light-skinned, blue-eyed, and freckled individuals. Ocular exposure to natural UV-B can also be reduced by avoiding mid-day sun exposure, using ocular lenses (UV blockers) and wearing wide-brimmed hats.

VISIBLE LIGHT

The unaided human eye is able to detect light (visible radiation) within a narrow band of the electromagnetic spectrum between 400 nm (red end) and 780 nm (violet end). Its peak sensitivity is at 555 nm. These wavelengths are acted on by the retina, which transduces the energy exposure to intelligent vision. Visible radiation is emitted from natural sources, such as the sun as well as from other ordinary illuminating equipment, including lasers, welding, spotlights, and flashbulbs. At a 1974 NIOSH symposium it was concluded that extreme high levels of illumination could result in retinal or macular damage and there is laboratory evidence, which confirms that chronic exposure to excessive bright light is responsible for degeneration of the cones. Low lighting conditions, on the other hand, have been associated with generalized negative effects on worker eyesight, though not with serious clinical conditions such as cataracts or glaucoma. The effects of illumination on job performance, particularly low illumination, are often considered as a factor. Glare has also been shown to affect long-term eyesight by damaging the adaptive abilities of the retina and pupil, leading to reduced visual perception, visual fatigue, reversible iritis and blepharospasm. These effects may also be noted with long-term VDT screen exposure.

<u>Prevention-</u> installation of louvers to lighting fixtures; use of light-toned non-reflective wall and desk surfaces; enclosure of light sources in bowl reflectors; and glare reduction by reducing incidence of natural and artificial light sources.

INFRARED RADIATION (IR)

Any object with a temperature greater than absolute zero emits infrared electromagnetic radiation, though the precise characteristics of the radiation vary according to the source. There are many industrial and domestic sources, in addition to the sun, which emit intense amounts of infrared radiation. Among these are incandescent light bulbs and heat lamps used for baking, as well as equipment used in dehydration operations, drying of paints, and heating of metal parts. There are three bands of infrared radiation: IR-C (far) has the longest wavelength and it’s the furthest from visible light. Its physiologic effects are primarily thermal. As with IR-B (middle) these wavelengths are almost totally absorbed and invisible to the eye. On the other hand, IR-A (near), as it pertains to solar reflection, may occasionally be seen as a dull, red glow. Since they tend to absorb the greatest amount of infrared radiation, the skin and eyes, manifest the greatest tissue effects.

<u>IR (skin effects)-</u> the effects on the skin are based primarily on the reaction to the thermal stress, which include vasodilatation of the capillary beds and hyperpigmentation. Capillary vasodilatation with increased circulation, sweating, and ambient air movement allows the skin to dissipate the heat load imposed by

IR radiation. This heat load is perceived initially as warmth, which relates to the rate at which the skin temperature is reached, usually in the order of 0.001 to 0.002^0 C/ sec. This perception decreases as the skin area increases. The pain associated with IR exposure is related to the skin temperature, while the extent of tissue damage is dependent on both the skin temperature and the duration of exposure. Note that although the acute thermal injury resulting from an intense IR exposure is due to overheating, the intensity of the effect is determined by the wavelength of the radiation.

IR (ocular effects)- the energy absorbed by the ocular epithelium imparts damage to the cornea. At wavelengths less than 1.3 μm the iris is particularly susceptible to IR radiation effects. The iris can dissipate its heat load only to surrounding ocular tissue, thus serving as a heat sink mitigating the amount of radiation reaching the lens. The lens selectively absorbs wavelengths from 1.4-1.6 μm and from 1.8-2.0 μm. Cataract formation depends on the initial heating to anterior portions of the eye, especially the cornea and the iris. The so-called "glassblower's cataract", are an example of the results of elevated temperatures affecting the anterior surface of the lens. Higher incidence of posterior cortex cataracts has also been attributed to IR radiation exposure among glass and furnace workers and in those who handle molten materials at temperatures above 1500^0 C. In these cases near-IR or visible wavelength components have also been implicated. Note that the retina dissipates heat by conduction to adjacent structures, particularly the choroids layer. Tissue damage occurs when heat cannot dissipate fast enough to maintain tissue temperature below 45^0 C. Since the eyelids and eye do not have adequate thermal warning properties they are susceptible to IR overexposure with the formation of corneal ulcers and choroidal and retinal damage.

