Laser Surgery Cures

By Howard Rausch

Laser technology is beginning to make many surgical procedures less painful for the patient and his pocketbook. But more important are prospects for treating conditions that cannot be dealt with effectively by other means.

The principal attraction for surgeons is the laser's exquisite precision. In fact there's a whole range of precisions available: spatial, temporal, power, and wavelength, not to mention precision of delivery through fiber-optic endoscopes.

Most laser precisions of interest to surgeons are based on the physical nature of photons. Unlike a stainless-steel scalpel, photons traverse media—such as body tissue—without any effect until they are absorbed. At that time the photons cease to exist, and the absorbing molecule dissipates the acquired energy in several ways: by re-emission of photons (fluorescence and phosphorescence), by chemical reactions or rearrangements (photochemistry), or by nonradiative de-excitation (heating).

Hence, laser wavelengths can be selected to confine their energy to substances that absorb at that specific "color." For example, outputs from certain laser dyes are absorbed by various pigments that can be made to fluoresce and thereby be tracked as they flow through the patient's body. Greater laser power can destroy such color-sensitive pigments and the malignant cells to which they selectively attach themselves.

In contrast, water absorbs a carbon dioxide laser's infrared output, acting as a heat sink to prevent radiation from proceeding farther than desired.

First surgical application

Precision isn't the laser's only appeal in the operating room, however. Another is the radiation's cautery effect that controls bleeding and sterilizes wounds. This property was the basis of the laser's first surgical application involving photo-coagulation; first in eyes, then in stomachs.

Here's a look at a few applications of these attractive properties.

Spatial control comes from the compactness of photon bundles, from the ability to focus them to even greater concentrations, and from their transmission through hair-thin fiber waveguides that can be microscopically controlled. Because of these capabilities, a laser beam can be focused on an area as small as a human cell—a thousandth of a millimeter in diameter—and vaporize the target. Adjacent healthy tissue is protected from injury, allowing rapid healing and minimal postoperative discomfort.

Such precision can be critical, for example in treating diabetic retinopathy, a disease common to diabetics. For a reason that is not well understood, the malignant process can be arrested by eliminating thousands of red cells in the outer portion of the retina—the sensitive, innermost layer of the eye on which light rays are focused. Conventional surgery would be very dangerous, because the cells of the inner retina lie only a quarter of a millimeter below those of the outer retina, and inadvertent damage to those inner-retina cells would cause irreparable blindness. The argon-ion laser can accurately focus on the outer-retina cells alone, and its blue-green beam is readily absorbed by those red cells.

Power and temporal control

Because the surgeon almost always begins with low power and short pulses before going on to higher power in continuous bursts of the laser, power and temporal control are especially important—particularly in gynecology. "We try to use the highest power densities that we can and still move the beam as fast as we can," says Louis Burke a faculty member at the Harvard Medical School.

The speed is to minimize lateral heating, which Burke calls "our biggest bugaboo as far as healing is concerned." Rapid movement of a high-power beam allows healing "without scarring as a general rule," he adds.

One candidate for laser surgery is precancer of the cervix. If detected at an early stage, such pre-cancers can be cured by conventional treatment. There are two problems, however: the usual treatment in many cases requires a long and expensive stay in the hospital, and it tends to cause severe incidental damage to the tissue just below the malignant cells, making it difficult—or impossible—for the cured patient later to engage in sexual intercourse or to give birth.

The carbon dioxide laser is gentler. It can remove the malignant material cell by cell, leaving the underlying tissue relatively unscathed. "There's no heat damage to the connective tissue," Burke says. "We do this by varying either the spot size, the time in which we allow the beam to be on the tissue, or the power that we are applying to that particular probe."

Burke cites another class of operation where the laser prevented unnecessary removal of healthy organs. The patient was a 21-year-old woman whose condition, if subjected to conventional surgery, would have resulted in removal of half of her vagina. Now, four years after treatment with a laser, she has a normal Pap smear and is able to have coital function without pain.

A similar laser technique is effective against herpes, he reports, but only if the lethal virus can be treated before the primary lesion breaks down into a proliferation of secondary lesions.

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Tumor photoradiation therapy involves lasers and the light-sensitive haematoporphyrin derivative (HPD). Generation of singlet oxygen ($O_2^*$) is believed to be the cell-destroying species. HPD is selectively retained by the tumor tissue, rather than "selectively bound" to tumors as suggested in the diagram from Michael W. Berns et al., University of California at Irvine and Bell Laboratories, in Lasers in Surgery and Medicine, Vol.2, No 3.

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Repair of a hardened artery. On the left is a scanning electron micrograph of a burn, with 10 joules of CO₂ laser energy, on the inner surface of a pig's aorta. Note the symmetrical vaporization. In the center is a light photomicrograph of a section where a 3-joule laser burn removed a lesion within the artery. Some charring is visible on the crater surface, but no damage to the deeper part of the wall is visible. On the right is the same tissue shown eight weeks after the laser surgery. The two "hills" alongside the top (inner) surface of the vessel are part of the lesion.

