Lasers in the Operating Room
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LASERS IN THE OR

AORN VIDEOTAPE STUDY GUIDE
AORN INDEPENDENT STUDY ACTIVITY

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OVERVIEW

This independent study activity is developed for nurses and other healthcare professionals who participate in procedures in which lasers are used. Fundamentals of laser-tissue interactions and current clinical applications of prominent healthcare laser systems are reviewed. Steps that must be taken to ensure safe use of healthcare laser systems in the operating room are emphasized, including engineering, administrative and procedural controls, use of personal protective equipment, smoke evacuation, and fire and electrical safety are discussed in detail.

OBJECTIVES

After viewing the videotape and completing the study guide, the participant will be able to:

1. outline criteria for the classification of healthcare laser systems;
2. list several prominent healthcare laser systems, along with their most common clinical applications;
3. discuss measures that must be taken to ensure safe use of healthcare laser systems, including engineering controls, administrative controls, and procedural controls
4. describe the use of personal protective equipment in laser treatment controlled areas; and
5. discuss the importance of various safety measures in laser treatment controlled areas

INTENDED AUDIENCE

This self-paced educational program is intended for use by perioperative nurses and other healthcare professionals who participate in procedures in which lasers are used.

GUIDE FOR STUDY

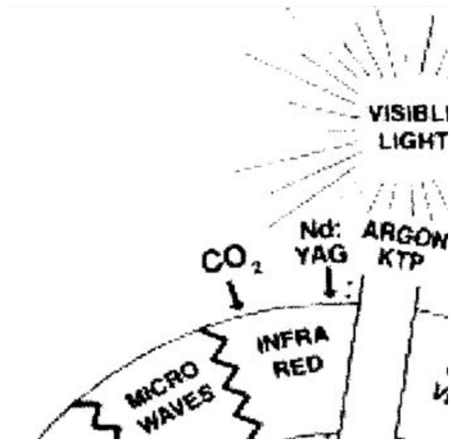
This study guide is intended for use in conjunction with the accompanying videotape, Lasers in the OR. We suggest that you take the following steps to complete this educational activity.

1. Read the overview and objectives for this educational activity and compare them with your own learning objectives.
2. View the videotape.
3. To reinforce your learning, return to the study guide and review the content, paying particular attention to those areas that reflect the objectives.
4. Consult the glossary or a dictionary for definitions of unfamiliar words.
5. Consult the list of suggested readings for further information.

INTRODUCTION

No longer considered a futuristic, “space age” technology, medical laser systems have become a familiar sight in modern operating rooms. In this day and age, every perioperative nurse should be knowledgeable about the safe operation of these powerful and sophisticated medical devices. This study guide reviews the tissue effects and current clinical uses of the most prominent types of healthcare laser systems, and focuses on steps that must be taken to ensure the safe application of this technology in healthcare facilities.

As you may recall, the word “laser” is an acronym for “Light Amplification by Stimulated Emission of Radiation” which represents the physical process by which laser light is produced. When stimulated by high-voltage electricity, high-intensity light, or radio frequency emissions, a laser’s active medium generates an intense, directional beam of energy in the ultraviolet, visible, or infrared portion of the electromagnetic spectrum. The wavelengths of the lasers most commonly used in medical applications are illustrated in Figure 1.



Electromagnetic Spectrum

Depending on the type of laser, the beam may be delivered in one or more operational modes, varying from ultra-short pulses to continuous waves (CW). In CW lasers, a constant beam of laser energy is delivered to the tissue, as long as the laser beam switch is on. Pulsed lasers interrupt the laser beam and deliver it in a series of short, repetitive bursts of energy.[1] Pulsing the laser beam permits the delivery of higher laser energy, while allowing dissipation of any built-up heat before the arrival of the next pulse.[2]

LASER CLASSIFICATION

The American National Standards Institute (ANSI) defines a healthcare laser system as an apparatus that includes, in addition to the laser itself, a delivery system to direct the output of the laser, a power supply with control and calibration functions, mechanical housing with interlocks, and associated fluids and gases required for the operation of the laser. Healthcare laser systems are classified by their manufacturers according to their relative ability to harm healthcare workers or patients[3]:

- Class 1 lasers are considered to be incapable of producing damaging levels of laser emission. Neither control measures nor medical surveillance is required for Class I lasers. An example would be the laser scanners used at supermarket checkout counters and some high speed copy machines.

- Class 2 lasers emit a visible beam that may be viewed directly for time periods less than or equal to 0.25 seconds (the aversion response time). Only if one purposely overcomes the natural aversion response to bright light can a Class 2 laser pose a real ocular hazard.[4] Helium laser pointers and some alignment devices are examples of Class 2 lasers.

- Class 3 lasers may be hazardous for direct exposure or exposure to specular reflection. Class 3a lasers (1 to 5 mW in power) pose a moderate ocular hazard under viewing conditions where most of the beam enters the eye. Even momentary viewing of Class 3b lasers (5 to 500 mW) is potentially hazardous to the eye. An example of a Class 3a laser is Helium-Neon gas and Class 3b is Diode Semi-conductor or Dye liquid laser.

- Class 4 lasers present significant skin and fire hazards, as well as eye hazards, if not properly used. Virtually all surgical lasers fall into Class 4.

Appropriate safety measures are specified by ANSI for each laser classification.

LASER-TISSUE INTERACTION

There are four possible interactions between laser light and tissue[5]:

- Most of the laser energy is absorbed by the tissue.
- Some laser energy is reflected back off the tissue.
- Some laser energy is scattered into surrounding tissue.
- Some energy is transmitted through the tissue.

The degree to which laser light is absorbed, reflected, scattered, or transmitted depends on both the wavelength of the laser energy and the absorptive properties of the material with which it interacts.[6] Most of the tissue effects of medical lasers result from absorption of light energy, which can have thermal, ionizing (photodisruptive), and photochemical effects[7]:

- The thermal effects produced by laser radiation depend on the wavelength, power, energy, and spot size of the incident beam, as well as the absorption characteristics of the tissue. Heating of tissues can have two effects: (1) coagulation, sealing, or cauterizing with minimal necrosis occurs at temperatures above 45° C; or (2) tissue vaporization for incising or excising occurs at temperatures over 100° C in tissue with high water content.

- Very high power and short duration pulses of laser radiation can ionize the molecules in the target tissue, creating acoustic shock waves. The resulting photodisruption is employed primarily in ophthalmic practice.

