DEPARTMENT OF THE NAVY
BUREAU OF MEDICINE AND SURGERY
2300 E STREET NW
WASHINGTON DC 20372-5300

IN REPLY REFER TO

BUMEDINST 6470.23
BUMED-212
18 Aug 1999

BUMED INSTRUCTION 6470.23

From: Chief, Bureau of Medicine and Surgery
To: Ships and Stations Having Medical Department Personnel

Subj: MEDICAL MANAGEMENT OF NON-IONIZING RADIATION CASUALTIES

Ref: (a) OPNAVINST 5100.23E, Chapter 22
(b) OPNAVINST 5100.19C, Volume I, Chapter B9
(c) SPAWARINST 5100.12B (NOTAL)
(d) SPAWAR Technical Manual E0410-BA-GYD-010/7034 Laser (NOTAL)
(e) American National Standards Institute, ANSI Z-136.1 1993 (NOTAL)
(f) American National Standards Institute, ANSI/IEEE C95.1-1991
(g) DoD Instruction 6055.11
(h) NAVMEDCOMINST 6470.19
(i) MCO 5104.1
(j) MCO 5104.2

Encl: (1) Medical Evaluation and Treatment of Laser Injuries
(2) Medical Treatment and Evaluation of Radiofrequency Injuries

1. Purpose. To issue permissible exposure limits (PELs), medical surveillance requirements, and casualty management procedures for personnel exposed to non-ionizing electromagnetic radiation.

2. Cancellation. NAVMEDCOMINST 6470.2A.

3. Scope. This instruction applies to all Department of the Navy activities using sources of non-ionizing radiation that may affect the safety or health of personnel. Personnel not employed by the Department of the Navy must comply in all respects with this instruction when engaged in a Navy sponsored program or operation, or when visiting Navy ships, aircraft, or stations. This instruction does not apply to the exposure of individuals to non-ionizing radiation when used for the diagnosis or treatment of medical or dental conditions of those individuals.

4. General

a. Reference (a) assigns the Chief, Bureau of Medicine and Surgery (BUMED) with responsibility for:

(1) Establishing non-ionizing radiation personnel exposure limits.

(2) Providing non-ionizing radiation health effects analysis and technical support to Navy commands.

(3) Maintaining non-ionizing radiation injury and overexposure investigations.

(4) Providing assistance through the NAVENVIRHLTHCEN for non-ionizing radiation hazard evaluations of medical and industrial activities.

(5) Sponsoring biological research on non-ionizing radiation health effects.

b. References (a) through (c) issue guidance on establishing command non-ionizing radiation control programs and includes requirements for laser system safety officers (LSSOs), personnel training, personal protective equipment, warning signs, and administrative and engineering protective control measures.

c. Reference (d) provides introductory information on laser principles, laser biological effects, and supplementary guidance to reference (c) on laser safety and control measures.

5. Non-ionizing Radiation Exposure Standards

a. Lasers

(1) The PEL is the level of laser radiation below which there are no hazardous effects or adverse biological changes in the eye or skin. The Department of the Navy uses the limits established in reference (e) as its exposure standard for ultraviolet (UV), visible, and infrared lasers.

(2) Only qualified LSSOs should apply the PELs, or attempt to calculate nominal ocular hazard distances or nominal hazard zones described in reference (e). Reference (c) contains a complete series of tools for the proper application of reference (e) for most Navy and Marine Corps laser systems. The laser classification scheme described in paragraph 6 acts as a guide for protection from medical or experimental laboratory laser applications where reference (e) does not apply.

b. Radiofrequency (RF) Electromagnetic Fields (EMF)

(1) RF EMF PELs are the exposure limits below which no adverse health effects occur even after repeated or long-term exposure. The Department of the Navy uses the PELs listed in references (f) and (g) as its exposure standards for RF EMF between frequencies of 3 kHz (kilohertz) and 300 GHz (Gigahertz).

(2) Only qualified personnel should attempt to interpret or apply the standards of reference (f). Enclosures (4) through (7) of reference (g) give detailed guidance on the evaluation of personnel hazards from RF EMF and the application of the standards.

(3) The PEL maintains personnel exposure below an SAR (specific absorption rate) of 0.4 watts per kilagram (W/kg). An SAR of 4 W/kg is a threshold, above which, there is an increasing possibility for adverse effects. The PEL incorporates a safety factor of 10, yielding an SAR of 0.4 W/kg. Since SAR is difficult to measure, PELs are in terms of the measurable field parameters as means of demonstrating compliance with SAR. See reference (f).

