Paparella: Volume I: Basic Sciences and Related Principles

Section 7: General Surgical Principles

Chapter 34: General Principles of Laser Surgery

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This chapter focuses on the principles, applications and safety considerations necessary for the use of lasers in otolaryngology-head and neck surgery. This information provides a foundation to build on as new laser technologies emerge.

Laser Physics

Albert Einstein postulated the theoretic foundation of laser energy in 1917 (Einstein, 1917). He discussed absorption and spontaneous emission of electromagnetic energy and proposed a third process: stimulated emission. This type of interaction is the basis of laser energy and is the reason for the acronym laser (*l*ight *a*mplification by the *s*timulated *e*mission of *r*adiation).

In 1954, Townes and two of his students were able to produce stimulated emission in the microwave range of the electromagnetic spectrum. This first maser (*m*icrowave *a*mplification by the *s*timulated *e*mission of *r*adiation) led the way for the development of the first working laser.

Townes and Schawlow published "Infrared and Optical Masers" in 1958 (Schawlow et al, 1958). They discussed the possibility of extending the range of electromagnetic wavelength to the infrared and visible ranges of the spectrum. In 1960, Maiman built the first laser (Maiman, 1960). This laser produced electromagnetic radiation at a wavelength of .69 microns in the visible range of the spectrum. A synthetic ruby crystal was used to produce the laser energy.

A laser, then, is a device that produces electromagnetic energy. This energy is coherent and collimated and, therefore, is called organized light. This organized light energy is produced by stimulated emission. A brief review of this concept is necessary.

The atoms of a stable atomic system contain a proton that is balanced by an electron that orbits the nucleus at one of several discrete distances specific to each atom. Electrons can only orbit the nucleus at particular levels, or "floors". Radiation of energy does not occur while the electrons remain on any of these levels. Each electron orbit is associated with a specific energy level of the atom. The ground state is the lowest energy level of an atom. In the ground state, the electrons are in the nearest orbit to the nucleus. The further the electrons orbit from the nucleus, the greater the overall energy of the atom.

Electrons can change orbits or energy levels. Raising the electrons to a higher orbit results in a excited atom. Extrinsic energy is required to raise an electron to a higher orbital level. The packet of extrinsic energy that raises the orbital level is called a photon. The photon of energy causes the electron to be displaced to a higher orbital level, resulting in an atom that is at a higher energy level. Absorption is the term used to describe the interaction of photon interaction with an atom to produce a higher energy state. As the electrons move from a higher to a lower orbital level, the energy that was absorbed is given up and the atom returns to its stable resting state. The release of the photon of energy is called spontaneous emission.

Einstein theorized that if an atom in a high energy state were to absorb a photon at the same energy as the original photon, then return to the stable atomic state would be accelerated. In addition, Einstein theorized that two photons of equal frequency and energy would be produced when the atom returned to the stable state. This process, called stimulated emission of radiation, is the underlying principle of laser physics.

All laser devices have a lasing medium that is contained within an optical resonating chamber. The lasing medium may be a gas (CO_2) or a solid (neodymium:yttrium aluminum garnet (Nd:YAG)). An external source of energy, such as an electrical current or flash lamps, is used to stimulate the atoms of the lasing medium. The atoms of the lasing medium absorb the energy and their electrons go into a higher orbital level. When more than half of the atoms in the optical resonating chamber are in an excited state, a population inversion has occurred. Spontaneous emission of energy then begins with photons going off in all directions. Those photons emitted in the direction of the long axis of the optical resonating chamber reflect off a 100 per cent reflective mirror at one end of the chamber and a partially reflective mirror at the other end. Stimulated emission occurs when a photon interacts with an excited atom in the optical cavity, giving off pairs of identical photons of energy that are of equal wavelength, frequency, and energy. This process occurs at an increasing rate with each passage of the photons through the lasing medium as they are reflected back and forth. Some of the electromagnetic radiation is emitted through the partially reflective mirror as laser energy. A state of equilibrium is quickly reached between the laser energy leaving the optical cavity through the partially reflective mirror and the rate at which the extrinsic energy source replenishes the population of excited atoms.

