the articulations that are most widely adapted to arthroscopic procedures, but smaller joints such as the ankle, elbow, wrist, and temporomandibular joint are under investigation from the standpoint of feasibility. The small size of the laser fibers available make this type of surgery almost ideal for lasers and would seem to offer the best application of lasers in intra-articular joint surgery.

SPINAL SURGERY

Spinal surgery with lasers is being done more frequently. The percutaneous insertion of the laser fiber through a relatively small needle into a disc space is now a fairly widely used technique. Neodymium YAG, holmium YAG, and KTP lasers are recognized devices for this application. However, the procedures are done blindly under x-ray control. The limitation of the procedure is that the location of the tip of the needle can only be inferred by judging its position on the fluoroscopic screen. Future applications of this methodology would include small deflectable endoscopes that could be inserted percutaneously into the disc through which the laser fibers would be introduced. Once the laser fiber had been protruded from the flexible catheter in the disc space, it would have to be strong enough to tolerate some physical stress, as the fibers deflected within the disc against dense rubbery discal tissue. In addition, the surgeon's visualization of the working surface through the deflectable endoscopic might be imperfect and there should be some fail-safe technique, such as reading of the fluoroscopic reflectance from the tissues being ablated. Excimer laser technology would be helpful and appropriate in this application so that the laser energy would only be deployed against disc material and not nerve root or spinal cord. At present, lasers are used almost exclusively in the lumbar spine because of these safety concerns. If the procedures could be made fail-safe, it would be possible to use lasers more aggressively in the cervical or thoracic spine, as well.

JOINT REVISIONS

Lasers are currently used by some surgeons for the removal of polymethylmethacrylate bone cement during total joint revisions. With the ongoing development of total joint replacement technology, there may be fewer and fewer patients requiring revision surgery. Nevertheless, development of a high powered laser to remove bone cement from deep within the canal of a femur or tibia would facilitate this type of surgery, when required. Until now, the laser has been used primarily through a laparoscope in this application, but the technology is imperfect and could be improved upon with the development of more specific instrumentation.

In the future, lasers might be extremely useful in performing primary total joint replacements if the lasers could be used to perform osteotomies. At present, none of the lasers available are sufficiently powerful to cut bone and there is an almost universal dependence on mechanical devices for this application. In total joint replacements, it is necessary to achieve as precise a fit as possible between the prosthetic implant and the bone in which the device is being inserted. Mechanical devices are being improved constantly and reamers are being programmed to make it possible to carry out this part of the procedure robotically. Lasers should be easier to adapt to this application and, if a laser can be made that would ablate to or cut bone quickly and effectively, there might be an extremely broad application for lasers in this area.

TISSUE WELDING

Tissue welding in orthopedics is in its earliest experimental stages. While it is convenient for some surgeons to use this technology in the welding of skin, blood vessels, and small nerves, the dense rubbery tissues encountered in orthopedics are more resistant to the diffuse heating necessary to permit the tissues to flow together. The development of laser energy absorbing dyes to be used in solders would be of potential benefit in this regard. Similarly, hemodynamic therapy has not been considered in the treatment of musculoskeletal tumors.

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Lasers in Gynecology

BY DAVID S. MCLAUGHLIN

During the past decade, lasers have had a dramatic positive impact on the treatment of diseases in women. The precise application of intense light energy of varying wavelengths may be clinically used to safely destroy only diseased tissue areas, while maximizing preservation of the normal reproductive tract. The result is often less scarring and post-operative pain during a shortened recuperative time.

The inherent advantages to the gynecologist include:

- *Precision*—To destroy only abnormal tissue while preserving the lower and upper reproductive tract (vulva, vagina,

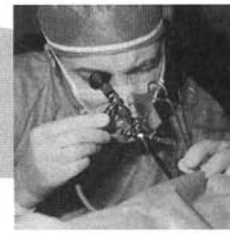

FIGURE 1. LARGE UTERINE FIBROID CAUSES ABDOMINAL SWELLING.

cervix, uterus, tubes, and/or ovaries).

■ *Less blood loss*—Small blood vessels are sealed, reducing the chance of excessive bleeding that might require a transfusion.

■ *Reduced risk of infection*—The sterilizing heat reduces the risk of bacterial, fungal, and/or viral colonization and growth.

■ *Accessibility*—Improved ability to reach previously inaccessible areas by reflecting the focused laser beam with mirrors.