6. Personnel Exposure Guide

a. Lasers

(1) The laser classification scheme provides a practical alternative to determining the hazards of a laser in terms of the applicable PEL. The Code of Federal Regulations, Title 21, Part 1040 require laser manufacturers to affix the laser classification and warning statement to every laser requiring protective actions. This laser classification specifies relative hazards of a laser without the need for any measurements or calculations and infers the type of administrative or engineering controls needed to provide protection of those laser systems. Military exempt laser systems bought for the Department of Navy require review and approval by the Navy's Laser Safety Review Board with laser classification designated in the development cycle. Unclassified lasers that are intended primarily for indoor classroom training and demonstration, industrial operations, scientific investigations, and medical applications shall not be designated as military exempt lasers.

(2) Laser output parameters determine laser classification as summarized below:

(a) Class 1 lasers emit levels of laser radiation that are not hazardous under any reasonable operation or viewing condition, and consequently require no controls or warning labels. Class 1 laser products also refer to totally enclosed lasers of higher classification that cannot expose people during normal operation. There are no controls required unless the beam is accessible by removal or damage of the enclosure (such as during alignment or maintenance).

(b) Class 2 lasers are visible beams that are safe for momentary unintentional viewing and hazardous only when intentionally viewed for more than 10 seconds. The human aversion response (i.e., eye blink) provides protection from deliberate viewing of bright light. A yellow caution label on the laser warns against intentional staring directly into the beam. These lasers require no other control measures.

(c) Class 3a lasers are visible beams that are safe for momentary unintentional viewing but are potentially hazardous if viewing the beam directly with magnifying optics such as binoculars. These lasers have a yellow caution label warning against viewing the direct beam with optical instruments. Required control measures prevent situations where personnel could inadvertently view the direct laser beam through magnifying optics. (Class 3a lasers with red "danger" labels warning against direct eye exposure to the laser beam require all control measures of a 3b laser.)

(d) Class 3b lasers include both continuous and pulsed UV, visible, and infrared lasers that are potentially hazardous if viewing the direct beam or specular reflection with the unprotected eye, but cannot produce (unless focused) hazardous diffuse reflections. These lasers have a red danger label warning against direct eye exposure to the laser beam. Operators must avoid intrabeam viewing and control specular reflections from mirror-like surfaces. Personnel should wear laser eye protection. Control measures must preclude inadvertent exposures of all personnel to the direct beam or specular reflections.

(e) Class 4 lasers are high-powered lasers that are hazardous to the eye from directly viewing the beam and from specular reflections. In addition, class 4 lasers may produce hazardous diffuse reflections, or constitute a skin or fire hazard. These lasers have a red danger label warning against eye or skin exposure to the direct beam or scattered reflections. Class 4 lasers require strict control measures, such as, wearing

laser eye protection and operating with door interlocks or baffles to guard against transient personnel entering during laser operations. Outdoor range operations require strict control over large distances to prevent inadvertent exposure to personnel.

(f) Military exempt lasers is a designation, not a classification, applying to military lasers designed for combat operations or training, or exempted in the interest of national security. As implied by the name, these lasers are exempt from Federal requirements applicable to commercial laser products. All military exempt lasers require further hazard classification (class 1, 2, 3a, 3b, or 4). In most cases, military exempt lasers require controls equivalent to class 4.

b. Radiofrequency (RF) Electromagnetic Fields (EMF)

(1) RF EMF exposure guidance applies to areas defined as either controlled or uncontrolled environments. Designation of these environments is the responsibility of the command in charge of the RF EMF emitter. The PELs associated with these environments are in reference (f).

(a) Controlled environments are areas where the RF EMF has been measured, defined, and control mechanisms are in place. These are locations where one would reasonably be aware of the potential exposure by virtue of obvious indicators such as fences, control points, antennas, radar dishes, and others. Awareness need not be based upon any command training program and may be assumed in most situations as being obvious to any reasonable person.

(b) Uncontrolled environments generally include public areas, living quarters, and work places where there is no expectation of encountering RF levels above those in normal workplaces.

(2) No special RF exposure limits or additional exposure restrictions are necessary for pregnant persons.

7. Laser Medical Surveillance Program. The Laser Medical Surveillance Program acts to detect biological damage or effects. The health risk of laser radiation is from accidental, acute injury and does not imply biologic changes or damage that may result from chronic subthreshold exposure. The Laser Medical Surveillance Program limits enrollment to those personnel who are clearly at risk from overexposure to laser radiation.

a. A preplacement ocular examination establishes a baseline for comparison and measurement following an accidental exposure or ocular damage. A termination ocular examination, given when a person leaves the program, provides evidence of retinal health at that point. Ocular examinations should have clear labels of whether they are a preplacement or termination laser eye examination.