The middle (valley) of the section shows a completely healed burn with no evidence of new formation of plaque inside the artery. The animal was killed immediately after initial surgery, according to Ross G. Gerrity at the Cleveland Clinic.

Ninety-five percent cure rates

Small CO₂ lasers, already affordable for some gynecologists' offices, are achieving 95 percent cure rates on a form of cervical cancer that otherwise requires a hysterectomy. The laser can evaporate the lesion without anesthesia. "It requires no special treatment," Burke says. "Except for some minor cramping, or some complaints of heat at the end of the procedure, most patients just get off the table and go home." Healing is rapid, and the cost is about $700 instead of the usual $3,000 hospital bill.

At the Italian National Cancer Institute in Milan, more than 1,000 cases are treated each year in an outpatient procedure of CO₂ laser surgery that is integrated into the institute's routine activity. Costs are one-fourth to one-third those of comparable in-patient treatment.

Trend toward dye lasers

The importance of wavelength control was evident in the first known application of a laser to surgery in 1961. The ruby laser, the first type ever built, emits radiation at 0.694 micrometer. This output was the basis for iridectomy, producing a small hole to relieve pressure caused by glaucoma. The ruby laser has largely been replaced by the argon laser for this application, and there is now a trend toward dye lasers at even more desirable wavelengths.

In all, ophthalmologists use lasers to treat more than 40 eye problems.

Perhaps the most dramatic application of wavelength selectivity is the labeling of cancerous cells with a light-sensitive chemical as targets for destruction by laser. The chemical, haematoporphyrin derivative, seems to be retained preferentially by malignant cells. HPD fluoresces under the output of a krypton laser.

Under the influence of a suitably tuned red laser, however, HPD can be made to destroy a cell harboring it, apparently by transferring energy from the excited HPD to oxygen in the host cell. This transfer of energy upsets the electron structure of the oxygen atom, transforming the atom momentarily into a highly reactive singlet oxygen that attacks everything around it, chewing up the membrane of the cell.

At the Roswell Park Memorial Institute near Buffalo, Thomas Dougherty and colleagues, using this technique, have removed tumors from nearly 300 patients. Although they are careful to avoid claiming cures, their work is deemed sufficiently important to have earned the W. B. Mark Award Medal for 1983, the highest honor given by the American Society for Laser Medicine and Surgery (ASLMS). The HPD approach is being tried elsewhere in the United States as well as in Britain, Japan, and Australia.

Another application of wavelength selectivity is the removal of crimson birthmarks, called port-wine stains, caused by a network of capillaries just below the outer layer of skin. An argon laser beam passes through the skin without leaving a trace, sealing off the capillaries to block the flow of blood and to lighten the blemish.

Coronary arterial surgery

In cardiology, lasers promise to revolutionize coronary arterial surgery. At least half a dozen groups are studying the effects of radiation on coronary artery segments. One group, headed by Daniel S. J. Choy of New York and including Ivan P. Kaminow of Bell Laboratories, has completed four years of experimentation on human cadavers and in-vivo research with dogs and rabbits. The team now has applied to the Food and Drug Administration for permission to perform such laser surgery on living humans.

A slower, more deliberate approach is pursued at the Cleveland Clinic by Leonard Golding, a cardiac surgeon, and Ross G. Gerrity, a histologist. Their effort with animals receives support from the American Hospital Supply Corp. The lasers employed are developed at the Massachusetts Institute of Technology; the laser specialist on the project is Michael
### Lasers of Importance in Surgery

<table>
<thead>
<tr>
<th>Type of laser and wavelength</th>
<th>Power</th>
<th>Principal applications</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide 10.6 micrometers</td>
<td>to 500 W</td>
<td>Removal of tissue of any kind by excision, incision or vaporization</td>
<td>Precision when coupled with a microscope</td>
<td>High powers have not been transmittable through fibers (but this may be remedied by the time this article is published)</td>
</tr>
<tr>
<td>Argon-ion .488 and .514 micrometers</td>
<td>to 10 W</td>
<td>Coagulation; Repair of retinal detachment; Coagulative treatment of superficial lesions such as tattoos and portwine stains</td>
<td>Transmittable through quartz fibers; Absorbed by red</td>
<td>Energy is absorbed by blood from bleeding vessels</td>
</tr>
<tr>
<td>Neodymium-yag 1.06 micrometers</td>
<td>to 100 W</td>
<td>Coagulation of bleeding, chiefly in gastrointestinal tract</td>
<td>Transmittable through quartz fibers; Not absorbed readily by blood</td>
<td>Difficult to estimate and control depth of damage</td>
</tr>
<tr>
<td>Argon-laser-pumped dye Tunable near .631 micrometer</td>
<td>3-4 W</td>
<td>Photoactivation of HPD</td>
<td>Transmittable through fiber optics</td>
<td>Mechanical maintenance; system is sensitive</td>
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S. Feld, director of MIT's spectroscopy laboratory.

The laser—argon-ion in the case of Choy's group—has vaporized fatty deposits within arteries and has opened new circulatory channels in heart muscle. One goal is a gentle and less expensive alternative to arterial bypass surgery.