- Photochemical effects include photoablation (short-pulse ultraviolet laser radiation, which cuts tissue with no visible necrosis and no hemostasis); photodynamic therapy for cancer treatment; and photoradiation (an investigational application designed to enhance wound healing).

MEDICAL LASERS AND THEIR CLINICAL APPLICATIONS

More than 1,000 different materials have been shown to lase, including solids, liquid dyes, and gas mixtures; however, only about a dozen different types of laser systems are in everyday clinical use.[8] The active media of the most frequently used medical lasers are carbon dioxide ($C0_2$), argon, and neodymium:yttrium-aluminum-garnet (Nd:YAG). Holmium:YAG (Ho:YAG), potassium titanyl phosphate, frequency-doubled Nd:YAG; potassium titanyl phosphate (KTP), helium-neon (HeNe), visible dye, and excimer lasers (e.g., ArF [argon - fluorine], KrF [krypton - fluorine], XeCl [xenon - chlorine], or XeF [xenon - fluorine]) also are used for therapeutic purposes.[9] The wavelengths, power ranges, and absorbing chromophores of 11 different medical laser systems are summarized in Table 1.

Table 1. Laser types and characteristics.

Laser type-	Wavelength	Active medium	Power (W)	Absorbed by
CO_2	10600 nm	CO_2, nitrogen, and helium gas	<1 to >100	water
Ho: YAG	2140 nm	holmium in YAG	<1 to 20	water
Nd: YAG	1064 nm	neodymium in YAG	<1 to >100	dark-colored tissue
HeNe	633 nm	helium	.001 to .025	dark-colored tissue
Dye	400-600 nm	Organic compound in solution	<1 to 5	pigmented lesions
KYP	532 nm	neodymium in YAG	<1 to 20	hemoglobin, melanin
Argon	514 & 488 nm	argon ions	<1 to 15	hemoglobin
XeF	351 nm	xenon fluoride	<1 to 20	proteins and water
XeCl	308 nm	xenon chloride	<1 to 20	proteins and water
KrF	248 nm	krypton fluoride	<1 to 20	proteins and water
ArF	193 nm	argon fluoride	<1 to 20	proteins and water

Carbon Dioxide

The most common type of laser employed in surgical applications is the CO_2 laser, which can be operated in pulsed or CW mode.[10] The CO_2 laser beam is strongly absorbed by water. Because some 85% of most biological tissue is made up of water, CO_2 laser energy has extremely superficial penetration.[11] It cuts or vaporizes tissue by rapidly heating and vaporizing the water inside the cell, resulting in rupture and lysis of the cell wall,[12] and thereby cutting and vaporizing all colors of tissue.[13]

The CO_2 laser beam is delivered as a free beam by way of an articulating handpiece or through a hollow metal guide. Because the beam is invisible, it must be used in conjunction with a red helium-neon aiming beam. Having the beam free can create a safety problem if, while being directed, it is inadvertently allowed contact with unintended areas.

CO_2 lasers are used in all clinical specialties,[14] particularly gynecology, general surgery, urology, otorhinolaryngology, podiatry, neurosurgery, and plastic surgery.[15]

Holmium:YAG

The Ho:YAG laser is a recent addition to the growing array of surgical lasers. It is a pulsed laser cooled by a sealed, self-contained, chilled water system. The Ho:YAG beam can be delivered fiberoptically in either a contact or a noncontact mode.[16] Its invisible wavelength is used in conjunction with a red diode aiming beam.[17]

The high pulse energy and shallow penetration of the Ho:YAG laser make it useful in laparoscopic, urologic, ophthalmologic, and arthroscopic surgery.[18] It is used by orthopedic surgeons in the treatment of torn menisci, articular degeneration, and synovial disease. Potential future clinical applications include any applications that are suited to the CO_2 wavelength, but require more pronounced coagulation.

ND:YAG

The Nd:YAG laser is invisible in the near-infrared portion of the spectrum. Its output power may exceed 100 watts in a continuous wave or pulsed mode. A Q-switched Nd:YAG laser emits a very high peak power for an extremely short (nanosecond) period of time, creating tiny explosions within the matter that absorbs it. These explosions create shock waves that can break up material that it strikes, without thermal damage to the lased tissue.[19]

Like the CO_2 laser, the Nd:YAG requires a visible HeNe aiming beam. The beam can be delivered fiberoptically, which provides for more directional control of the beam, but can cause hazards if inadvertent exit occurs at any break point in the fiber.

The Nd:YAG wavelength is strongly absorbed by dark pigments. It is also scattered within tissue, making it difficult to predict the exact depth of the tissue interaction.[20] It penetrates most tissues deeply, making it clinically useful in the coagulation of bleeding vessels.

In the noncontact mode, the Nd:YAG laser is used for volumetric tissue coagulation. In the contact mode, the energy can be focused so that it has the scalpel effect like a CO_2 beam.[21] Principal applications of the Nd:YAG wavelength are in photocoagulation and excision. It is used in ophthalmology, gastroenterology, urology, and other surgical specialties.[22]

Helium-Neon

HeNe lasers are low-power lasers operating in the visible portion of the electromagnetic spectrum. They have gained widespread use in aiming and pointing applications in the medical industry and many other fields. Their predominant medical application is as an aiming beam used in conjunction with invisible treatment beams.

Tunable Dye

The active medium of tunable dye lasers is an inorganic dye dissolved in an alcoholic solvent to a specific molar concentration.[23] By using different types and concentrations of dyes, these lasers have the unique ability to be tuned to different wavelengths to match individual lesions,[24] making them more specific than argon lasers for this purpose.

The dye laser beam can be delivered fiberoptically in a pulsed or CW mode [25] Typically, these systems require a

lot of maintenance, including dye changes every few months, mirror alignment and cleaning, and preventive maintenance for the fiberoptic cables and connections.[26]

Dye lasers are used primarily in ophthalmology, urology, plastic surgery, and dermatology.[27] Because dye wavelengths are preferentially absorbed by oxyhemoglobin, they are highly suited for treating port wine stains and telangiectasias, especially in children. Tunable dye lasers have also been used in photodynamic therapy for cancer. Pulsed dye lasers can also fracture kidney stones, thus eliminating the need for an open surgical procedure.

KTP

When an Nd:YAG laser beam is passed through a KTP crystal, the interaction between the laser light and the crystal lattice halves the beam's wavelength and doubles its frequency. Thus, the KTP laser operates at half of the Nd: YAG's 1064 nm wavelength (532 nm).