The electromagnetic energy produced from the optical resonating chamber is composed primarily of one wavelength (monochromatic), is extremely intense and unidirectional (collimated), and is coherent both temporally and spatially. Temporal coherence refers to photons that alternate sinusoidally in phase with one another. Spatial coherence refers to the equal and parallel relationship of the photons across the wave front. These properties of monochromaticity, intensity, collimation, and coherence distinguish the organized energy of lasers from the disorganized energy of a light bulb or other light source (Ossoff et al, 1985).

When the laser energy exists the laser, it must be delivered to the surgical site. Two different delivery systems are in use today. The wavelength of the electromagnetic laser energy determines the delivery system. The midinfrared wavelength of CO_2 cannot be delivered through standard optical bundles. Its energy is delivered by reflection off specially coated optical mirrors to the surgical site. The visible and near-infrared laser energy can be delivered through conventional optical fibers.

Control of Laser Energy

The physician can control three variables with each particular laser wavelength. These are the power, measured in watts; spot size, measured in millimeters; and exposure time, measured in milliseconds to seconds. The power setting is the least useful variable. It may be kept constant with widely varying results when the spot size and time duration are changed.

Power density is the term used to relate the distribution of laser energy over a given area. Power per unit area of the beam or power density is a measure of the power output of the laser in watts divided by the cross-sectional area of the focal spot in square centimeters.

PD (watts/cm^2) = (Power in focal spot) / area of focal spot.

If the time of exposure is kept constant, the relationship between power density and laser tissue injury is a non-linear function as the spot size is varied. Power density is the parameter that surgeons should become familiar with for each particular surgical procedure. The power density is affected by the spot size. The spot size for lasers using lenses is a function of the focal distance of the lens. Present microlaryngeal CO_2 lasers have a spot size of 800 microns at 400 mm, and a spot size of 200 microns at a focal distance of 125 mm. With fiber delivery systems, the spot size is a direct function of the angle of divergence of the laser beam as it exits the fiber and also the distance of the fiber from the tissue interface.

Current CO_2 lasers emit electromagnetic energy with a beam configuration different from that produced by older model lasers. Transverse electromagnetic mode (TEM) refers to the distribution of energy across the focal spot and determines the shape of the laser's spot. The fundamental transverse electromagnetic mode is TEM 00, appearing circular when cut in cross section; the power density of the beam follows a gaussian distribution, with its greatest amount of energy at the center of the beam, and diminishing progressively toward the periphery. TEM 01 and TEM 11 modes are modes that have a more complex distribution of energy across the focal spot. The focal spot (spot size) can be varied in lasers using a lens. The focal spot increases directly with an increase in the focal length of the laser lens. The surgeon can take advantage of this relationship by defocusing the laser lens, creating a larger spot size with a corresponding decrease in power density.

Varying the exposure time of laser energy to tissue is the third method the surgeon can use to control the laser tissue interaction. The term radiant exposure (RE) refers to the amount of time (measured in seconds) that a particular power density has been delivered to tissue.

RE = Power Density x Time.

Radiant exposure is expressed as joules/cm^2.

Therefore, the surgeon can control laser-tissue interaction of each particular wavelength by controlling the power output, the area of laser energy on tissue, and the time of laser-tissue interaction.

Tissue Effects

The effects on tissue from exposure to electromagnetic energy are specific for each wavelength. Laser energy can be reflected from tissue, absorbed at the surface, pass through the tissue or be scattered into the tissue. Most present surgical lasers rely on the conversion of laser energy into heat to cause a desired surgical effect. There is, however, a nonthermal effect on tissue that can be produced by pulsing the laser beam to a short nano or picosecond pulse. It is not within the scope of this chapter to discuss nonthermal tissue effects and plasma flow.