Transmission via fiber-optic waveguide is critical to many of these applications. It's these tiny fibers, rather than the lasers themselves, that are holding up the development of surgical applications. The principal shortcoming has been the lack of a fiber for transmitting high powers of the most widely used laser radiation: the CO₂ laser's infrared output. The fiber must be small, flexible, and nontoxic. Until very recently, no fiber met those standards.

Lately two candidates have emerged. One, developed by Terry Fuller at Sinai Hospital in Detroit and to be manufactured by a new company called Medlase, Inc., is reported capable of delivering 100-millijoule pulses of 15 watts continuous-wave through a waveguide 0.035 inch in diameter. This fiber had not been used on patients up to last spring at least. Fuller is expected to announce details of the fiber, and perhaps of experiments, next month at the ASLMS's fifth annual congress, October 7-9 in Detroit.

The second fiber for CO₂ output is larger, transmitting 100 watts, according to the manufacturer, Sumitomo Electric Industries Ltd. in Japan. But it is considered too large for endoscopic applications.

**Across the surgical spectrum**

A fiber-optic delivery system for infrared laser radiation would stimulate activity across the surgical spectrum. In addition to extending the applicability of the CO₂ laser, it would expand the possibility of fulfilling the dream of having a variety of laser wavelengths available in small, flexible delivery tubes.

Such capability would be especially welcome among neurosurgeons. The brain and central nervous system, where these surgeons work, aren't like the rest of the human body. If cardiologists and urologists are the plumbers of the body, the neurologist is the electrician.

Unlike the skin, the brain doesn't heal; an error or a complication here is serious, permanent, and often fatal. Unlike the eye, the nervous system is not translucent to many visible wavelengths. Unlike the abdomen, the brain doesn't take kindly to someone exploring and moving things around to try to get at the affected area. Unlike almost any other organ, it does not tolerate much bleeding, because the...
ensuing pressure in the confined cranium can cause a major stroke or direct death. “Any tumor can be removed,” declares Robert Martuza, a neurosurgeon at the Massachusetts General Hospital in Boston. “The real question is whether you can leave the important stuff behind.”

Martuza appreciates the various capabilities that lasers offer, from the deep destruction with predictable effects and more complete hemostasis (stopping of bleeding) associated with neodymium-yag, to the shallower, more carefully controllable penetration of CO₂ laser output, to red blood cells’ affinity for absorbing argon-ion laser output. But Martuza objects to having to choose. “We have no single laser that will allow us to cut, to vaporize, and then to coagulate,” he notes. “We need a laser that has several of those capabilities built within it. It’s just a matter of marrying the various technologies.”

Until such a wedding takes place, a cohabitation arrangement may have to do, similar to one at the University of Turin’s Institute of Neurosurgery in Italy. Three lasers — CO₂, Nd-yag, and argon — are used in sequence for selective irradiation. Vistor Aldo Fasano predicts increased use of this laser troika because it can produce a large lesion and complete hemostasis, and requires a short time for surgery. No single laser can match these capabilities.

The danger of lasers

Less widely known than the laser’s dramatic successes in surgery are the dangers associated with it. In throat surgery, a common application of lasers, the operating room looks quite different from most surgical sites. The operating team all wear protective glasses. Because of the patient’s facial proximity to radiation, his eyes are covered with a plastic shield over wet eye pads. His face is covered with sopping wet towels. Instruments are coated with ebony to prevent reflection of the beam.

Combustibles must be kept moist with salt water, warns William Montgomery at the Massachusetts Eye and Ear Infirmary. Because the most common accident in throat surgery is explosion of endotracheal tubes into the windpipe under irradiation, the tubes must be taped with aluminum foil or made of reflective metal to keep the radiation away from the gas. “We also must have a beam aimed correctly at the onset to prevent hitting the laryngoscope and causing accidental burns to the patient’s face if the towels should happen to slip,” Montgomery adds.

The publicity about successes with lasers has created a steam of applications that seem questionable or worse. Ellet H. Drake, secretary of the ASLMS, cites a probably ineffectual treatment by biostimulation with a low-power laser. For facelifting, the laser — usually a helium-neon — irritates the tissue and causes swelling, which obliterates wrinkles for as long as the swelling persists. More ingenious is the practitioner who eliminates the laser and achieves a similar result by simply slapping people’s faces.

Drake concedes that biostimulation could achieve worthwhile results in some applications. But he says he hasn’t seen any yet.

New Societies Launched

With the promise of profound impact on surgical practice and economics, it was inevitable that a professional society should emerge and that a couple more should follow.

Founded four years ago, the American Society for Laser Medicine and Surgery now has more than 300 members in every state and in 11 foreign countries, according to the secretary, Ellet H. Drake, a cardiologist at Cincinnati Jewish Hospital. The society has a journal, Lasers in Surgery and Medicine, and a newsletter, Laser Medicine & Surgery News.

More specialized are two other organizations: the International Society for Laser Surgery and the Gynecological Laser Society.