Like the higher powered argon laser, the KTP laser generally requires flowing water for cooling. Its depth of penetration is less than that of the Nd:YAG. In fact, the characteristics and tissue effects of the KTP laser are very similar to those of the argon laser, which has a similar wavelength.[28] The KTP laser beam is delivered through an optical fiber, cuts tissue on contact, and coagulates in the noncontact mode. Principal applications are in dermatology, urology, and general surgery.[29]

Argon

The argon laser produces visible blue and green beams, which are readily absorbed by blood and pigmented tissue. The beam can be delivered fiber-optically or through an articulated arm. It operates primarily in a continuous, rather than a pulsed, mode.

In eye procedures, the argon laser has achieved prominence because it can travel unimpeded through the watery vitreous humor, yet is strongly absorbed in the retina, which contains the pigmented material melanin. (Melanin absorbs blue-green argon light 10,000,000 times more strongly than does water.) Ophthalmologic applications include iridectomy, iridoplasty, and trabeculoplasty to treat angle-closure and open-angle glaucoma. In addition, photocoagulation of the retina is used to treat vascular and structural abnormalities of the retina and choroid.[30]

The argon laser's absorption in blood and pigmented tissue also makes it useful for treating skin lesions such as port wine stains and hemangiomas.[31] It is effective for coagulation or vaporization of superficial vascular lesions, vaporization of strongly pigmented tissue, and coagulation of small vessels.[32] Still, the argon wavelength is not specific enough to make it the ideal tool for treating vascular lesions; its nonspecific beam can inadvertently damage the dermis and epidermis in these applications.[33]

Excimer

"Excimer" is an acronym for "excited dimer." The active medium of these lasers is a diatomic molecule consisting of an atom of noble gas and a halogen atom (e.g., ArF, KrF, XeCI, or XeF), which exists in only the excited state of one or both atoms and dissociates after emitting ultraviolet light.

Excimer lasers are believed to destroy tissue as a result of a photochemical process whereby chemical bonds of organic compounds in tissue are broken without heat dispersion or damage to surrounding tissue.[34] Target tissue is ablated with minimal necrosis, but microvascular hemostasis is not achieved.[35]

These lasers are used principally for photoablation for angioplasty[36] and in ophthalmologic applications for corneal sculpting. The excimer laser (193 nm) has received US Food and Drug Administration (FDA) approval for both photorefractive keratectomy and phototherapeutic keratectomy for correction of near-sightedness, far-sightedness, and astigmatism.[37] In orthopedics, arthroscopic applications result in dissolved cartilage without the carbon residual seen when the CO_2 laser is used. Because of its mutagenicity, the KrF excimer laser is not used medically.

LASER SAFETY

When handled properly, healthcare laser systems are safe and effective. If they are used improperly, however, these powerful instruments are potentially dangerous for the patient, the laser operator, and anyone else in the vicinity, Serious injury can result if settings are not properly controlled or if the laser beam is inadvertently aimed incorrectly. These risks can only be minimized by meticulously and scrupulously applying the necessary safeguards.

As the variety of healthcare laser systems and wavelengths increases, laser safety becomes increasingly complex. Perioperative nurses should be familiar with the unique features, operational aspects, and safety measures applicable to all the lasers used in their practice settings. The wavelength of a laser determines not only its unique tissue effects, but also what safety measures are appropriate (e.g., whether damage to the retina, cornea, or skin is the main safety consideration). The extent of potentially hazardous reflections, the type of eye protection required, and ancillary non-beam hazards can vary considerably from one laser wavelength to another.[38] In the event that multiple wavelengths are used (as with tunable dye lasers), appropriate safety measures must be taken for all potentially hazardous wavelengths to which the patient or healthcare professional may be inadvertently exposed.

Engineering Controls

Engineering controls are almost always the preferred method for controlling exposure to laser radiation.[39] They may be incorporated into the laser itself by the manufacturer or added by the user. Manufacturers are responsible for designing laser equipment that meets or exceeds federal and state safety regulations.[40] If engineering controls are impractical or inadequate, administrative and procedural controls and personal protective equipment are considered the next best line of defense.

Administrative Controls

Safe use of healthcare laser systems requires enforcement of administrative controls that encourage safe laser use. Administrative controls regulate work practices in such a way as to implement or supplement engineering controls, specify when procedural controls must be implemented, or stipulate how and when personal protective equipment must be worn.[41] Administrative controls related to laser safety may include, but are not limited to,

- appointment of a laser committee and laser safety officer (LSO);
- development of policies and standard operating procedures (SOPs);
- mandating documentation methods;
- compliance with regulations, standards, and recommended practices;
- certification criteria and skills validation; and
- medical surveillance.

Laser Committee and Laser Safety Officer

In facilities where a number of different practitioners use lasers and where diversity of laser usage warrants, a controlling body or laser use committee should be formed to govern laser activity and establish use criteria. This multidisciplinary committee should oversee all aspects of evaluation, equipment acquisition, operations, and clinical applications of laser technology in the healthcare facility.[42]

Each healthcare facility in which lasers are used should have an LSO, who is authorized and responsible for controlling laser-related hazards in that facility. Perioperative nurses and allied health professionals may function as LSOs if they are properly trained, knowledgeable, and able to maintain consistent application of laser safety standards in the clinical environment.[43]

According to ANSI, specific responsibilities of the LSO include:

- classifying of laser systems according to hazard;
- evaluating laser hazards;
- evaluating and updating procedural and engineering controls;
- approving SOPs for laser operation, maintenance, and service;
- ensuring appropriate use of personal protective equipment;
- ensuring use of appropriate warning signs and labels;

- auditing the safety of new and existing laser facilities and equipment;
- ensuring provision of appropriate laser safety education and training; and
- establishing personnel categories for medical surveillance.

In small medical clinics or physicians' offices, these duties are the responsibility of the person who is using the laser.

Policies and Procedures

Standard operating procedures are governed by facility policy and are developed, modified, and maintained according to the needs of individual facilities. The safety information incorporated into these procedures is gathered from a variety of sources, including the laser manufacturer. At a minimum, written policies and procedures should specify safety procedures required to avoid beam and non-beam hazards; laser team members and their responsibilities; personnel education, credentialing, and medical surveillance requirements; laser use documentation methods; and laser care and preventive maintenance.