(1) The command LSSO determines personnel enrollment in the Laser Medical Surveillance Program based upon their likelihood of overexposure to laser radiation, using the following guidance.

(a) Individuals routinely working with class 3b or class 4 lasers with a high likelihood of overexposure to laser radiation require medical surveillance. The following situations generally require medical surveillance:

1. Research and development and laboratory personnel routinely working with unenclosed class 3 or 4 laser beams.

2. Maintenance personnel who routinely repair, align, or boresight exposed or open class 3 or 4 laser systems.

3. Operators and down range personnel who routinely work with class 3 or 4 engineering laser transits, geodimeters, and alignment laser devices.

4. Operators who routinely work with class 3b and 4 industrial lasers where access to an unenclosed beam path is possible.

(b) Medical surveillance is generally not required for other laser users or personnel when it is possible, but unlikely, for them to exceed the PEL. This includes:

1. Personnel routinely working with class 1 or 2 laser systems or with laser systems containing class 3 or 4 lasers, but who are not exposed to the open laser beam.

2. Supervisory, clerical, custodial, and operating room personnel who work in laser areas and where laser safety procedures or system design preclude their exposure to levels of laser radiation greater than the PEL.

3. Operators (personnel behind the laser) of fielded military laser systems do not require medical surveillance when operating these systems solely on certified laser ranges and following prescribed laser safety procedures. The LSSO must verify no specular reflectors are present on the range.

4. Visitors or other personnel involved infrequently in testing laser equipment or in laser demonstrations and training require no medical surveillance, when the LSSO ensures these personnel have protection from exposure to levels of laser radiation greater than the PEL.

5. Personnel involved in "force on force" laser training exercises where appropriate protection is established, either in the form of administrative controls or procedures, or where laser protective eyewear is provided.

b. Laser Medical Surveillance Protocol. Conduct a preplacement medical examination before assignment involving the laser exposure risk. Examinations for other purposes that include the required information satisfy the requirements of this instruction. When constrained by ship operations or deployment, perform the examination at the earliest opportunity. Complete a termination examination when practical following termination of duties involving lasers. The purpose of the termination examination is to evaluate the possibility of unreported laser injury incidents, as there is no evidence to suggest that chronic health problems develop from working with lasers. Preplacement and termination laser eye examinations must include:

(1) Ocular histories with special emphasis on photosensitizing medications, lens surgery, unusual sensitivity to sunlight, and skin diseases. Record current refraction prescription and the date of the most recent examination.

(2) Visual acuity for far and near vision.

(3) External ocular and fundus examination.

(4) As deemed necessary by the medical examiner, Amsler grid or other tests of macular function for distortions or scotomas.

(5) As deemed necessary by the medical examiner, dilated, direct view ophthalmoscopic examinations of the retina and slit lamp examinations of the cornea and lens to describe any

pathology or deviations from the normal. Refer any retinal lesions to an ophthalmologist or optometrist for evaluation and photographic documentation.

(6) As deemed necessary by the medical examiner, skin examination if the worker has a history of photosensitivity or works with UV lasers.

8. Non-ionizing Radiation Overexposure Incidents. An over-exposure incident is when personnel are exposed beyond the laser or RF EMF PELs for controlled or uncontrolled environments.

a. Laser Overexposure Incidents. All mishaps involving suspected overexposure to class 3, 4, or military exempt lasers require an investigation and report through the appropriate chain of command. Additionally, those incidents involving suspected or observed laser eye injury require a complete medical examination.

(1) Medical Examination. Immediately refer personnel suspected of overexposure to an ophthalmologist or optometrist. Many lesions begin to fade or heal with time making diagnosis of injury more difficult and symptoms or physical signs of eye injury unapparent. Further, delay in evaluation may later reduce medical treatment options. Documentation of the injury requires color retinal photographs. If the capability for photography is unavailable, make a diagram of the eye documenting the injury and pathology. Send a notification message reporting the over-exposure or suspected overexposure to BUMED (MED-212) as soon as possible. Enclosure (1) provides a summary of management of laser overexposure incidents.

(2) Report of Medical Examination. Make the initial report of medical examination (including negative findings) within 4 hours of completion to BUMED (MED-212). Telephone, fax, message, or e-mail modes are authorized. The LSSO or medical officer will file follow-on written report to BUMED (MED-212) within 30 days of the mishap incident. As a minimum, reports should contain: a listing of personnel involved; a description of the laser or system (wavelength, mode of operation, power output, etc.); estimate of the exposure received as related to the maximum permissible exposure limit; copy of the medical examination and retinal photographs or pictures; a narrative summary of the events leading to the incident including photographs of the laser and its settings; and details regarding safety procedures and equipment used.

