Paparella: Volume II: Otology and Neuro-Otology

Section 3: Diseases of the Ear

Part 1: General Problems

Chapter 19: Use of Lasers in Otology

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Historical Overview

The use of lasers in the temporal bone was the object of experiments as early as 1967 by Sataloff and 1972 by Stahl. Perkins (1980) reported short-term results on 11 cases of otosclerosis performed with the argon laser and DiBartolomeo (1980, 1982) reported on 10 cases; in all three of these reports, the techniques used and the postoperative findings were similar. Perkins (1980) reported overclosure of the airborne gap in nine of 11 patients, with no evidence of adverse effects related to the use of the laser. In 1983, McGee reported the use of the argon laser in surgery for chronic ear disease and otosclerosis. He reported excellent results with no complications related to the use of the laser. Palva (1987) reported on the use of argon energy to perforate the footplate in a comparative study of 126 patients. The results of the patients in the group who had laser surgery were slightly better than those patients in the group who had mechanical footplate perforation.

Several authors have published experimental animal studies using argon and CO_2 energy in oval window surgery (Coker et al, 1985, 1986; Thomas et al, 1986). They found that laser energy caused damage to structures of the inner ear related to thermal changes in the vestibule. These results do not support the excellent clinical experience reported in human subjects. The conflicting evidence is most likely related to species difference and the energy parameters used in the experimental animal work.

Choice of a Laser

At the present time, there are four lasers approved by the Federal Food and Drug Administration that are generally used in surgery. These include the argon, KTP-532, CO_2, and neodymium:yttrium-aluminum-garnet (Nd:YAG). In the broad field of electromagnetic radiation, the energy of these lasers falls both in the visible and invisible portion of the spectrum, with wavelengths that range between 514 and 10.600 nanometers (nm). The energy of the argon (488-514 nm) laser and the KTP-532 (532 nm) laser is within the visible spectrum. This fact allows the treatment beam and the aiming beam (whose energy is measured in milliwatts) to be one in the same and makes it possible to deliver the energy from its source to a microadapter attached to the microscope via a flexible fiberoptic strand. The energy of the CO_2 (10.600 nm) laser and the Nd:YAG (1060 nm) laser falls in the invisible spectrum. Because of this physical property, the CO_2 is derived from another source. In addition, CO_2 laser energy cannot be conducted through a fiberoptic strand; it is delivered from its source to the microscope by reflection of the energy via articulated arms containing prisms and mirrors.

Each laser produces tissue responses that differ depending on the physical properties of the energy applied. The Nd:YAG laser is not suitable for use in otologic surgery because its energy penetrates and destroys tissue too deep below the treated surface. The light energy of the argon laser, which is seen as a blue light, and that of the KTP-532 laser, which is seen as a blue-green light, is selectively absorbed by pigment, with red being the preferred color. The invisible energy of the CO_2 laser is absorbed by fluid. Thus, the tissue response to all three lasers is a surface phenomenon with minimal radiation penetration and energy scatter to deep structures. This fact makes all three instruments suitable for otologic surgery.

The argon and the KTP-532 lasers are preferred for otologic surgery because their energy delivery systems allow the surgeon free movement of the microscope without the encumbrance associated with articulated arms necessary to conduct the invisible energy of the CO_2 laser. It is important that the aiming beam and the treatment beam be identical in their axes, as it is with argon and KTP-532 energy, to avoid the inaccuracies inherent when relying on a coaxial aiming beam to determine the location of the tissue to be radiated. Small errors between the location of the aiming beam and the treatment beam can cause damage to sensitive structures when working in the middle ear.

Of the two lasers with energy in the visible spectrum, the author prefers the KTP-532 laser for several reasons. The source of the energy is stable, is generated by a reliable system, and produces six to seven times more usable energy at the tissue level that does the argon source. Because it is capable of generating more energy with greater versatility, the KTP-532 laser can be used as a multispecialty instrument in an institutional environment. A dedicated laser room is not necessary, since the laser is portable and does not require hard wiring and plumbing. If the laser is to be used only for routine tympanomastoid surgery, the power generated by the argon source is adequate. Both lasers can be adapted to hand-held instruments that will accept fiberoptic strands ranging in diameter from 200 to 600 microns.