Laser policies and procedures should be reviewed and revised annually to ensure that they conform to current standards, procedures, and instrumentation.[44]

Documentation

A documentation system is needed to document perioperative laser use in the patient's chart, including type of laser used, laser settings, adherence to safety precautions, and problems encountered during the laser procedure.[45] The documentation format may be a permanent form or checklist that is attached to the laser, a log to be completed for each case, or a part of the operative record.[46] Documentation of laser safety is valuable in providing a legal record of laser use if there is ever a question or if litigation occurs.[47]

Any incident (e.g., fire or inadvertent patient or personnel harm by the laser) that causes tissue damage beyond what would be expected from normal therapeutic laser use must be reported to the FDA. In addition, note any incidents of personnel not following safety procedures, not applying smoke evacuators properly, not wearing masks, or refusing to wear or use safety glasses of the proper optical density and wavelength.[48]

Regulations, Standards, and Recommended Practices

The principal laser safety standard is ANSI Z136.3-1996, American National Standard for Safe Use of Lasers in Health Care Facilities, established by the ANSI. The ANSI standard represents a consensus among manufacturers, distributors, and users of lasers on all aspects of laser safety. Compliance with the ANSI standard is voluntary, but it has become a standard of care in the healthcare industry. Voluntary recommended practices also are published by the Association of periOperative Registered Nurses, Inc. (AORN).

Training and Credentialing

Safe use of healthcare laser systems requires a well-trained staff. Certification and credentialing are administrative responsibilities of the healthcare facility.[49] The ANSI lists 12 items that should be included in laser safety training for perioperative nurses[50]:

- laser biophysics;
- components of the laser, delivery devices, and instrumentation;
- federal, state, and local regulations;
- ANSI standards;
- facility laser policies/procedures;
- access to the laser key;
- medical surveillance;
- documentation/incident reporting;
- anesthesia hazards/controls;
- personal protective equipment;
- patient protection; and
- operational skills workshops, including demonstration and return demonstration.

In addition to these topics, the LSO has to be knowledgeable about laser hazard classification and procedures for laser safety audits. To ensure the smooth functioning of the laser team, laser safety training for perioperative personnel must be compatible with physician training.

Regular continuing education is needed to help staff stay abreast of the continually evolving laser technology, the impact of these developments on clinical practice, and new clinical procedures.[51] AORN recommends that "Healthcare facilities must commit adequate resources to education and training." Programs should be designed to meet individuals' needs and should include didactic and operational training, access to literature and publications, and periodic continuing education. Personnel should be required to demonstrate appropriate skill levels before assuming responsibility for operating laser equipment. Personnel should be required to complete performance evaluations annually and any time new laser equipment, accessories, or safety equipment is purchased.[52]

Medical Surveillance

ANSI standards recommend ocular surveillance for Class 3b and Class 4 laser users. Surveillance also is recommended for other healthcare personnel who may be exposed to laser radiation.[53]

Ocular surveillance should be performed as a pre-employment examination and after any suspected abnormal exposure to laser radiation. Such surveillance has three purposes: (1) to provide a baseline of visual performance against which damage can be assessed in the event of a laser accident; (2) to identify any pathology that appears following abnormal exposure and provide an accident evaluation report; and (3) to identify individuals who may be at special risk from ultra-violet (UV) hazards (primarily dermatological). Many employers also require ocular examinations at the time of employment termination, as a means of protecting the employer from unwarranted claims for damage by former employees who might hold the facility responsible for ocular injury that allegedly occurred during the period of employment.[54]

As long as vision is normal, visual acuity testing is all that is required. Color vision may be tested at the discretion of the examiner.[55] Any deviation from acceptable performance, however, requires identification of the pathology using additional testing methodologies as appropriate.[56]

Procedural Controls

According to ANSI, procedural controls that reduce the hazards associated with laser use may include:[57]

- Adherence to written safety policies and procedures, as discussed previously.
- Assignment of a dedicated laser operator. This laser-trained team member must be responsible for monitoring the safety of the patient, the environment, the staff, and the equipment during laser procedures. He or she should be empowered to enforce compliance with safety policies and procedures.[58] The circulating nurse should not be expected to assume responsibility for laser operation and assistance in addition to performing other responsibilities involved in procedural patient care.
- Requiring storage or disabling (removal of key) of the laser to prevent unauthorized operations, in accordance with Occupational Safety and Health Administration's (OSHA) requirements. Never leave the key in the laser during storage; keep it in a secure area, and restrict access to authorized personnel only.
- Provision of an emergency shut-off mechanism to enable rapid shutdown of equipment with staff informed of the location and operation of this mechanism.
- Assurance that the standby function is activated when the laser is set up and not being fired in order to prevent inadvertent activation.[59]
- Use of dull anodized or matte (beaded or roughened) non-reflective instruments near the beam path to decrease the amount of direct laser beam reflection and scattering.[60] Instruments ebonized with surface paint or lacquer are not recommended because the paint may flake off and enter the wound site.[61] Some equipment manufacturers will dull the surface of existing surgical instrumentation for use in laser surgery, generally by sandblasting.[62]

Additional procedural controls include controlling access to the laser treatment area, controlling access to the laser activation foot pedal, posting of warning signs, and regular calibration and testing of laser equipment.

Controlled Access

Access to the laser treatment area should be limited to appropriately trained healthcare professionals or other authorized persons, including the patient.[63] Within the laser treatment controlled area, define the limits of a nominal hazard zone (NHZ) within which protective eyewear must be worn.

ANSI defines the NHZ as the spherical space within which the level of the direct, reflected, or scattered radiation during normal laser operation exceeds that to which a person may be exposed without hazardous effects or adverse biological changes in the eye or skin. The size of the NHZ varies with the wavelength of the laser in use. For example, the NHZ for a continuous-wave Nd:YAG laser is much larger than that for a CO_2 laser.[64] Because it is cumbersome to figure out exactly who, in what particular operating room, should wear protective eyewear, based on the NHZ for a particular laser, most facilities consider the entire procedure room a hazard zone, no matter what laser is being used.[65]