(3) Mishap Investigations and Reports. Follow the normal mishap reporting procedures outlined in references (a) through (c), with the addition of BUMED (MED-212) address on all messages.

b. RF EMF Incidents. Investigate and notify chain of command of all incidents or mishaps where measurements indicate personnel exposure in excess of the PELs. The command exercising operational control of the RF source has primary responsibility of investigation, notification, and reporting if necessary.

(1) Medical Evaluations. Refer for medical examination and followup, all personnel reporting physical symptoms or those suspected of exposure to levels in excess of 5 times a PEL. Treat symptomatically and resolve any fears or anxieties of the patient by providing information on potential biological effects of RF EMF. Medical personnel should refer to enclosure (2) for information on RF biological effects.

(2) Notifications and Investigations. Make initial notification of the occurrence by telephone, fax, message, or e-mail to the appropriate technical assistance point listed in paragraph 10. Technical assistance should determine extent of investigation and necessity for reporting and assistance in making RF measurements or an exposure evaluation. A determination of the RF exposure is central to any investigation since these incidents often involve emotional concerns or health worries not easily addressed when measured data is not available. Performing RF measurements is often beyond the technical capabilities of the local command or the nearby medical facility. In cases where it is necessary to reconstruct events or reestablish equipment configurations for conducting an RF exposure assessment, the re-creation accuracy is crucial to the validity of the subsequent RF measurements. The command's investigating officer should obtain written statements from those involved giving detailed equipment setups, as well as obtaining appropriate charts, diagrams, or photographs indicating the locations of exposed.

(3) Exposure Incident Reports. The following situations require reports of RF EMF exposures:

(a) Injury of personnel or physical symptoms believed associated with RF exposure experience.

(b) Preliminary investigation determines personnel exposure exceeded the appropriate PEL in terms of power density

by a factor of five or more. (For exposure determinations, provisions for time averaging and spatial averaging can be used in conjunction with transmitter duty factors and antenna rotation or scanning rates to establish maximum likely exposure levels.)

(c) Inadvertent exposure occurred to members of the general public or to other noninvolved personnel as a result of naval operations that have exceeded the appropriate controlled PEL.

(d) Exposure circumstances or the severity of the incident or mishap leads to anticipation of inquiries from news media, or are of interest to the chain-of-command.

(4) Reports. The command shall submit a final report on the RF incident to the Naval Safety Center and to BUMED (MED-212), with copies to appropriate headquarters and systems commands. The report to BUMED will also contain pertinent medical records and identification data for exposed personnel. BUMED must maintain a permanent repository for RF exposure incidents.

9. System Safety Requirements

a. Lasers. Class 3b (3a with "danger" logo), class 4, and military exempt lasers require establishment of a laser hazard control program as outlined in reference (d). Reference (d) is applicable to Navy and Marine Corps activities, except for lasers planned solely for experimentation. References (h) and (i) clarify and amplify reference (d), for medical and Marine Corps laser systems, respectively.

b. RF EMF Emitters. References (a), (b), and (j) describe the system safety requirements for RF emitters. Reference (a) applies to naval shore facilities, reference (b) applies to all naval activities afloat, and reference (j) applies to the United States Marine Corps.

10. Technical Assistance. Local safety and health offices and other interested personnel can obtain technical assistance and advice concerning non-ionizing sources of radiation as follows:

a. Lasers

(1) For medical and industrial laser applications, contact NAVENVIRHLTHCEN, 2510 Walmer Avenue, Norfolk, VA 23513-2617, DSN 253-5584/5500, and commercial (757) 462-5584/5500, fax (757) 444-3672.

(2) For laser systems safety evaluation and assistance in certification of surveys of laser firing ranges, contact Naval Surface Warfare Center Dahlgren Division, Code G-71, 17320 Dahlgren Road, Dahlgren, VA 22448-5100, DSN 249-1060/1149, commercial (540) 653-1060/1149, or fax (540) 653-8453. The requesting command shall provide funds for services. Also, obtain laser range certification surveys assistance by contacting Naval Surface Warfare Center, Naval Weapons Assessment Station, (Code SC-41), Corona, CA 91718-5000, DSN 933-4090, commercial (909) 273-4090, or fax (909) 273-5089.

(3) For laser bioeffects and medical research issues, or assistance in evaluating laser induced injuries, contact the Naval Health Research Center Detachment Brooks AFB, 8301 Navy Road, Brooks AFB, TX 78235-5365, DSN 240-6924/6552, commercial (210) 536-6924/6552, or fax (210) 536-6439/1466.