Familiarization with the Laser

As with any surgical tool, the surgeon must be familiar with the instrument and become knowledgeable about its limitations and hazards. The microadapter adds an appendage to the microscope head that increases both its weight and operating distance. The objective lens must be increased to 250 millimeters to allow adequate space in which to pass instruments between the operative field and the microadapter. The surgeon should perform several surgeries without the laser turned on to "get the feel" of working with a microadapter attached to the microscope. One should then become familiar with the "joystick". This lever controls a reflecting mirror in the adapter which directs the energy to the tissue. The energy is activated by depressing a foot-switch controlled by the surgeon. Thus, hand, eye, and foot coordination is necessary to use the instrument. The skills are similar to those used in playing video games, and the learning curve improves with practice. When the laser is first used, the energy should be directed into a mastoid bowl, away from sensitive anatomy, at low power and short increments of exposure until the surgeon feels comfortable with the eye, hand and foot coordination skills required for attaining accuracy.

The KTP-532 laser has many built-in, fail-safe safety devices to prevent the laser from overheating and to protect the surgeon from retinal photocoagulation. The final electronic circuit that fires the laser is activated by a transparent, orange-colored shield contained in the microadapter, which slides across the surgeon's field of vision when the foot-switch is depressed. This shield absorbs all the light energy reflected through the microscope. The patient's eyes must be closed during the use of the laser, and personnel in the operating room should wear protective lenses. The glass surrounding the operating room should be appropriately shielded with pigmented glass to prevent passers-by from inadvertently being exposed to the light energy. To date, no patients or operating room personnel in proximity to the laser have suffered any ill effects from random scatter of energy.

Presurgical Preparation

When using the microadapter, a protocol for adjusting the optics of the microscope, focusing the aiming beam, and calibrating the laser should be established and followed prior to each day of surgery. The microscope lens system and the aiming beam must be focused at infinity. This is important, since it assures that the treatment beam's point of greatest energy density will be in the focal plane of the optics of the microscope regardless of the magnification used. Any tissue in focus in the operative field will receive maximum energy in that plane and not above or below that plane. This procedure takes place less than a minute and is done in the following manner:

1. Place the setting on the eyepiece at zero.

2. Focus the microscope at its highest magnification on a small dot on a flat piece of paper.

3. Activate the aiming beam and adjust its focus beside the dot until the edges of the beam are sharp. When in focus, the diameter of the aiming beam and thus the treatment beam, will be about 150 microns.

4. Without moving the microscope head, return the microscope to its lowest magnification.

5. The dot and the beam on the paper will now be out of focus. Adjust each eyepiece individually until the dot and the aiming beam are in sharp focus. The optics are now focused to infinity. The aiming beam and the tissue to be treated will be in focus at all magnifications.

It is necessary to correlate the energy generated in the laser with that being delivered to the tissue, since there is a decrease in energy as it traverses the fiberoptic strand leading to the microadapter. In the KTP-532 laser, this is done automatically with a calibrating pod. The aiming beam is directed into the pod and a switch is depressed that activates and calibrates the treatment beam. After calibration, an onboard computer then automatically calibrates the energy loss occurring during transmission along the fiberoptic strand and displays on the CRT screen the amount of energy being delivered to the tissue each time the power is changed. Calibration of the argon laser is similar, except that the energy delivered to the pod is manually read and recorded for each power change (McGee, 1983).

Surgical Uses of the Laser

The light energy of the laser is focused to a point of maximum energy density that generates precisely controlled heat energy. The power of the energy generated in watts per square centimeter, the duration of radiation, and the diameter of the spot of the laser beam determine how tissue will be altered. Depending on the parameters selected, the laser is a tool that can vaporize, cut, or coagulate tissues. Of these three functions, vaporization is the most useful.

Vaporization

Tissues containing pigment are ideal targets for lasers whose wavelengths are in the visible spectrum. The amount of energy necessary for vaporization depends on the size and the type of lesion, the color of its pigment, and the location of the pathologic lesion. In spite of these variables, guidelines for safe vaporization have been established. In chronic ear surgery, a spot size from 150 microns to 2 millimeters in diameter, delivering energy to the tissue in the order of 1.6 to 2 watts/cm^2 for time increments of 0.1 to 0.2 second are safe parameters to use. By varying these parameters, the laser will vaporize granulations, scar, pigmented cholesteatoma, and mucosal bands without causing trauma to surrounding tissue. If tissue is to be removed from the oval or round window, the spot size is adjusted to a diameter of 150 microns, the power is set at 1.4 to 1.6 watts/cm^2, and the time of radiation is reduced to 0.1 second. Repeated pulsing into the oval and round windows at 1-second intervals at these settings will cause no damage to adjacent structures.