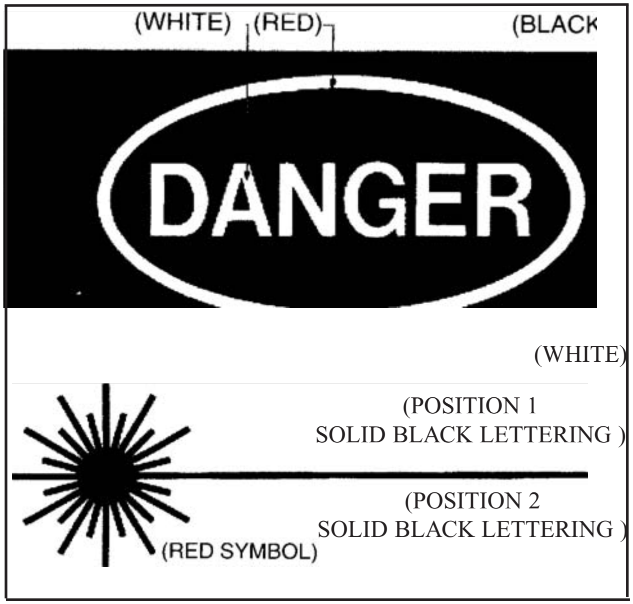
Controlling Access to the Foot Pedal

Only the operating surgeon should operate the laser foot pedal. Laser surgery must not be performed with one surgeon activating the foot pedal while another guides the fiber or handpiece.[66] Accidental firing of a laser has occurred because of confusion created by multiple foot switches positioned below the procedure bed.

Warning Signs

Access to areas in which lasers are in use must be strictly controlled. Warning signs must be conspicuously displayed at all entrances to areas where lasers are used and in locations where they will best serve to warn onlookers. Some facilities use a flashing light in addition to the sign.[67] Warning signs prevent unexpected interruption of the operator and warn passersby of laser usage in progress before they enter the controlled area. They reduce the possibility of exposing the eyes and skin to hazardous levels of laser radiation and other hazards associated with the operation of laser devices during testing, normal operation, and maintenance.

ANSI specifies the designs, symbols, and wording to be used on warning signs for each class of lasers. For Class 4 lasers, the warning sign includes a red sunburst pattern with the words, "DANGER" and "Laser Radiation-Avoid Eye or Skin Exposure to Direct or Scattered Radiation",[68] as shown in Figure 2.



Calibration and Testing

Following the manufacturer's instructions, test all lasers, delivery systems, and safety equipment before the patient enters the room. Wear appropriate eyewear during such tests. In particular, check the power output. Prior to use, examine all fibers for breakage or damage to the distal tip, proximal connector, or catheter sheath.[69] Calibrate fibers to verify adequate transmission of power. During the procedure, monitor fibers for distortion of the beam, accumulation of debris on the tip, loosening of the connector, or decreased power delivery.[70]

When working with invisible wavelengths, always verify that the aiming beam and the laser beam are aligned before beginning a procedure.[71] Accomplish alignment according to the manufacturer's instructions, usually by firing the laser onto a stationary test target such as a wet wooden tongue depressor.[72] Wear appropriate eyewear during such alignment procedures; the most frequent laser-related eye injuries occur during ocular alignment of the equipment.[73]

If testing reveals that the beams are not properly aligned, do not use the laser until it has been repaired by a service representative or designated maintenance personnel.

Personal Protective Equipment

Protective equipment for personnel and patients may be in the form of eyewear for personnel and patients, window coverings, skin protection, or other devices that attenuate laser radiation. Protective equipment must be used by all personnel, including perioperative nurses and their patients, who are within the NHZ when a Class 3b or Class 4 laser is in operation.

Personnel Eyewear

Seventy-two percent of all laser-related injuries are to the eye.[74] Most eye injuries can be attributed to failing to wear protective lenses or to wearing the wrong kind of eyewear for the laser being used.[75] Although the eye has a natural lid reflex, which limits the retinal exposure to very intense visible light or infrared rays, some laser beam intensities are so great that injury can occur faster than the 0.2 to 0.25 seconds in which this reflex occurs.[76]

Lasers operating in the retinal hazard region of the optical spectrum (i.e., between 400 and 1400 nm, the visible violet and near-infrared bands) are particularly dangerous to the eyes, because they can be transmitted through clear ocular media and absorbed in the retina.[77] An acute incident can damage a small area of the retina and can result in a scotoma (a blind spot in the field of vision). Continual low-power exposure can promote cataract formation in the lens of the eye and can damage the retina. Retinal cones, the structures that detect color, are usually the first to be affected.[78] At wavelengths outside the retinal hazard region, in both the ultraviolet and far-infrared regions of the spectrum, injury to the anterior segment of the eye, including the cornea, is possible.[79]

Regardless of the type of laser, all personnel in the room must wear appropriate protective eyewear when a laser is in use. The only exception is when a physician is protected by a filter within a microscope or eyepiece. Protective eyewear may include:

- Goggles or eye protectors. Goggles are usually semi-fexible, fit tightly around the eyes, and have adjustable straps. Most goggles can be placed over regular corrective glasses.[80]
- Spectacles, which may fit over regular corrective glasses. Such eyewear should have built-in side shields to protect the eyes from tangential beams and scattered reflections.[81]
- Permanently affixed filters for the eyepieces of endoscopes, flexible and rigid bronchoscopes, and microscopes. [82]
- Monocle safety glasses that protect the physician's second eye when an endoscope or microscope is being used in conjunction with the laser.
- Prescription eyewear with special filter materials or reflective coatings (or a combination of both). Regular prescription eyewear has two deficits: (1) many lenses are plastic or have a film coating that has not been tested against a laser beam; and (2) they have no side shields. Wearing goggles over prescription glasses is better solution.[83] Contact lenses and reading (half) glasses do not provide sufficient protection.[84]

Lenses of protective eyewear may be made of either plastic (polycarbonate) or glass. Plastic typically breaks less easily than glass, is lighter in weight, and is easier to form into desired shapes. However, plastic is also more easily scratched, and dyes can be bleached or darkened by long-term exposure to light and heat. Generally, glass shows a higher threshold for laser beam penetration.[85]

All laser protective eyewear is rated according to its optical density (OD) at it certain wavelength, defined as the logarithm to the base 10 of the reciprocal of the transmittance. Generally, in the procedure room, eyewear with an OD of 4 (which attenuates the beam by a factor of 10,000) is required.[86] All laser protective eyewear must be clearly and

permanently labeled with the OD and wavelength for which protection is afforded[87] (e.g., "OD=4 at CO_2 wavelength of 10.6 micron"). Do not rely on color as an indication of the type of laser for which eyewear is appropriate.