(4) For guidance on laser exposure limits and health issues, contact BUMED (MED-212), Non-ionizing Radiation Health Branch, 2300 E Street NW, Washington, DC 20372-5300, DSN 762-3448, commercial (202) 762-3448, or fax (202) 762-0931.

(5) For technical assistance and questions concerning laser eye protection, contact Naval Air Warfare Center, Aircraft Division, 48110 Shaw Road, Patuxent River, MD 20670-1906, DSN 342-8480, commercial (301) 342-8480, or fax (301) 342-8801.

b. RF EMF Emitters

(1) For RF health hazards, personnel exposures, and exposure incidents from industrial and medical RF emitting sources, contact the NAVENVIRHLTHCEN (Code 31), 2510 Walmer Avenue, Norfolk, VA 23513-2617, DSN 253-5584/5500, commercial (757) 462-5584/5500, or fax (757) 444-3672.

(2) For measurement surveys for shipboard RF emitting systems, contact Naval Surface Warfare Center Dahlgren Division, Systems Electromagnetic Effects Branch (Code J-52), 17320 Dahlgren Road, Dahlgren, VA 22448-5100, DSN 249-8594, commercial (540) 653-8594, or fax (540) 653-7494.

(3) For site certification and measurement surveys for shore based RF emitting systems, contact Space and Naval Warfare Systems Center (SPAWARSYSCEN), (Attn: Code 323), P.O. Box 190022, North Charleston, SC 29419-9022, DSN 588-5372, or commercial (843) 974-5372, or fax (843) 974-4238. For shore

facilities within the Pacific Division, Naval Facilities Engineering Command (PACNAVFACENGCOM) geographical region, contact Space and Naval Warfare Systems Activity (Attn: Code 9132), Building 992, 675 Lehua Avenue, Pearl City, HI 96782-3356, DSN 315-471-0620, commercial (808) 471-0620, or fax (808) 471-4054.

(4) For RF bioeffects and medical research issues, or assistance in evaluating personnel overexposure incidents, contact the Naval Health Research Center Detachment Brooks AFB, 8308 Hawks Road, Brooks AFB, TX 78235-5324, DSN 240-4699/6532, commercial (210) 536-4699/6532, or fax (210) 536-6439.

(5) For guidance on RF exposure limits and health issues, contact the BUMED (MED-212), Non-ionizing Radiation Health Branch, 2300 E Street NW, Washington, DC 20372-5300, DSN 762-3448, commercial (202) 762-3448, or fax (202) 762-0931.

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Available at:
http://navymedicine.med.navy.mil/instructions/external/external.htm

MEDICAL EVALUATION AND TREATMENT OF LASER INJURIES

1. The human body largely absorbs light energy, including laser light, superficially. As the eye is transparent to light and has the ability to focus certain wavelengths of light, it is the most sensitive human organ to laser injury. The amount of absorption, reflection, and transmission depends on a number of factors, but in general:

a. The cornea and lens in the anterior segment of the eye primarily absorb UV light (<400 nm) with some reaching the retina. The skin as well absorbs some near UV light (315-340 nm).

b. The retina absorbs visible light (400-700 nm) primarily in the photoreceptors, pigmented epithelium, and choroid. The skin also absorbs visible light. The longer wavelengths (red) absorb more deeply in the retinal and choroidal tissue than shorter wavelengths (blue). Visible light due to focusing by the eye increases the energy flux on the retina.

c. The retina and choroid absorb near infrared light (700-1400 nm) while the cornea also absorbs the far infrared (>1400 nm). The skin also absorbs infrared light. A transition zone from 1200-1400 nm exists where retina, cornea, and lens all absorb.

2. The amount of laser damage to human tissue is proportional to the amount of absorbed energy and is a function of the wavelength of the light, exposure duration, pulse width, repetition rate, and irradiance. There are three primary mechanisms of laser light damage:

a. Photochemical changes, prevalent with UV and short visible wavelengths, such as UV corneal burns and sunburns of the skin.

b. Thermal changes prevalent with most low power visible and continuous infrared wave lasers, such as photocoagulation, i.e., superficial and deep corneal burns and retinal burns.

c. High-power continuous wave and pulsed lasers produce both thermal and mechanical tissue disruptions by the super heating of fluids, gas creation, and release.

3. Adverse Effects. The formerly listed mechanisms for damage relate to the following potential adverse effects:

a. Ultraviolet (UV) Light

(1) The most common effect of UV light is epidermal reddening or erythema (sunburn), due to the absorption of light energy by melanin pigment. Onset of skin erythema may be delayed for hours to days after exposure.