The thermal effect of laser-tissue interaction is the result of laser energy absorption by tissue components called chromophores. For example, the chromophore for the carbon dioxide laser is water.

There are three distinct laser-tissue reactions: (1) the thermal effect, which has been described; (2) the mechanical disruption of tissue produced by nonthermal tissue reaction; and the chemical reaction produced by an alteration of a molecule within a cell.

The concept of photodynamic therapy is an example of a laser-tissue chemical reaction. In this type of reaction, a molecule is allowed to enter a cell. The molecule is capable of absorbing a certain wavelength of electromagnetic energy. The absorption of laser energy by the molecule can result in a change in a molecular bond, leading to a change within the cell such as the release of singlet oxygen, which is toxic to cellular metabolism. This description is theorized to be the mechanism of photodynamic therapy (Dougherty et al, 1975).

Types of Lasers

Argon Laser

Argon lasers emit a blue-green light of 0.48 to 0.51 microns in wavelength. The absorption of this wavelength of energy is color dependent. Much of the energy passes through clear liquid without being absorbed. Tissue pigments, such as beta-carotene and melanin, and the hemoglobin molecule absorb the energy. A localized thermal reaction takes place when the energy is absorbed. The surgeon may use the selective absorption of the laser energy by hemoglobin to destroy the dilated vessels of a port-wine stain by photocoagulation. Two main techniques are used to treat port-wine stains with an argon laser. One technique employs continuous delivery of argon laser energy to the port-wine stain (Parkin et al, 1981). The second technique uses minimal treatment retreatment methods by delivering the energy in short bursts of low power to cause blanching of the target area (Keller et al, 1985). This technique may reduce the heat damage to the overlying epithelium. It does this in two ways. First, the absorption of the argon laser energy is kept to the minimum necessary to coagulate the vessel. Second, by delivering low power and short pulses, the absorption of energy by the beta-carotene and melanin skin pigments is kept to a minimum.

When the beam of an argon laser is focused to a small spot size, the power density is sufficient to produce vaporization of soft tissue.

The small sport attainable with the argon has allowed otologists to perform stapedotomy in patients with otosclerosis. The white color of bone does not absorb sufficient argon laser energy to vaporize bone. Therefore, when performing an argon laser stapedotomy, a drop of blood must be placed on the stapes footplate to cause absorption of the laser energy and subsequent vaporization of the footplate (Sataloff, 1967; Escudero et al, 1979).

The argon laser has been used to photocoagulate bleeding nasal vessels in patients with hereditary hemorrhagic telangiectasia. The small spot size and precise absorption of the argon laser energy by hemoglobin can cause coagulation of the telangiectatic vessels. However, the volume heating of tissue by the Nd:YAG laser offers better control of these telangiectatic nasal vessels (Shapshay et al, 1984).

Nd:YAG Laser

The Nd:YAG laser has a wavelength of 1.06 microns, placing it in the near infrared part of the electromagnetic spectrum. This wavelength of laser energy can be carried through a flexible fiberoptic delivery system. The beam is invisible and requires a second laser beam in the visible spectrum, the helium-neon laser, to allow for aiming.

The tissue absorption of energy from a Nd:YAG laser is color dependent. The energy can be transmitted through clear liquids, with very little loss of energy. In biologic tissue, a scattering of energy, both forward and backward, determines the effective extinction length, which is usually 2 to 4 mm. Back scattering can account for up to 40 per cent of the total amount of scattering. Back scatter can be minimized by delivery of the energy perpendicular to the tissue interface. The zone of damage produce by the incident beam of a Nd:YAG laser produces a zone of thermal coagulation and necrosis that may extend up to 4 mm deep and lateral from the surface, making precise control of tissue injury impossible. The primary applications of the Nd:YAG laser in otolaryngology-head and neck surgery are photocoagulation of vascular lesions and palliation of obstructing tracheal bronchial and esophageal lesions.