Be aware that a high OD at a given wavelength indicates not only greater absorbency and safety but, with certain filters, causes lower visibility for the wearer.[88] Eyewear with low visibility causes eye fatigue with extended use and can completely attenuate some normally visible beams. In addition, some filters affect the wearer's ability to see blood and tissue, colored warning lights, laser emission indicators, and other important instrument displays.[89]

Protective eyewear should be cleaned and inspected periodically to ensure the integrity of the absorbing and reflecting surfaces. Most manufacturers recommend cleaning with mild soap and water, using a soft cloth, and air drying. Avoid harsh abrasives and chemicals (e.g., certain disinfectants) that can damage the lens.[90] Regularly inspect eyewear for pitting, crazing, cracking, or discoloration of attenuation material; frame integrity; and wear or damage to retaining devices or straps.[91]

Keep appropriate laser-protective eyewear near the posted laser warning signs to help ensure compliance with eye protection policies.

Patient Eyewear

If the patient is awake during a laser procedure, provide him or her with appropriately labeled eyewear similar to that worn by healthcare personnel. Provide thorough pre-operative patient education to ensure that the patient understands the rationale for eye protection during the laser intervention .[92]

If the patient is anesthetized, AORN recommends taping the patient's eyelids closed or closing the eyelids, covering with saline-moistened pads or other nonflammable material, and taping.[93] When facial areas, particularly around the eyes, are being treated (e.g., for port wine stains or neoplasms), protective glasses may not be enough. For treatments on or near the eyelids, corneal shields should be used. When researchers tested the effectiveness of six commercially available eye shields and four types of lasers potentially used in peri-orbital surgery, they concluded that metallic eye shields were safest.[94] Many of the plastic shields tested exhibited significant thermal damage; plastic shields are not recommended for use in peri-orbital laser surgery.

Window Coverings

Limit windows and viewing areas, as they may extend the NHZ beyond the room in which the laser system is installed.[95] Ensure that all viewing windows in the laser room provide adequate protection specific to the laser wavelength in use. Normal window glass typically has an OD in excess of 5.0 for lasers operating in the spectral range of 180 to 300 nm (e.g., KrF at 248 nm), or in the range of 4.0 to 1000 microns (e.g., CO_2 at 10600 nm). When other types of lasers are in use, windows require additional covering or filtering to prevent the laser beam from being accidentally transmitted through the glass. Sheets of laser-absorbent filters in various sizes, absorbencies, and wavelengths are available to shield observation windows and other areas from laser radiation. These sheets allow observers to view laser procedures through a window from outside the laser treatment room without wearing protective eyeglasses.[96]

Doors should be closed during laser operation. Door interlocks may be used to place the laser in standby mode automatically when the treatment room door is opened.[97]

Skin Protection

The skin is less vulnerable to injury than the eye. Significant skin injuries from accidental exposure to industrial or medical lasers are rarely reported.[98] Thresholds of injury to the skin are normally such that they do not occur outside of the focal zone of a surgical laser.[99] Usually, if skin exposure lasts for a second or more, a pain response causes the individual to pull the exposed tissue away from the laser beam, thereby limiting the exposure duration to a second or less.

Nevertheless, lasers can damage the skin via either photochemical mechanisms (predominant in the ultraviolet end of the spectrum) or thermal mechanisms (predominant in the infrared end of the spectrum). Potential skin and tissue effects range from a mild reddening to blisters or charring (first-, second-, and third-degree burns, respectively). The extent of the burn depends on the degree of absorption, the duration of the exposure, the extent of local blood flow within the tissue, and the size of the area irradiated. UV-B wavelengths in the 0.25- to 0.4-micron spectral region are most injurious to the skin.[100]

Whenever necessary (usually when using high-power surgical lasers, such as CO_2 or YAG), take the following precautions to protect the skin and other tissues of patients and healthcare workers from aberrant and reflected laser beams.[101]

- Generally, no special clothing or skin protection is required for personnel.
- If a gloved hand is burned, remove latex surgical gloves and apply water to the burned area. The latex melting into the tissue is as hazardous as the burn.[102]
- Protect exposed tissues around the operative site with saline- or water-saturated materials (e.g., towels, sponges, nonflammable material) when thermally intensive lasers are being used. Remoisten these materials periodically to ensure proper protection.[103]
- Where applicable, use backstops or guards during laser surgery to prevent the beam from affecting non-target tissue. Titanium and quartz rods are effective backstops for the CO_2 laser. Argon and Nd:YAG wavelengths can be transmitted through clear rods; therefore, titanium rods are preferred for use with these lasers.[104] Do not use glass rods, as thermal stress may cause breakage and fragments may get lost in the abdominal cavity.

Smoke Evacuation

Photovaporization of tissues by Class 4 lasers produces potentially hazardous laser-generated airborne contaminants (LGAC), including toxic gases, bioaerosols, dead and live cellular material, and viruses. LGAC can also contain blood and bloodborne pathogens, and laser users need to use standard precautions to protect against such agents.

At certain concentrations, noxious odors and irritating fumes produced by laser-tissue interaction can cause coughing, lacrimation, nausea, abdominal cramping, and vomiting.[105] Laser plume has been shown to produce pathologic lung changes[106] and to have mutagenic and carcinogenic potential.[107] It also can create visual problems for the physician.

High filtration laser masks should be worn by personnel during procedures that generate smoke plume.[108] High filtration masks, (masks that filter particulate matter at 0.3 μm to 0.1 μm) or laser masks, can provide added protection if worn properly,[109] and may help to reduce noxious odors. However, these masks should not be viewed as absolute protection from chemical contaminants,[110] and should always be used in conjunction with recommended engineering controls. In general, there are three major control measures available to reduce the concentrations of LGAC to acceptable levels. They are exhaust ventilation, respiratory protection, and isolation of the process.[111]

Appropriate local exhaust ventilation techniques should be considered the first line of protection[112] to decrease the odor of burned tissue, to keep the view of the target tissue unhindered, and to eliminate exposure to potentially harmful LGACs.[113] During plume-generating laser vaporization procedures, evacuate laser plume and noxious fumes through a portable smoke evacuator using charcoal and/or high-efficiency particulate air (HEPA) filters.[114] To maximize the effectiveness of smoke evacuation, take the following precautions:

- ♦ Position the nozzle of the evacuator as close as practical to the site of laser interaction,[115] preferably within 2 inches (5 cm) of the operative site.[116]
- ♦ Activate the smoke evacuator at the same time or before the laser procedure begins, and make sure the system is operating efficiently during the entire time the laser is in operation.[117]
- ♦ Whenever possible, use instruments such as laryngoscopes and specula with built-in provisions for evacuation of the laser plume.[118]
- ♦ Do not wear soft contact lenses during laser surgery. OSHA cautions that they are prone to absorb hazardous airborne chemicals that have been identified in the plume.[119]
- ♦ Follow the manufacturer's instructions regarding monitoring and changing of smoke evacuator filters. Usually, when a lingering odor is noticed in the air, the filter needs to be changed. Some smoke evacuation units have an indicator light that notes when the filter needs to be changed.[120]
- ♦ Treat smoke evacuator filters as a possible biohazard. Dispose of them as contaminated waste, using gloves and clean technique, and place in plastic bags.[121]

In the past, some facilities have used wall suction lines to exhaust smoke from surgical sites, but this practice is not recommended.[122] Particulate matter in the smoke can cause hospital vacuum systems to become clogged, and the suction created by the wall unit may not be high enough to capture smoke generated at the procedure site.[123]

Fire Safety

Accidental fires are among the most significant hazards of laser use. The intense heat of the laser beam can ignite or vaporize almost anything. Deadly fires may begin by ignition of drapes, sponges, endotracheal tubes, clothing, or hair; or the combustion of ointments, prep solutions, anesthetic gases, or flatus. Specific fire-prevention measures include the following:

- Do not use alcohol-based or other flammable topical anesthetic agents; instead, use injectable local anesthetic agents.
- Use only noncombustible anesthetic gases and localized exhaust techniques. Intravenous anesthetic techniques are preferred to prevent laser pyrolysis of gaseous anesthetic agents or buildup of oxygen concentrations that will support combustion.
- Do not use alcohol-based or other flammable prep solutions.
- Do not use flammable or combustible drying agents, ointments, plastic resins, or plastics near the laser site.
- Do not allow prep solutions to pool under the patient. Pooled prep solutions can retain laser heat and burn tissue.[124]
- Use only wet sponges or towels or wet or fire-retardant drapes in the operative field.[125] Ignition of drapes can be particularly hazardous to anesthetized patients, who are unable to warn OR staff of the sensation of heat.[126] No standard surgical drapes will resist direct laser beam impact.[127] Anecdotal reports indicate that misfiring of a laser when not in use or undetected breakage of optical fibers has led to drape fires and serious patient injuries.[128]
- To avoid exploding methane gas when procedures are performed in the vaginal vault, cervix, uterus, or anus, insert saline-moistened, counted sponges or gauze rectal packs with water-based (not petroleum-based) lubricants into the rectum.[129] Provide adequate exhaust ventilation in colonic procedures.[130]

Endotracheal Tubes

Patient safety is a particular concern when using lasers near the trachea. Endotracheal tubes can ignite and support combustion if they are not laser-safe. To avoid this problem, always take the following precautions during laser surgery in the aerodigestive tract. [131]

- Use FDA-approved, nonflammable, chemically treated, laser-resistant endotracheal tubes and/or endotracheal tube wrapping material when endotracheal anesthesia is used.
- Plastic, armored, or wire tubes are particularly hazardous. Do not use polyvinyl chloride (PVC) endotracheal tubes, either wrapped or unwrapped, because they can be ignited easily by a laser beam and will support combustion.[132]
- Inflate endotracheal tube cuffs with sterile saline. If a small amount of methylene blue dye is added to the saline, and the cuff is subsequently damaged by the laser beam, the saline will dissipate the heat and leaking of the methylene blue dye will immediately alert the physician.[133]
- Externally protect endotracheal tube cuffs with wet cottonoids.
- Use the lowest possible concentration of oxygen in laryngotracheal procedures.

In Case of Fire

For accidental fires within the sterile field, keep a basin of water or saline handy. For accidental fires of the laser unit, keep an operational and prominently located UL-approved portable fire extinguisher readily available.[134] The fire extinguisher should conform to requirements of the National Fire Protection Association or applicable state and local building codes.[135]

At the first sign of an endotracheal tube fire, stop ventilating the patient's lungs and stop the flow of all anesthetic gases, including oxygen. Extinguish the flames with saline, and quickly remove the endotracheal tube. Reintubate immediately to prevent laryngospasm. Conduct a complete bronchoscopic examination of the mouth, oral cavity, and bronchial tree. If airway burns are extensive, mechanical ventilation of the lungs and the administration of antibiotics and steroids may be necessary.[136]

At the first sign of an equipment fire, personnel should have been trained to respond by disconnecting the electrical equipment from the power source and by using a fire extinguisher to put out the fire.[137]

Electrical Safety
Surgical lasers in the clinical environment pose certain safety problems that are common to all electrical and electronic equipment. Some lasers have sizable power requirements; ensure that the electrical circuitry in the area of laser use has adequate amperage to meet those requirements. Failure to provide sufficient power can trip circuit breakers that serve other outlets. Electrical cords and cables should be in good condition and placed away from heavy traffic areas. Do not use extension cords. Ensure that the system is properly grounded.

Do not place liquids on the laser unit. If water is seen leaking from the laser console, shut off the laser, immediately unplug the power cable from the outlet, and call a service engineer. Do not let anyone plug the laser in until the problem has been repaired.[138]

Do not place the laser foot pedal on or near liquids. Spilled liquid may act as a conductor and cause internal short-circuiting.

SUMMARY

By using a realistic and balanced approach to laser safety, perioperative nurses can confidently assist in the application of this important medical technology, while protecting themselves, their patients, and their colleagues from needless injury.

GLOSSARY

Aiming beam - A Helium-Neon laser (or other light source) used as a guide light; used coaxially with infrared or other invisible light.

Anodization - The process by which an electrolytic action changes the molecular makeup of a metal, then coats it with a protective or colored film.

Aversion response - Movement of the eyelid or the head to avoid an exposure to a noxious stimulant or bright light. The aversion response to bright light (including the eye blink reflex) can occur within 0.25 seconds.

Backstop - A material (e.g., quartz or titanium rod) that stops the laser beam from penetrating beyond the expected impact site.

Chromophore - Optically active (colored) material in tissue that acts as an absorptive target for laser light.

Continuous wave - Laser output that is operated in a continuous rather than pulsed mode. A laser operating with a continuous output for a period of 0.25 seconds.

Cornea - The transparent outer coat of the human eye, which covers the iris and the crystalline lens.

Ebonized - Covered with a black, nonretlective surface.

Excimer - An acronym for “excited dimer.” A diatomic molecule consisting of a halogen atom and an atom of noble gas (argon, krypton, or xenon), which exists in only the excited state of one or both atoms, and dissociates after emitting ultraviolet light.