(2) At low powers, UV light lasers produce a photochemical reaction in the cornea of the eye, known as photokeratitis. This epithelial injury is usually painful and can be visually disabling. There may be a latency period of several hours between the exposure and the development of the corneal pathology and symptoms. Mild corneal lesions should heal within a few days, but more significant pathology could produce a decrement in visual function. The threshold for skin burns is similar to that of the cornea of UV light wavelengths.

(3) The retina also absorbs some wavelengths of UV light and this energy can potentially cause erythema of the retina.

b. Visible Light

(1) Most eye structures including the neurosensory layer of the retina are transparent to visible light; therefore the majority of damage takes place in the deeper retinal pigmented epithelium (RPE). When the RPE absorbs sufficient laser light energy, collateral damage in the form of thermal coagulation of adjacent photoreceptors and other structures of the retina can occur. Unlike injuries to the cornea, laser injuries affecting the RPE, retina and other intraocular structures are usually painless. Any pain occurring resolves in a few minutes.

(2) In addition to direct thermal injury to the RPE and adjacent retina, visible and near infrared lasers of sufficient power can produce hemorrhage in the highly vascularized choroid. This bleeding can significantly disrupt vision. If pooled beneath the photoreceptor layer of the retina, blood accumulation can cause retinal detachment from the pigmented epithelium. Subretinal bleeding can result in additional injury to photoreceptor cells, resulting in a scotoma (blind spot). Bleeding into the vitreous may disrupt vision by obstructing light passing through the eye to the retina.

(3) Laser injury to the retina may also damage the conducting fibers (axons) of the retina, producing a visual field defect peripheral to the site of injury.

(4) The skin's threshold for visible and infrared laser burns is much higher than for the retina, since the focusing power of the eye is not a factor.

c. Infrared Light

(1) Infrared laser light, especially the near infrared, causes damage similar to visible lasers. In addition to the effects listed above, the cornea absorbs far infrared laser light, resulting in immediate burns to all corneal layers. Lesions from far infrared lasers can produce permanent scarring of the cornea, and if the energy is sufficiently high, the cornea can perforate, potentially leading to loss of eyesight.

(2) The threshold for skin burns from far infrared lasers is similar to that of the cornea.

d. Other Harmful Laser Effects

(1) Visible laser light can interfere with vision even at low energies that do not produce eye damage. Glare, flash blindness, or afterimages can have detrimental effects on vision that could impair mission accomplishment.

(2) Near infrared and visible laser light can interfere with visual enhancement systems such as night vision devices and forward looking infrared radar. While not causing physical damage to the eye, temporary blooming, or pitting of the sensitive phosphor surface can impair operation.

(3) Amounts of laser light that would not damage the eye in unaided viewing may damage the eye when using binoculars or magnifying optics.

4. Symptoms. The symptoms of laser injury may be subtle or dramatic, depending on the location and severity of the injury. Patients may present a history of experiencing glare, a bright flash, flash blindness, sensitivity to bright lights, decreased vision, pain, or any combination. Complaints of unexpected sudden eye discomfort, poor vision, or seeing bright flashes of light should alert medical personnel to a potential laser injury. Obvious lesions, such as skin or corneal burns, retinal burns, and retinal hemorrhages make diagnosis more certain, especially when associated with a history of seeing bright, colored lights. At very high energy levels, visible and near infrared light overwhelm the retinal photoreceptors, causing a perception of

intense white light, even invisible lasers create the perception of light when energy levels are intense enough. A detailed history of spontaneous fires, unexplained damage to electro-optical instruments, such as night vision goggles help in validation of subtle symptoms.

5. Examination. Definitive diagnostic tests of subtle laser injuries to the eye are generally unavailable in the field. At the earliest suspicion of laser injury, consultation with laser experts at BUMED (MED-212), NAVENVIRHLTHCEN, or local eye clinics is advisable. While the following are not definitive, they may assist the physician in referral of suspected eye injuries.

a. Vision Examination. Various vision examinations are helpful in diagnosis. Snellen acuity, confrontation visual fields, and Amsler grid are essential tests in the initial field evaluation.

(1) Snellen acuity determines visual resolution in the eye and tests fovea vision. A decrease in visual acuity generally relates to injury close to the fovea region.

(2) Confrontation visual field testing helps identify gross peripheral visual field defects such as from a large hemorrhage if patient is unable to see the fingers of the examiner.