The technique of treating endotracheal or endobronchial neoplasms requires that the laser energy be delivered parallel to the long axis of the trachea and bronchi. This limits the spread of laser energy to surrounding intrathoracic structures. Treatment of obstructing neoplasms of the trachea is usually done with a power setting of 40 to 50 watts and a pulse duration of 0.5 seconds (Toty et al, 1981; Dumon et al, 1982; Shapshay et al, 1983; McDougall et al, 1983; Beamis, 1984). Patient selection is of utmost importance in treating neoplasms of the tracheobronchial tree for palliation. Their lesions should be endotracheal or endobronchial. Patients with neoplasms that are primarily extraluminal and that compress the airway should not be treated by endoluminal laser techniques. Removal of tumor within the lumen in this situation can result in collapse of the airway. If malacia of the airway is present with endoluminal tumor, no attempt should be made to remove the tumor because of the possibility of resultant airway collapse.

The introduction of sapphire tips to the end of the flexible fiber carrying the Nd:YAG laser energy has resulted in a new technique called Nd:YAG contact surgery. The sapphire tip absorbs the laser energy. The resultant heat is used to incise tissue, similar to the process used in cutting diathermy.

Carbon Dioxide Laser

The absorption of energy from the carbon dioxide (CO_2) laser by tissue is dependent on the water content of the tissue. Therefore, the CO_2 laser is color blind. As the water absorbs the laser energy, the temperature of the tissue rises. At 60 to 65°C (140 to 148°F) the protein in the tissue denatures. When the tissue reaches 100°C (212°F), vaporization of intracellular water occurs. This causes vacuole formation, cratering, and tissue contraction. CO_2 laser energy can generate temperatures in the hundreds of degrees centigrade. These high temperatures cause vaporization of the target tissue and transmission of heat laterally. Immediately adjacent to the area of vaporization is a zone of thermal necrosis measuring approximately 100 microm wide. Next is an area of thermal conductivity and repair, which is usually 300 to 500 microm wide. Small vessels, nerves, and lymphatics are sealed in the zone of thermal necrosis; the minimal operative trauma combined with the vascular seal probably account for the notable absence of postoperative edema that is a characteristic of wounds from CO_2 lasers (Mihashi et al, 1976).

The CO_2 laser has found its greatest use in otolaryngology-head and neck surgery for the management of benign and malignant diseases of the larynx. This laser also has been used to treat diseases of the oral cavity, the nose and nasal cavities, and the middle and inner ear.

Laser Applications

Nasal Applications

The most common nasal lesions treated with the CO_2 laser are papillomas, telangiectasias, rhinophyma, and nasal polyps (Simpson et al, 1983). The treatment of choanal atresia (Healy et al, 1978; Mittleman, 1980; Selkin, 1985) have been reported. Local anesthesia is usually employed for anterior lesions, and general anesthesia is used for posterior lesions. The operating microscope with a 300-mm lens and laser can be used at the head of the operating table. A large ear speculum can be used for anterior nasal laser surgery. Suction can be provided by a number 7 ear suction. Self-retaining nasal speculums can be used for more posterior nasal laser applications.

Oral Cavity Applications

Transoral excision of oral cavity lesions can be done with the CO_2 laser. Strong, McDonald, and Simpson recognized the unique properties of the CO_2 laser for management of oral cavity neoplasms (Strong et al, 1979a; Strong et al, 1979b; McDonald et al, 1983). They used the CO_2 laser coupled to an operating microscope to perform resections of transoral neoplasm. They noted the advantages of this laser were that it allowed precision, maintained hemostasis, and decreased postoperative edema and pain. Our present protocol for management of oral cavity lesions includes use of the CO_2 laser. The excisional biopsy is done in the operating room with either a regional anesthetic block for lesions of the anterior tongue and floor of the mouth or a general anesthetic for lesions of the posterior tongue and oropharynx. The laser is coupled to the operating microscope with a 300-mm lens and is used for all but anterior tongue lesions. The lesions of the anterior tongue can best be excised with the operating handpiece of the CO_2 laser. All lesions are stained with toluidine blue. The lesion is excised with the CO_2 laser, oriented on a saline-saturated specimen mount, and hand carried to the pathologist (Duncavage et al, 1986). The laser excision is gently wiped with a saline-soaked sponge to remove the charred carbonaceous debris. The debris may cause a foreign body giant cell reaction (Durkin et al, 1986).