Prevention- there is no legal exposure limits to infrared radiation except in cases of laser use. Ocular damage from incandescent hot bodies reveals a threshold effect at 4-8 W-sec/cm^2. The American Conference of governmental Industrial Hygienists has recommended an IR exposure limit of 10mW/cm^2.

RADIOFREQUENCY RADIATION
Microwave/radio (MW/RF)

Radio, television and telecommunication systems utilize a broad range of electromagnetic wavelengths (3 km- 1mm) with frequencies from 100 kHz to 300 GHz. RF heaters and sealers, medical equipment, AM, FM, amateur radio, television, air traffic control and mobile radar units as well as a variety of telecommunication units operate in this range. Similar wavelengths are also used in several industrial operations, including capacitance heating, and inductance heating. For example, microwave ovens and radiofrequency sealers use capacitance heating in manufacturing, wood lamination, veneer processes, embossing and drying operations, the curing of plastics, wood resins, polyurethane foams, concrete binders, rubber tires and epoxy resins. In addition, inductance heating is also used in metal-heating furnaces and processes associated with hardening, hammering and soldering. Despite the wide use of these electromagnetic wavelengths, most reported accidental exposures usually occur as a result of leaks in high frequency systems or as a result of work in close proximity to transmitters or aerial installations. Law enforcement radar operators have also been found to receive up to 20,000 times the median urban background RF exposure, though still considered below the regulatory standards. One should recall that MW/RF radiation has been known to potentially interfere indirectly with electronic devices, such as cardiac pacemakers.

Thermal Effects- RF exposures in the microwave band cause thermal effects. The outcome of heating from RF sources is no different than the climatic heat stress caused by any other exogenous heat source, except that the rate, degree and distribution are less predictable. Thermal RF exposure alters cell division, cell growth, metabolism, immune response and surface evaporation. However, since skin receptors are not activated by MW/RF radiation the energy is absorbed deep within body tissues without awareness of the exposure. Intermittent hypertension and sustained neuropsychologic symptoms have been reported in individuals exposed to MW radiation in sufficient amounts to alter body temperature. Further, heat sensitive organs such as the eye may sustain damage from high-energy exposure, including cataracts, corneal damage, and retinal lesions. Low intensity MW may also cause eye damage, mainly in the form of small reversible lenticular opacities, which typically occur after a latent period of several weeks. However, the present consensus, based on several epidemiological studies, is that very high intensity exposure (>1.5 kW/M^2) is required to produce detectable eye damage.

Non-thermal Effects- resonance effects from RF radiation have been noted to affect cell growth of in-vitro cultures. Temporary alterations of the blood brain barrier and bone marrow function are also known to be affected by both pulsed and continuous microwaves. Although results of behavioral studies reported in the Eastern literature indicate neurasthenic symptoms and abnormal electroencephalogram responses resulting from RF exposures, at present there is no conclusive evidence to support these findings.

Prevention- the potential for electrical injury resulting from RF sources should be a consideration in all engineering designs. Engineering controls and job designs should also be used to minimize chronic exposures. Any high-intensity RF exposure source with the potential to cause acute thermal effects should be shielded and posted with the appropriate warning signs. Due to the thermal sensitivity of certain organs, in particular the eye and testicles, body parts should be protected by the use of personal protective devices.