(3) Amsler Grid is sufficiently sensitive to detect lesions as small as 50 μm (micrometer). Abnormalities in testing may indicate old stable conditions or new retinal/vitreal pathology and help locate the area of injury.

b. External Examination. Physical examination of the periocular tissues (lids and conjunctiva) and anterior segment (cornea, anterior chamber, and iris) should look for redness of conjunctiva suggestive of ocular inflammation; corneal cloudiness; a small pupil in an inflamed eye suggests intraocular inflammation; blood in the anterior chamber. Staining of the cornea with fluorescein dye may be consistent with possible damage. More severe corneal burns may cause whitening of the cornea. Ruptured corneas should be apparent on external examination. The cornea will be seriously damaged. The anterior chamber will be shallow. The pupil may be eccentric and irregularly shaped. Iris tissue may be in or protruding through the corneal wound.

c. Direct ophthalmoscopy should normally enable a clear and undistorted view of the posterior pole in undamaged or mildly damaged eyes. Poor visualization of the pole can result from corneal or lens opacities or a vitreal hemorrhage. Most laser injuries to the RPE and retina are located where they can be seen with direct ophthalmoscopy. They may be variable and include isolated rows or groups of retinal burns or retinal/vitreal hemorrhages. Retinal burns initially appear white, but may fade after a few days. Weeks later, there may be a black pigmented reaction where the burn took place.

6. Treatment

a. Corneal Injuries and Ruptured Globes

(1) Corneal burn treatment is the same as for burns of other etiologies, namely topical antibiotic coverage and eye dressings. Other treatment principles regarding facial burns, smoke inhalation, and airway maintenance apply. Dress and patch only the injured eye. Any associated iritis and pain can be treated with pupil dilation using cyclopentolate hydrochloride (1% cyclogel) ophthalmic solution, proparacaine hydrochloride (0.5% ophthaine) ophthalmic solution, or 1% atropine ophthalmic solution (if longer duration of 1-2 days is not deemed excessive). Place one drop in the affected eye every 8-12 hours. Pain medication may be required for patient comfort. Topical anesthetics, such as proparacine hydrochloride (ophthaine) 0.5% ophthalmic solution, may be used to facilitate examination and treatment of the nonruptured globes, but should not be used beyond the examination setting to control pain due to its associated toxicity.

(2) A ruptured globe is a medical emergency. Use a metal eye (Foxx) shield to protect from external pressure and do not use regular patches. Do not use eye drops or ointments on a ruptured eye. Any patient with a ruptured globe should be medically evacuated to an ophthalmologist immediately. Administer intravenous antibiotics pending ophthalmology evaluation.

b. Retinal Injuries

(1) Treatment of retina/choroid laser injuries is not well defined. Use of ocular and oral corticosteroids for treatment of retinal burns and hemorrhage remains controversial.

(2) Personnel with vitreal hemorrhages should be maintained on bed rest with heads positioned so the blood settles away from the visual axis, particularly for the first few days. Delayed or tertiary treatment of vitreous hemorrhage consists of vitrectomy and associated procedures, but only for those eyes that do not have adequate spontaneous absorption of the blood.

7. Evacuation Criteria

a. Personnel with best corrected vision worse than 20/40 in the better eye should be removed from duty and considered for evacuation. In general, patient evacuation priority is based upon the severity of injury and the likelihood of saving the eye. Therefore, ruptured eyes and severe corneal burns would have a high evacuation priority. In contrast, retinal damage and vitreous hemorrhage would have a lower priority. Note, soon after the injury, the vision may be poor, but it may improve over several days. The capability of medical evacuation and the intensity of the military operations will determine whether these casualties will be evacuated or remain.

b. Ophthalmologists may be available at level 3 in-theatre care and are available at out-of-theatre definitive care sites. Optometrists may be available at level 2 in-theatre care, usually available at level 3 in-theatre care, and are available at out-of-theatre definitive care sites.

MEDICAL TREATMENT AND EVALUATION OF RADIOFREQUENCY INJURIES

1. Like other forms of non-ionizing electromagnetic radiation, electromagnetic radiation between the frequencies of 3-Kilohertz (kHz) and 300-Gigahertz (GHz) deposits energy in matter. The degree of absorption, reflection, scattering or transmittance of energy is highly variable and is dependent upon the type of material, the frequency of the radiation, the size of the object being exposed, and the distance to the source. The amount of energy absorbed dictates its effect. Based upon the absorption characteristics, the electromagnetic spectrum of interest can be subdivided into four frequency ranges.

a. The subresonance range, less than 30 Megahertz (MHz), where surface absorption dominates for the human trunk, but not for the neck and legs, and the absorption of energy decreases rapidly with decreasing frequency.

b. The resonance ranges, which extends from 30 MHz to about 300 MHz for the whole body, and up to about 400 MHz if partial body (head) resonance is considered. High absorption cross sections are possible and whole-body-averaged SARs approach maximal values when the long axis of a body is parallel to the E-field vector and is four tenths of a wavelength of the incident field. Maximal absorption occurs at frequency near 70 MHz for standard man (height = 175 cm) and results in an approximate seven-fold increase of absorption relative to that in a 2,450 MHz field.