Excision of anterior tongue lesions is usually followed by primary closure using a suture that dissolves in 10 days to 2 weeks. The laser excisions of the posterior tongue and oral cavity are allowed to heal by secondary intention, and the patient is instructed in good oral hygiene (Duncavage et al, 1989).

Skin Surgery

The CO_2 laser has been used to remove cutaneous lesions such as small benign and malignant skin lesions, rhinophyma, and superficial scars (Shapshay et al, 1980; Kirschner, 1984). Photothermal peel and tattoo removal can be done by defocusing the CO_2 laser, gently vaporizing the target area, and removing the charred debris with a saline-saturate sponge (Levine et al, 1982; Reid et al, 1980).

Laryngeal Applications

The CO_2 laser is well suited for management of benign and malignant lesions of the larynx. The ability to perform surgery in which the surgeon's hands do not have contact with the patient can provide increased precision and decreased postoperative edema.

The communication between microlaryngeal surgeon and anesthesiologist is crucial in the management of laryngeal lesions. The patient can be ventilated by endotracheal intubation, Venturi-jet ventilation, high-frequency ventilation, or the apneic technique. Two separate suction setups should be used. One provides evacuation of the laser plume from the operative field and the second is connected to a microsurgical suction for removal of blood and mucus from the operative site. A red rubber or Silastic endotracheal tube is wrapped with a reflective, aluminum tape and is used for endotracheal intubation.

Safe instrumentation can be provided if the instruments are nonflammable. They should be nonreflective and have provision for adequate laser plume evacuation incorporated into their design, such as in laser microlaryngoscopes (Ossoff et al, 1984).

The selection of power density and radiant exposure for microlaryngeal laser surgery is important. The selection of the lowest power density (1200 to 2000 $watts/cm^2$) and the shortest time exposure ensures the greatest tissue effect and the lowest level of lateral thermal damage. The palpation of the lesion can aid in assessing its depth and size. Using the laser in a skipping manner can limit lateral thermal damage to adjacent tissue. The continuous delivery of CO_2 laser energy to the larynx should be avoided.

Polypoid Degeneration

The surgical treatment for polypoid degeneration of the vocal folds uses the microflap (Karlan and Ossoff, 1984) and the CO_2 laser. The polypoid tissue is retracted medially and an incision using the CO_2 laser is made on the superior lateral surface of the true vocal cord. The epithelium is raised from lateral to medial and the mucoid fluid in Reinke's space is removed with suction. The redundant epithelium is excised with a microscissors. The remaining epithelium is placed over the true cord. Both true vocal cords can be treated with this technique at the same sitting if 2 to 3 mm of epithelium over one true vocal cord is preserved at the anterior commissure.

Granulomas

Granulomas of the larynx can be excised with the CO_2 laser when medical management fails. The posterior commissure is exposed using a posterior commissure laryngoscope (Ossoff et al, 1983). The granuloma is vaporized down to the perichondrium, but an attempt should be made to preserve the perichondrium. Benjamin and Croxson have noted no difference in recurrence rates when the granulomas were excised by either conventional microlaryngeal or laser technique (Benjamin and Croxson, 1985).

Nodules

The excision of true vocal cord nodules may become necessary for fibrotic nodules and in those patients who have been compliant with voice therapy and who do not improve. The CO_2 laser should be set at the lowest power density (800 watts/cm^2) that will vaporize the nodule. The technique of shaving or using only half of the laser beam to vaporize the nodule, allowing the other half of the laser beam to impact on the operating platform, is the preferred method.