Hand-held tools are used to debulk tumors utilizing fiberoptic strands of 500 to 600 microns in diameter at power settings of 2 to 5 watts/cm^2. These tools are used in the continuous time mode. The spot size and rate of vaporization can be regulated by varying the distance between the tip of the fiber and the tumor surface.

Cutting Tool

Incision of tissue with the laser is a form of vaporization. The parameters of power and time are increased, whereas the spot size is reduced to its minimum. As an example, when old mastoidectomies are revised, the surgeon frequently encounters dense scar tissue that cannot be incised with conventional sharp tools. To cut this tissue, the power should be increased to 4 to 6 wats per square centimeter, the radiation time is set on continuous mode, and the spot size is reduced to 150 microns. The beam can then be moved through the tissue, acting as a cutting tool that produces little or no bleeding. These parameters will vary depending on the density of the tissue.

The laser is also used to section the vestibular portion of the cranial nerve VIII with precision. A small segment of the nerve can actually be vaporized without traumatizing the adjacent auditory fibers. The power settings must be increased to 8 to 10 watts per square centimeter to cause vaporization, because the nerve tissue contains little pigment, thus absorbing more energy before charring occurs. The spot size should remain at 150 microns with a time increment of 0.1 second. When making skin incisions, the laser has no advantage over conventional sharp or thermal tools.

Coagulation

Microbleeding can be controlled with a laser when it is used as a tool for coagulation. A small suction, 26-gauge, is necessary to control the bleeding point while directing the laser beam at the bleeding vessel. Power is reduced to 0.5 to 1 watt per square centimeter, and the spot size is enlarged to 200 to 600 microns. The time of exposure is increased to 0.2 to 0.5 second. Energy used at these parameters should be sufficient to coagulate blood in the vessel lumen without causing vaporization of the vessel wall. This technique has been used safely to stop microbleeding on the facial nerve sheath during facial nerve decompression. The laser is not useful in controlling bleeding from large vessels, since too much pigment is present. The energy is absorbed by the massive amounts of pigment, and the bleeding point tends to "boil" rather than coagulate. For the same reason, the laser is not useful for vaporizing vascular masses such as glomus jugulare tumors.

The final procedure in tympanomastoid surgery after removal of cholesteatoma is to sweep the mastoid bowl with the laser beam to coagulate and destroy any vestige of microscopic squame that might remain. To do this, the spot size is defocused to measure 2 to 3 millimeters in diameter, radiation time is set on continuous mode, and the power is adjusted from 1.6 to 2 watts per square centimeters. The beam is slowly moved around the mastoid bowl, producing a brown to black char at the site of any residual tissue.

Surgical Example - Laser Stapedotomy

Under local anesthesia supplemented with intravenous medication, a tympanomeatal flap is turned in the conventional manner, and adequate exposure of the oval window is obtained. With the laser set at 1.4 to 1.6 treatment watts/cm^2, a time increment of 0.1 second and a spot size of 150 microns, the stapedial tendon is vaporized, followed by vaporization of the posterior crus. The fine bone char is removed with a small suction, and the incudostapedial joint is disarticulated. If the anterior crus is visible, it too is vaporized and the superstructure of the stapes is removed. A series of six to eight laser flashes are grouped in a circular pattern on the footplate, creating a fenestra slightly larger than 0.6 millimeter in diameter. The fine bone char is removed with a small oval window rasp and a 26-gauge suction. The fenestra can be created accurately without instrumentation, even when the footplate is floating. A piston 0.6 millimeter in diameter is inserted into the fenestra, secured tightly to the long process of the incus, and sealed with tissue or clotted blood. The incision is closed and the canal is packed in the usual manner.

At the time of this writing, the author has used the laser in over 3000 tympanomastoid surgical procedures, of which 500 were primary cases of clinical otosclerosis. During this time, there have been no complications related to the use of the laser. The laser is a safe tool to use in microsurgery. In addition, it is cost effective because it reduces the time of hospitalization following certain surgical procedures. As an example, small fenestra laser stapedotomy performed in patients with otosclerosis is done as an outpatient procedure. Outpatient surgery is possible because trauma, bleeding, and oval window instrumentation are minimal, thus reducing the incidence of incapacitating postoperative sequelae. Patients experience little or no vertigo and are fit to return home 1 to 2 hours after surgery.

Lasers do not replace hand-held instruments in otologic surgery. However, they add a dimension in instrumentation that reduces trauma, increases accuracy, and makes microsurgery easier to perform.

As experience and familiarity with laser instruments increases, situations in which the laser is selected as the tool of choice will increase. The adaptation of laser energy to surgery is a significant event in the evolution of microsurgery of the ear.