VIDEODISPLAY TERMINAL RADIATION (VDT)

VDT's are associated with potential exposure to high frequency electromagnetic energy. Rapidly moving electrons strike the screen and generate X-rays while creating a visible image. Electrons are arrested at the screen and as a result the X-ray emissions are clinically insignificant (<0.5millirem at 5cm from any accessible surface). The intensity of field radiation varies among computers. In the worst case the magnetic flux densities range from 9-23 mG. To date ELF exposures have not been quantified for VDT's.

<u>Reproductive Effects</u>- no specific studies have been performed to evaluate the carcinogenic potential of VDT's. However, since most habitual users are of reproductive age concerns over VDT use have focused on the reproductive system. Clusters of birth defects have been reported since the 1980's and more than a dozen clusters have now been associated with the use of VDT's. Preliminary studies on the effects of electromagnetic radiation, on both male and female human germ cells, are still pending. Of approximately 10 human studies only one has been found to have a statistical positive correlation between VDT use and spontaneous abortions. However, the best studies from the California Department of Health and Human Services and NIOSH have not demonstrated changes in reproductive outcomes associated with VDT use.

<u>Non-Reproductive Effects</u>- skin rashes have been reported on VDT users from the effects of static electricity due to the increase of alpha radiation exposure resulting from charged radon particles. Although the claims of skin rashes related to static electricity by VDT users is possible, dermatological evaluations of these cases have failed to confirm the association. Visual screen fatigue has also been reported primarily from poor screen resolution and room lighting, which affects the electronically displayed information. Fatigue, stress and repetitive hand and arm motion injuries have also been reported. Keyboard and mouse design contribute to the repetitive muscle injuries and other musculoskeletal complaints associated with VDT use.

<u>Prevention</u>- placing the operator at arm's length distance or greater from the video terminal may help reduce radiation exposure. Shielding the electric supply can also decrease the electric alternating current field. Liquid crystal displays (LCDs) may also decrease significantly the size of the electromagnetic field since LCD fields are outside the potentially injurious ELF frequency range. Personal protective equipment or add-on devices claiming to eliminate electromagnetic field radiation or to alter the nature of the electromagnetic field should be closely scrutinized as to the validity of these claims. Many countries have already created exposure limits that include VDTs.

EXTREMELY LOW FREQUENCY RADIATION (ELF)

ELF fields are associated primarily with the process of generating, transporting and using electricity. The biologic effects resulting from exposure to ELF had been questioned for years, since the type of energy found in this range is less than the energy resulting from background ionizing radiation or from naturally occurring electromagnetic fields. It is believed that biologic changes result from alterations to normal ion flow and interactions with the cell membrane, however this has not been validated. It is expected that with modernization and technical advancements these assessments will improve. Power lines are the most ubiquitous sources of exposure producing damaging electrical and magnetic fields. Step-down transformers found situated atop of every third or fourth utility pole produce the most intense magnetic fields, as they transform high-voltage electrical power into useful household electrical current.

<u>Health Effects</u>- Some of the first epidemiological reports concerning exposure to power lines came from the Soviet Union where symptoms of insomnia and loss of libido were reported among high-voltage electrical substation workers. In 1979, in the U.S., reports of higher incidence of leukemia were reported among children in the Denver area who lived near step-down transformers. Cases of leukemia among adults who work around power lines have also been reported but the association remains inconsistent. The U.S. and Scandinavian literature have also reported the association of central nervous system tumors with residential as well as workplace ELF exposure. However, not all studies support the findings. Other reported conditions include malignant melanomas, male and female breast cancer, lymphomas and immunologic changes. ELF exposure has also been associated with altered cellular responses, primarily to hormones and neurotransmitters. It has also been implicated with causing morphological disruption of CNS cells, proliferation of cellular enzymes, interference with DNA synthesis and RNA transcription, as well as with the growth of neoplastic cell lines.

<u>Prevention</u>- until more conclusive studies prove or disprove the association between ELF exposure and negative health outcomes, occupational physicians should endeavor to minimize worker exposure.