Bilateral True Vocal Cord Paralysis

The CO_2 laser can be used to manage bilateral true vocal cord paralysis (Ossoff et al, 1984). The surgeon can precisely vaporize the mucosa and underlying arytenoid cartilage layer by layer. The precision associated with the use of the laser facilitates performance of this operation even by surgeons who have had difficulty mastering the conventional techniques of endoscopic arytenoidectomy (Thornell, 1948).

Laryngeal Malignancies

The management of squamous cell carcinomas of the larynx using the CO_2 laser endoscopically is an extension of the use of this surgical instrument. The micro- and mini-midcordal malignancies have been managed with cure rates that are equal to radiation therapy (Blakeslee et al, 1984; Ossoff et al, 1985; Strong, 1975).

Stenosis

The CO_2 laser offers a precise method to remove scar and soft tissue stenosis of the larynx (Duncavage et al, 1985; Kaufman et al, 1981). The location of the stenosis may be of importance in the therapeutic response (Dedo et al, 1984; Simpson et al, 1982). Anterior glottic webs may improve after laser vaporization. The stenosis located at the posterior commissure, subglottic larynx, or both often fail endoscopic CO_2 laser surgery because of the extensive vertical depth, circumferential nature, loss of cartilaginous support, and fixation of the arytenoids. The use of supplemental treatment employing periodic dilations and intralesional steroids, stents, or micro-trapdoor flaps (Duncavage; Campbell et al, 1986) may improve the results of CO_2 laser vaporization of laryngeal stenosis (Campbell et al, 1986; Shugar and Biller, 1982; Healy, 1982; Duncavage et al, 1987).

Bronchoscopic Applications

Current indications for bronchoscopic CO_2 laser surgery include the management of recurrent respiratory papillomatosis or granulation tissue involving the trachea, and laser excision or vaporization of selected areas of tracheal stenosis (Ossoff and Karlan, 1982; Ossoff et al, 1985). Tracheal and proximal endobronchial adenomas and webs can be resected using the CO_2 laser. The CO_2 laser can be used for palliation in patients with obstructing tracheal and proximal endobronchial malignancies. The two major contraindications to CO_2 laser bronchoscopy are tracheal malacia and extraluminal compression by tumor. This can be determined by axial CT scans and coronal tomograms (Duncavage et al, 1986).

Safety Considerations

The surgeon must exercise good judgment in the selection of which laser to use and when to use a laser in management of diseases of the head and neck. Exposure to a formal education program in laser surgery must by a prerequisite to the use of the laser as a surgical tool.

A hospital performing laser surgery should establish a laser safety committee. The purpose of this committee is to develop policies and procedures for the safe use of laser in the hospital environment. This committee may be a subcommittee of the Operating Room Committee or directly responsible to the Executive Committee. This committee would also establish credentials for laser users and set guidelines for education of surgeons, anesthesiologists, and nurses who work with the laser. Other responsibilities of this committee include the accumulation of patient data when investigational lasers are used and review of all laser-related complications.

Eye Protection

Specialists working with lasers may receive corneal and/or retinal injuries from reflected laser energy. It is advisable for all operating room personnel who will be working with lasers to have a baseline eye examination. A sign must be placed on the operating room door warning that the laser is in use. Protection of the eyes of the patient, surgeon, and operating room personnel must be provided by the appropriate eyewear that is designed specifically for the particular laser wavelength to be used.

A double layer of eye pads moistened with saline is placed over the patient's eyes when using the CO_2 laser. All operating room personnel must wear protective glasses with side protectors made of glass, transparent plastic, or quartz. The surgeon should wear protective glasses except when using the operating microscope (Ossoff et al, 1983).

When using the Nd:YAG laser, the patient's eyes are protected by a double layer of saline moistened eye pads covered by aluminum foil that has been crumpled. In a patient who is awake, wavelength-specific glasses are used.

The argon laser emits a blue-green light. Wavelength-specific glasses are used by all personnel in the operating room, and protective glasses are used for patients not undergoing a general anesthetic.