Healthcare laser system - A laser system used in healthcare applications, including a delivery system to direct the output of the laser, a power supply with control and calibration functions, the mechanical housing with interlocks, and the associated fluids and gases required for the operation of the laser.

High-efficiency particulate air (HEPA) filter - An element of a modern smoke evacuator filter that captures particulate matter; the ANSI standard for HEPA filters is 99.97% efficient in trapping 0.3 micron sized particles in air flow.

Laser - Acronym for "light amplification by stimulated emission of radiation." A device that produces a coherent, collimated, monochromatic beam of light by stimulating electronic or molecular transitions to lower energy levels.

Laser safety officer (LSO) - A person appointed by administration to administer a laser safety program. He or she is responsible for effecting the knowledgeable evaluation of laser hazards and is authorized and responsible for monitoring and overseeing the control of laser hazards.

Nominal hazard zone (NHZ) - The space within which the level of the direct, reflected, or scattered laser radiation during normal operation exceeds the level to which a person may be exposed without hazardous effects or adverse biological changes in the eye or skin.

Optical density (OD) - The light absorbing quality of a translucent substance; defined as the logarithm to the base 10 of the reciprocal of the transmittance. For example, an optical density of 5 attenuates the beam by a factor of 100,000 (1 X 105).

Photodynamic therapy - An experimental treatment for cancer wherein laser light transforms a photosensitizing drug into a cell-killing agent. After the drug is injected into the body, it is selectively retained by the diseased cells. Laser energy of the appropriate wavelength then interacts with the drug which, in turn, destroys the cancer.

Plume - Aerosol created by vaporization of tissue or metals that may contain viable bacteria, virus, cellular debris, or noxious and possibly toxic metallic fumes.

Pulsed laser - A laser that delivers its energy in the form of a single pulse or a train of pulses.

Q-switched laser - A laser that emits short (nanosecond), highpower pulses by means of a device (a Q-switch) that enhances the storage and dumping of electronic energy in and out of the lasing medium, respectively.

Retina - The sensory membrane lining the inside of the human eye; it receives the incident image formed by the cornea and lens.

Tunable dye laser - A laser system that can be tuned to emit laser light over a continuous range of wavelengths or frequencies.

Wavelength - The distance measured between two successive peaks of an electromagnetic wave.

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NOTES

POSTTEST

Multiple choice. Please choose the word or phrase that best completes the following statements.

1. A healthcare laser system that presents significant skin and fire hazards if used improperly is classified
   A. Class 1 laser.
   B. Class 2 laser.
   C. Class 3 laser.
   D. Class 4 laser.

2. Most of the energy emitted by a medical laser is:
   A. absorbed by the tissue.
   B. scattered within the tissue.
   C. reflected off the tissue.
   D. transmitted through the tissue.

3. The carbon dioxide laser wavelength is strongly absorbed by:
   A. protein.
   B. water.
   C. melanin.
   D. hemoglobin.

4. Fiberoptic transmission is not possible for the beam produced by the:
   A. CO_2 laser.
   B. Nd:YAG laser.
   C. Ho:YAG laser.
   D. argon laser.

5. The argon laser is most useful in the specialty of:
   A. orthopedics.
   B. urology.
   C. ophthalmology.
   D. dermatology.

6. When an Nd:YAG laser beam is passed through a KTP crystal, the interaction between the laser light and the crystal lattice:
   A. doubles the frequency of the laser energy.
   B. halves the frequency of the laser energy.
   C. doubles the wavelength of the laser energy.
   D. doubles the amplitude of the laser energy.

7. Photorefractive keratectomy is performed with a(n):
   A. CO_2 laser.
   B. Nd:YAG laser
   C. excimer laser.
   D. tunable dye laser.

8. The first line of controls for limiting exposure to laser radiation is:
   A. administrative controls.
   B. engineering controls.
   C. procedural controls.
   D. personal protective equipment.

9. In small medical clinics or physicians' offices, the responsibilities of the LSO must be fulfilled by:
   A. the nurse.
   B. the laser committee.
   C. the person who is using the laser.
   D. a consultant.

10. A laser safety standard that represents a consensus among manufacturers, distributors, and users of lasers on all aspects of laser safety is published by the:
    A. AORN.
    B. ANSI.
    C. FDA.
    D. OSHA.

11. Ocular surveillance may be performed on laser users:
    A. during a pre-employment physical.
    B. after any suspected abnormal exposure to laser energy.
    C. upon termination of employment.
    D. all of the above.

12. During a procedure, when the laser is not being fired it should be:
    A. turned ON and ready to use.
    B. turned OFF.
    C. in STANDBY mode.
    D. removed from the room.

13. The laser foot pedal should be accessible only to the:
    A. LSO.
    B. operating surgeon.
    C. surgical assistant.
    D. laser operator.

14. For Class 4 lasers, the warning sign posted outside the laser treatment area should include a red sunburst pattern and the word:
    A. "DANGER."
    B. "CAUTION."
    C. "NOTICE."
    D. "WARNING."

15. Protective eyewear must be used by all personnel, including perioperative nurses, who are within the nominal hazard zone during the operation of a:
    A. Class 2 laser.
    B. Class 3a laser.
    C. Class 3b or Class 4 laser.
    D. all of the above.

16. The only person who need not wear protective eye wear when a laser is in use is:
    A. a physician protected by a filter within a microscope or eyepiece.
    B. the circulator.
    C. the laser operator.
    D. the patient.

17. If the patient is awake during a laser procedure that does not involve the face, his or her eyes should be protected with:
    A. corneal shields.
    B. eyewear similar to that worn by health care personnel.
    C. saline-moistened pads.
    D. No eyewear is necessary if the procedure does not involve the patient's face.

18. When an argon laser is in use, the preferred backstop material is:
    A. titanium.
    B. quartz.
    C. glass.
    D. any of the above.

19. During procedures in which laser plume is produced, the following control measures should be implemented:
    A. proper exhaust ventilation.
    B. smoke evacuation system.
    C. properly fitting high filtration face mask.
    D. all of the above.

20. A laser-caused fire within the sterile field should be extinguished:
    A. by smothering with a drape.
    B. with water or saline.
    C. with a fire extinguisher.
    D. any of the above.

Lasers in the Operating Room
Answer Sheet

Question	Answer
1	D
2	A
3	B
4	A
5	C
6	A
7	C
8	B
9	C
10	B
11	D
12	C
13	B
14	A
15	C
16	A
17	B
18	A
19	C
20	B