INVITED PRESENTATIONS FROM HARVARD

Recent Advances in Laser Otolaryngology

Marvin P Fried

Harvard Medical School and Harvard Medical Laser Center, Boston, MA, USA
(Received for publication on August 24, 1993)

Key words: lasers, otolaryngology, otorhinolaryngologic-diseases

Throughout the world lasers have become an integral part of an otolaryngologist’s practice for the treatment of a number of disorders. Brought into practice over 20 years ago the carbon dioxide (CO₂) laser remains the prototypical device used largely in laryngology.¹ The CO₂ laser was first introduced for the treatment of recurrent respiratory papillomatosis, an ideal indication for precise resection, vaporization and hemostasis. Since then a number of new wavelengths have been introduced and applied to disorders of the head and neck. Unfortunately, no single wavelength has found universal application and the ideal device has yet to be invented. As physicians become more familiar with lasers, it becomes apparent that specific disorders will require a search for the most applicable wavelength and parameters, rather than the forced application of currently manufactured instruments for universal applications often without a good “fit”.

Biologic Effect

In order to achieve the desired biologic effect, the physician must consider the wavelength of the laser, the characteristics of the tissue being treated, and energy density. Currently, there are a number of laser wavelengths commercially available which include the carbon dioxide, the neodymium-yttrium aluminum garnet (Nd:YAG) and its derivative, the double frequency potassium titanyl phosphate (KTP) laser. The argon laser has been used for a number of years for cutaneous applications and is now being applied to otology and laryngology. The holmium laser has been introduced in the United States and is undergoing clinical trials for paranasal sinus applications. In the future the erbium laser may find applications as a bone cutting instrument. In clinical practice, however, when the otolaryngologist considers the use of a laser for a particular application, the choice as to wavelength needs to be based on the availability at the hospital or clinic and whether the device has been approved for use for the application considered.²

New microspot lasers that can achieve spot sizes to 0.15 mm in diameter are very efficient cutting tools, being able to incise hard tissue with only 1–2 W of power at very short exposure durations. The independent variables of power, duration, and spot size can be altered producing the optimum biologic effect. The use of continuous energy is rarely needed and can have an adverse effect on the surrounding tissue causing greater than anticipated tissue destruction due to heat absorption without adequate tissue thermal relaxation. Vaporization may require larger spot size and high energy whereas coagulation necessitates lower power output with a variable spot diameter.

Anatomic Considerations

Laser applications intranasally have found limited benefit over conventional techniques. Hemostasis is improved, but rapid bleeding still cannot be overcome. The depth of penetration of the laser to the contiguous areas still needs to be monitored with potential risk to intracranial and intraorbital structures. Treatment of such disorders such as hereditary hemorrhagic telangiectasia has certainly been benefited by selective photocoagulation of vasculature. Turbinate tissue reduction can be achieved and appears beneficial.³

Intraorally, tissue excision with concomitant hemostasis, particularly using the CO₂ laser has become a standard technique. Lessened intraoral pain is observed clinically, but as yet the mechanism is unexplained. The potential of sealing nerve endings with diminished neural transport is one such possibility.⁴ Although some surgeons use the laser for tonsillectomy and uvulopalato-
The benefits of laser-assisted microvascular anastomosis have been for laryngeal disorders. The debulking of large tumors potentially obstructing the airway, whether benign or malignant, is readily accomplished. Endolaryngeal resection of limited lesions whether supraglottic or glottic has been demonstrated by a number of surgeons. The adequate treatment, however, of large lesions (T2 or greater) has not been uniformly accepted and indeed may carry the risk of obviating a potential larynx preserving modality such as partial surgery or radiation therapy.

Inappropriate application of the laser for benign laryngeal processes, such as polyps or cysts, may induce submucosal scarring and permanent voice alteration. The precise utilization of laser energy in experienced hands can afford excellent results, but may add no benefit when compared to techniques using new microinstrumentation without the laser.

Obstructing tracheobronchial tumors have been palliated with fiber delivered wavelengths such as Nd:YAG. These procedures are designed not to be curative, but rather to open major pulmonary airways to prevent atelectasis and pneumonia and control hemorrhage.

In the esophagus, laser surgery has not been generally accepted because of the difficulty in maintaining a patent lumen and the high risk of complications such as mural perforation. Obstructing esophageal lesions localized to the straight segment of the esophagus (cervical and thoracic) can be treated by either antegrade or retrograde approach diminishing the degree of dysphagia, however, appropriate patient selection is mandatory.