c. The "hot spot" range, extending from about 400 MHz up to 2,000 MHz or even to 3,000 MHz, where significant localized energy absorption can be expected at incident power densities of about 100 W/m^2. The size of hot spots range from several centimeters at 915 MHz to about 1 centimeter at 3,000 MHz. Resonance (at lower frequency) or quasi-optical focusing (at higher frequency) of incident fields cause hot spots. For the human head, the hot spot range extends from 300 MHz to 2,000 MHz.

d. The surface absorption range is at frequencies greater than 2,000 MHz.

2. Electromagnetic energy within the frequency spectrum of 3 kHz to 300 GHz does not carry enough energy to break atomic bonds, however, is capable of inducing atomic/molecular vibration and minor voltages that drive current flow. Energy transfer from both of these mechanisms results in heat generation. The basic

unit of energy absorption is the Specific Absorption Rate (SAR), in W/kg. The SAR can be calculated, or in some instances determined experimentally, for given exposure situations. The SAR can be used to compute the total (integral) absorbed energy dose over the exposure time, or the specific absorption in Joules per kilogram.

3. Adverse Effects. Absorption of electromagnetic radiation energy of sufficiently high intensities produces a variety of adverse health effects. Such effects include cataracts of the eye, overloading of the thermoregulatory response, thermal injury, and altered behavioral patterns. Of these, the most statistically consistent effect in mammals at the lowest observed is behavioral disruption.

a. Behavioral Disruption

(1) In spite of marked differences in field parameters and thresholds, behavioral impairment is found within a narrow range of whole body averaged SARs about 4 W/kg for primates. Reference (f), therefore, seeks to limit exposure to RF electromagnetic fields to one tenth of this level or 0.4 W/kg averaged over the whole body.

(2) Behavioral disruption is a collection of symptoms, changes, or interference associated with subtle increases in body temperature. Like heating from other physical agents, these symptoms disappear once exposure stops and the body's thermo-regulatory response returns it to a normal temperature. There are no scientifically proven long term effects or disorders associated with repeated or chronic exposure to RF EMF at or below the PELs.

b. Other Adverse Effects

(1) RF electromagnetic shocks and burns can result from touching ungrounded metal objects that have been charged by an EMF or from contact of a charged body with a grounded metal body. The current flowing into the body has a strong dependence on the size of the object, and is a function of both the RF EMF and the impedance of the object to the ground. If the current at the point of contact exceeds 50 milliAmperes (mA), there is risk of burning tissue.

(2) Cataract formation from extremely high direct near field RF EMF exposures to the head and eye has been described. The limited data on RF EMF induced cataracts in human beings

following acute, high-intensity exposure suggests possible threshold intensity and a thermal mechanism of induction. The threshold level for cataract formation is believed to be well above the existing PELs, and perhaps as high as 150 mW/cm^2 for a 100 minute exposure.

(3) Transitory decrease in sperm count may occur from high RF EMF exposure. This effect is similar to what can be expected from other forms of heat, (e.g., a hot bath or exercise) and is reversible.

4. Symptoms. Acute symptoms from overexposures to RF EMF are related to its heating effects, such as redness of skin, or at very high level increase in core body temperature. There is a possibility that subtle heating effects may aggravate existing medical problems, such as dermatitis, especially RF EMF of high frequency. Feelings of warmth and sensations of pain may result.

5. Medical Assessment. The principal concern of medical evaluation should be to quantify exposure history in relation to any existing symptoms and to document.

a. Determine if the patient is in any type of acute distress. In an overexposure incident, it is extremely unlikely that patient will experience any acute stress or demonstrate any psychological upset. In all situations, treat the patient symptomatically.

b. Interview the patient. The patient should be reassured, calmed and asked to relate the facts of the incident. Ask the patient if any sensations were noted during the incident. Use the biological effect information in this enclosure to help answer questions and put the incident into proper perspective. Care should be taken not to suggest symptoms or sensations that were not present.

c. Evaluate each patient and record the following:

(1) Oral temperature. If greater than 101°, monitor rectal temperature.

(2) Initial blood pressure and after 5 minutes recumbent.

(3) Clinical observations with particular emphasis on visual acuity, skin, psychological and neurological responses, and anatomical areas where symptoms were noted. If the incident involved the head or upper body, a slit lamp examination should be performed if possible.

(4) No laboratory examinations are necessary immediately following the incident.

d. Develop a summary of the incident with estimated exposure to the various anatomical areas and any sensations noted by the patients.