LASERS

Laser is an acronym for “light amplification by stimulated emissions of radiation.” A laser is a device that emits an intense monochromatic, visible or invisible, coherent (non-ionizing), continuous or pulsed narrow beam of light. This beam of light is typically less than one inch in diameter at the source widens over long distances. At a large distance a laser can irradiate the whole body and with enough energy it can burn clothing, skin or any part of the body exposed to the radiation beam. However, there are many types of lasers and most are not strong enough to generate burns. Lasers are used with varying applications in military settings, instructional arenas, as recreational displays and in health care. No matter how and where they are used, lasers pose a threat to workers, particularly those in the health care field. Lasers have wide application in a large number of outpatient clinical areas, such as dermatology, gynecology, ophthalmology, gastroenterology and podiatry as well as in the surgical inpatient settings.

Ocular Effects- injuries to the eye result when the energy of the laser is absorbed by the various ocular structures. The ability of the eye to concentrate whatever light enters makes this organ the most sensitive and vulnerable to the effects of laser radiation. The cornea, which acts somewhat like a filter, does not allow all wavelengths to pass through. Since most of the eye structure is transparent to visible light, the majority of the damage occurs in the deeper pigmented retinal epithelium. The energy concentrated on the back of the retina can be 100,000 times greater than the energy that enters the front of the eye. If the laser light is inadvertently focused on the retina it can raise the temperature to 1000 degrees, at the point where the laser focuses on the retina, causing a thermal reaction that vaporizes the cells due to rapid heating. However, the lack of pain fibers in the retina may cause corneal damage to not be apparent for several hours. Note that the laser effects are affected by existing atmospheric conditions, as well as by individual factors such as the worker's pupillary size, the ability to focus, and the presence of myopia or aphakia. The distance from the laser source and the angle of the laser may also determine the degree of the injury. The frequency of the laser also determines which structures absorb and are subsequently affected by the laser energy. Pulsed lasers, for example, can induce a mechanical shock and cause multiple areas of intraocular bleeding.

Ultraviolet lasers- lasers in this energy range (<400nm UV-A,B,C) are absorbed in the anterior segments of the eye, primarily the cornea, and by the lens. At low powers, UV light lasers can also induce a photokeratitis that can be painful and disabling.

Visible lasers- laser energy in the visible spectrum (400-700nm) is absorbed within the retina, the pigment epithelium, and the choroid.

Infrared lasers- lasers operating in the near-infrared region (700-1400nm IR-A) affect primarily the retina and choroids, while laser radiation from the far infrared area (>1400nm IR-B,C) is absorbed by the cornea and the lens, damaging these structures (i.e. scarring; cataracts) but leaving the retina intact. IR lasers, of sufficient power, can also produce a choroid hemorrhage with significant visual disruption.

Temporary reversible changes in visual function can be produced at low levels of laser energy. Glare and flare reactions can be induced by many lasers operating within the visible spectrum as well as with other light sources, such as search lights, flares and strobes which tend to disappear when the energy source is turned off. Absorbed laser energy can heat retinal tissue and other retinal structures inducing a severe inflammatory process, which can result in scotoma (blind spots) of varying sizes. On the other hand, pulsed-laser energy can superheat retinal tissue inducing an explosive change with shock waves, which create a mechanical disruption of the affected tissue. This mechanical disruption can blow a hole through the retina resulting in a retinal hemorrhage and severe visual loss.

Skin Effects- skin burns result from lasers operating in the ultraviolet and far-infrared wavelengths. In the near-infrared and visible spectrum the effect on the skin is minimal. Burns on the skin usually indicate the use of UV or IR lasers.

Prevention- eye shielding, including side protection, must be selected in accordance with the laser wavelength. This should include absorptive filters, preferred over reflective filters, because they are not affected by the incident angle of the beam. Lasers should be enclosed while in use. The eyes and skin should be kept out of the direct path of the beam or from indirect beams resulting from other reflective surfaces. Protective barriers for both workers and bystanders should be provided during laser beam operations. Eye protection issues are covered by the American National Standards Institute (ANSI) Guidelines for the Safe Use of Lasers (Z136.1-1986).