Tissue Welding

When applied at powers well below one half of a watt (500 mW), the laser can induce tissue alterations leading to coaptation of vessels and nerves. This has been achieved with a number of wavelengths and appears to be a thermal rather than wavelength specific phenomenon. The mechanism of tissue welding has not been elucidated, but appears to be mediated through collagen modification. The annealing of vasculature is primarily a research tool having found little clinical application since current microsurgical techniques with suture have been firmly established. The potential of new devices that allow for increased rapidity and simplicity still remains. The benefits of laser-assisted microvascular anastomosis are diminished foreign body reaction and granuloma formation. For neural anastomosis the additional potential attribute of less neuroma production and more rapid healing still needs to be demonstrated.

New Devices and Instrumentation

Most lasers are microscope mounted and can be directed by micromanipulators. New quartz delivery fibers are currently manufactured that are less than 200 μm in diameter and can be used in conjunction with endoscopes. This technology has been applied to the nose, sinuses and larynx as well as the tracheo-bronchial tree and esophagus. Fibers have been used for interstitial laser coagulation (ILP) in a percutaneous technique in order to reduce or eliminate solid tumors. As the concepts for minimally invasive surgery become applicable to more disease processes, technology will be advanced so that laser energy can be more precisely applied to a number of anatomic sites. In order to achieve maximum safety and improved accuracy, simultaneous imaging offers exciting new potential. The use of ultrasound or magnetic resonance imaging (MRI) in conjunction with endoscopic or percutaneous laser delivery is currently being investigated. In order to be effective, imaging must not only be realistic but also generated in a real time mode. This is imperative, particularly for safe surgery to be performed in regions of vital structures such as the head and neck. The addition of a 3 dimensional rendition allows pre-operative planning and intraoperative multiplanar access. If tissue changes and volume can be observed while the procedure is being performed, then rapid and dynamic modification can be accomplished. If MRI is to be used, instrumentation compatible with the high magnetic field must be created. Endoscopes would either be rigid or flexible with delivery fibers and dispersion tips that will generate laser energy compatible with tumor volume and configuration. This may require either single fibers or an array of multiple fibers. Additional access to the operative site will be required to debride tissue and move laser plume, excess blood, or tissue by-products.

Currently the Nd:YAG laser has been the wavelength most frequently used for thermal necrosis of tumors. However, the ideal wavelength has as yet not been devised. The search for wavelengths and laser parameters best suited for a specific clinical need can now be investigated in a number of sites throughout the world where free electron lasers (FEL) are located. The free electron laser uses electrons as the energy source, being altered in wavelength through a magnetic "wiggler" to produce photons of uniform wavelength and parallelism. Unique to this research instrument is laser energy that can be varied from the ultraviolet through the near infrared wavelength with energy exposures that begin at the pico-second range and upwards as well as a high variability in power output. This expensive research tool will allow for studies that will lead to lasers that are most perfectly suited for a particular clinical application.

Photodynamic therapy (PDT) using a photosensitizer
preferentially incorporated into tumor cells with subsequent tumoricidal exposure of light absorbed by the chromophore has been used to only a limited extent for mucosal lesions of the head and neck.\textsuperscript{15} PDT in conjunction with interstitial laser energy delivery may offer a method to diminish tumor volume regardless of surface characteristics. New light sources and delivery systems may overcome current limitations of PDT.

The basis of PDT appears to be the sensitized photoxidation of biomolecules. New photosensitizers are being investigated that cause cellular destruction not only by photosensitization, but also can overcome hypoxic cellular radiation resistance, augmenting radiation effects and inducing chemotherapeutic cellular destruction. An example of such an agent is platinum chloride complexed with rhodamine-123.\textsuperscript{16}

**Conclusion**

Considering the short time span of laser research and acceptance in medical practice, the number of laser uses is truly impressive. Many areas of investigation will lead to further clinical trials. Not all of the applications to be studied will be improvements over current techniques. Physicians are cognizant that new technology can bring new understanding of the pathophysiology of disease as well as new modalities of therapy potentially quite dissimilar to those we currently accept as standard. Our current decade will bring many areas of laser research to the forefront of otolaryngology.

**References**