Skin Protection

A double layer of saline-saturated surgical towels is used to protect all exposed skin and mucous membranes of the patient. Teeth are protected by saline-saturated telfa, surgical sponges, or specially constructed dental impression trays made of metal. It is possible for the laser beam to reflect off the proximal lumen of the microlaryngoscope, causing a burn to the patient's face. Moist saline towels should be used to completely cover the patient's face. Cloth drapes should be used instead of paper drapes to cover the rest of the patient.

Smoke Evacuation

All laser cases should have two separate suction setups; one for the removal of smoke and moisture from the operative field and the second for the suction of blood and debris. When working with an open anesthetic system or jet ventilation, suctioning should be intermittent and should coincide with the use of the laser. Filters in the suction lines should be used to prevent clogging by the particulate matter in the laser plume (Mohr et al, 1984).

Anesthetic Considerations

The safe management of a patient undergoing laser surgery of the upper aerodigestive tract must include attention to the safety of the patient, the hazards of the equipment used, and the requirements of the surgeon. A general anesthetic is usually required, and any of the nonflammable anesthetic agents is suitable. The concentration of oxygen used is important because oxygen is a potent oxidizing gas. Mixtures of helium and oxygen should be used to maintain the FIO_2 near, but not greater than, 40 per cent (Pashayan et al, 1985). Nitrous oxide is also a potent oxidizing gas and should not be used. Muscle relaxation is necessary to prevent movement of the vocal cords. Jet ventilation during laser surgery is good for selected patients (Edelist and Alberti, 1982), but the present lack of a satisfactory method of total intravenous anesthesia has limited its use in complicated cases or in cases requiring prolonged anesthetic time.

Protection of the endotracheal tube from either direct or reflected laser beam irradiation is extremely important. Should the laser beam strike an unprotected endotracheal tube that is carrying oxygen, ignition of the tube could result in a catastrophic, intraluminal, blow-torch-like endotracheal tube fire (Schramm et al, 1981). Red rubber endotracheal tubes wrapped circumferentially with reflective metallic tape reduce the risk of intraluminal fire. The cuff should be inflated with methylene blue-colored saline (Ossoff et al, 1983), and cottonoids saturated in saline need to be placed about the cuff in the subglottic larynx to further protect the cuff. These cottonoids must be moistened frequently during the procedure. Should the cuff become deflated from an errant hit of the laser beam, the already saturated cottonoids turn blue to warn the surgeon of impending danger. If this should occur, the tube must be removed and replaced with a new one. Use of the operating platform is strongly recommended. When inserted into the subglottic larynx above the level of the packed cottonoids, this instrument acts like a catcher's mitt to protect the cottonoids and the endotracheal tube and cuff from any direct or reflected laser beam irradiation (Ossoff et al, 1985).

Use of a Safety Protocol

The possible complications associated with laser surgery of the upper aerodigestive tract, including the risk of endotracheal tube ignition, were discussed by Strong and Jako in 1972 and Snow and associates in 1976. Several reports of complications from use of the CO_2 laser appeared following the early warnings (Alberti, 1981; Burgess et al, 1979; Cozine et al, 1981; Meyers, 1981). In a survey of laser-related complications conducted in 1984, Fried found that 49 of the 152 otolaryngologist-head and neck surgeons who used the laser reported 81 complications, which included 28 separate incidents of endotracheal tube fires. A recent analysis of complications unique to the use of the laser that occurred under a rigid safety protocol at Northwestern University Medical School and affiliated hospitals revealed a 2 per cent incidence of complications; no fires were included in this group (Ossoff et al, 1983). Healy and co-workers (1984) reported at 0.2 per cent complication rate in 4416 cases of CO_2 laser surgery in the upper aerodigestive tract. The conclusions of both of these reports are similar. First, certain precautions are necessary when laser surgery is being performed in the upper aerodigestive tract. Second, adherence to a rigid safety protocol allows laser surgery of the airway to be performed safely and with an extremely minimal risk of serious complications.