LASER CLASIFICATION

Laser classification provides a practical method to determining the hazards of lasers in accordance with permissible exposure levels (PEL). The PEL is the level of laser radiation, below which there are no hazardous or biological effects. Following is a detailed explanation of the established laser classification:

Class 1- lasers in this category are not hazardous under reasonable operations. These lasers do not require warning labels or controls unless the beam is exposed during alignment procedures or required maintenance.

Class 2- these lasers are essentially harmless visible beams, harmful only if intentionally viewed for more than 10 seconds. They are otherwise safe for momentary unintentional viewing. This type lasers are marked with a yellow caution label but require no other operational controls.

Class 3 (a)- this type lasers are harmful if the beam is viewed directly using any type of optical magnification equipment. They may otherwise be safe during momentary unintentional viewing. Lasers in this category carry a yellow caution label warning against direct viewing with optical magnification but carry no other controls. However, some lasers in this category, may carry a “red warning” label and as such are subject to additional controls as specified for Class 3 (b) lasers.

Class 3 (b)- this classification includes both continuous and pulsed UV, visible and IR lasers that are very hazardous to the unprotected eye when the beam is under direct observation. Specular reflections are also very dangerous. These lasers have a “red warning” label against direct laser beam eye exposure. Operators should also be cautioned to avoid intrabeam viewing and to control specular reflections from mirror like surfaces. Laser eye protection is required during laser operations.

Class 4- this classification of lasers includes high-powered instruments, which are considered very dangerous. Direct viewing must not occur and specular reflections are considered very dangerous. Lasers in this category may also produce hazardous diffuse reflections, which are extremely dangerous. Skin exposure is considered extremely hazardous. They also constitute a fire hazard. These lasers have a “red warning” label against eye or skin exposure directly from the beam or from scattered reflections. This classification requires strict control measures guarding against transient personnel entering operational areas (door interlocks), the wearing of eye protection, and outdoor operational safety measures.

The aforementioned classification separates lasers according to the exposure hazard based on the magnitude of the energy beam. Lasers are also defined by their frequency and wavelength and as noted previously these characteristics determine, to a great extent, the degree of the exposure and the type of tissue affected by the laser. Following is a list of common laser devices, the medium used to deliver the laser beam, and their applications:

Medium	Wavelength	Operation
Argon (AR)	458-515 nm	Instrumentation; entertainment; retinal photocoagulation
Carbon Dioxide (CO_2)	10.6 μm	Material processing; optical radar/ranging; surgery
Dye(s)	350 nm - 1 μm (variable)	Instrumentation
Excimer lasers	150-250 nm	Laser pumping; spectroscopy
Gallium arsenide (GaAs)	850-950 nm	Instrumentation; ranging; intrusion detection; communication; toys
Helium cadmium (HeCd)	325, 442 nm	Alignment; surveying
Helium neon (HeNe)	632.8 nm	Alignment; surveying; holography; intrusion detection
Neodymium glass (Nd-glass)	1.06 μm	Mat. processing; optical radar ranging; surgery; research
Ruby	694.3 nm	Material processing; ranging; research; holography

LASER EXPOSURE EVALUATION

Depending on the location and extent of the injury, laser exposure symptoms can be very subtle or extremely dramatic. The patient may present with a history of noticing a bright flash of light or a glare, a sudden flash blindness, a marked decrease in vision or even ocular pain of varying degrees. Medical providers need to be alert to the possibility of a laser injury whenever a patient presents a history of unexpected eye discomfort, visual loss, pain, poor vision or sensitivity to bright lights. At high energy levels lasers tend to cause the perception of intense white light due to a saturation of the visual photoreceptors. Flight Surgeons should be on the alert for the possibility of laser injuries on aviators with any of the aforementioned complaints. Whether in operational missions, such as fisheries patrols, drug interdiction, and law enforcement, at static public displays or while flying though entertainment areas displaying laser shows aviators are subject to the intentional or inadvertent effect of laser exposure radiation. A high index of suspicion is necessary since laser damage can result with little awareness from the individual. Following is a list of questions that can help determine the risk of potential laser exposure:

1. What was the initial event leading the individual to seek care? How long ago did it occur?
2. What if any protective equipment was being used?
3. Where there bright flashes of light? What color, intensity, pulsation? Can they be described? What was the suspected source, if possibly determined?
4. Was there a sudden visual disruption? Any flashblindness or afterimage, and if so, what were the colors or defining characteristics of those images?
5. Are there persistent side effects? Did symptoms resolve, and if so when?
6. What is the visual acuity, what are the visual fields, and color defects or photophobia?
7. Are there any gross physiological deficits? Any slit-lamp defects? Any fluorescein abnormalities indicating anterior chamber or corneal lesions?
8. Any ophthalmoscopic defects of the vitreous or retina? Any hemorrhages holes, windows or edema?
9. What is the estimated distance from the source, including slant angle and altitude?
10. Was it a directed light source or inadvertent pass through a beam of light?

11. Where there others exposed? Have they been examined? Do they have any complaints?

12. Where there any evasive maneuvers attempted?

Physical Examination-

The medical provider and/or Flight Surgeon should look for any conjunctival redness suggestive of ocular inflammation, corneal cloudiness, pupillary constriction in the affected eye and evidence of blood in the anterior chamber of the eye. The cornea should be stained with fluorescein dye to evaluate the possibility of damage, such as a corneal burn. Direct ophthalmoscopic examination should be conducted since most laser injuries occur where they can be seen through the ophthalmoscope. Retinal injuries can be seen as isolated groups or rows of retinal burns or vitreal hemorrhages. Retinal burns may initially appear white but after a few days they may be seen as a black-pigmented spot.

Management- it is important to note, that in a military setting, the on-scene medical provider may be called upon to manage suspected ocular or skin laser injuries pending medevac referral to specialized care. Understanding the primary care management of these injuries may prevent permanent loss of vision, alleviate pain and provide comfort and reassurance.

Corneal burns resulting from laser exposure are managed in the same manner as any other type of corneal burn, simply the application of topical antibiotics and ocular dressings. The care of associated facial burns; smoke inhalation and maintaining airway management should be conducted in accordance with established primary care principles. Associated iritis and pain can be managed with pupillary dilatation using cyclopentolate hydrochloride (1% cyclogel) ophthalmic solution, proparacaine hydrochloride (0.5% ophthaine) ophthalmic solution, or 1% atropine ophthalmic solution. One drop in the affected eye every 8-12 hours should suffice. A ruptured globe, which is considered a medical emergency, and other retinal injuries need to be medically evacuated and referred to an ophthalmologist for immediate evaluation. All personnel with suspected laser injuries should be referred for a complete ophthalmological evaluation as soon as conditions permit. Personnel with vitreal hemorrhages should be on bed rest with the head positioned so that blood pools away from the visual axis. If blood does not absorb spontaneously, after a few days, a vitrectomy is indicated. Personnel with best-corrected vision, worse than 20/40 in the better eye, should be removed from duty and considered for evacuation. Priority for patient evacuation should be determined according to the severity of the injury and the likelihood of preserving the vision on the injured eye(s).

Treatment following a laser injury is very important. Adequate, professional expertise should be made available at every level of care. Calm reassurance of the individual including explanation of the realistic expectations for recovery are essential. The potential psychological effects of a laser injury, particularly to the eye, can be significant. For this reason, it is important to return the member to duty as soon as it is medically indicated. Stress management needs to be implemented and psychological consultation considered whenever indicated. It is the responsibility of the medical provider to provide reassurance, to both the individual and the family, that residual symptoms will continue to improve and to stress the importance of rest, nutrition, hygiene and return to duty.

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