■ *Less scarring*—Following judicious use of lasers at the proper power densities by the experienced gynecologist.

Current uses of lasers in gynecology may be divided into lower and upper reproductive tract:

Lower Tract—(vulva, vagina, cervix)

A recent increase in diseases associated with Human Papilloma Virus (HPV), including condyloma (venereal warts) and cervical dysplasia (often a precursor to cervical cancer), are being more successfully treated with the laser. The CO_2 laser is primarily used in conjunction with an operating microscope (colposcope), although some physicians use the Nd:YAG laser with sapphire tips.

Upper Tract—(uterus, tubes, ovaries)

The uses of the laser may be further subdivided by application of the laser energy through an open incision (laparotomy) or microlaser surgery, (if a microscope is used), or an endoscope (laparoscope for intra-abdominal use, or hysteroscope for intrauterine use):

■ *Microlaser Surgery*—Using the laser through an incision is helpful to remove large benign uterine tumors (fibroids), as shown in Figure 1, or ovarian cysts without the need for removing the entire organ. This treatment preserves the option to conceive, often by using the CO_2 laser.

■ *Laparoscopic Surgery*—A rigid telescope is placed beneath the navel to view and treat pelvic pathology (such as smaller fibroids, shown in Figure 2) with the aid of the laser (CO_2, argon, KTP, and/or Nd:YAG with contact or sapphire tips). Endometriosis (displaced glandular lining outside the uterus), which may cause pain or infertility, can be safely destroyed. If diagnosed early, tubal pregnancies may be removed without removing the entire tube.

■ *Hysteroscopic Surgery*—A smaller rigid telescope is placed through the vagina and cervix to remove fibroids or vaporize endometrium with the aid of the Nd:YAG laser and/or an electrocautery loop. This outpatient procedure helps to successfully treat women who have excessive uterine bleeding, without requiring hysterectomy.

Lasers Now Used in Gynecology

1. *CO_2*—The most powerful in removing larger tissue masses. The delivery system, with a series of articulated joints and mirrors, is difficult to keep aligned with the beam in focus.
2. *Argon*—The least powerful fiber laser, preferentially absorbed by hemoglobin and endometriosis tissue. This laser is often used in conjunction with the laparoscope.
3. *KTP*—Similar to the argon in its current uses and abilities.
4. *Nd:YAG*—Most powerful fiber laser with tissue effects determined by the delivery system (naked fiber, sapphire tips, drawn-contact fibers).

The current factors limiting the increased use of lasers in gynecology are:

■ Smaller hospitals with declining revenue or larger hospitals that have over-expanded and are now faced with discounted reimbursement by third-party payors are finding it difficult to consider capital expenditures of such magnitude.

■ Cumbersome, heavy lasers with a multitude of wires and tubes with non-standard connections between laser manufacturers make it difficult for medical personnel to set the new technology into the operating room easily and efficiently. Fiber delivery systems made lasers more user-friendly.

FIGURE 2. LAPAROSCOPIC VIEW OF UTERINE FIBROIDS

■ The inability of some physicians to embrace new technology due to unyielding, conservative views or poor eye-hand coordination.

Patients' acceptance of laser treatment has been overwhelmingly good, occasionally with expectations exceeding reality due to publicity in the lay press. Future directions may include advances in photo-dynamic therapy (PDT) with chemically-sensitive cells (such as endometrial glands lining the uterus or outside the uterus—endometriosis) destroyed by the light laser activating the toxin in the previously sensitized cells, thus alleviating pelvic pain and/or uterine bleeding. Another fascinating potential application may be the use of lasers in IVF, (in vitro fertilization) to enhance fertilization and embryo growth by zona drilling (placing a small hole in the outer layer of the egg).

The definite trend is to help treat women's diseases in a more conservative manner, by preserving the reproductive organs and shortening the recuperation time.

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Photodynamic Therapy: Its Role in Cancer Therapy

BY T.J. DOUGHERTY

By now, the fundamentals of photodynamic therapy (PDT) are well known. A photosensitizer is injected intravenously into a patient who has a solid tumor of known location and, following localization of the sensitizer into the lesion, local photoactivation by an appropriate light source is carried out. Assuming that an effective combination of drug and light are used, the tumor can be reduced or, in many cases, completely eradicated, depending on size and location. Most phase II clinical trials are aimed at determining the appropriate drug-light combinations to achieve this with acceptable normal tissue damage. With Photofrin® as photosensitizer, these values range from an injected dose of 2.0 mg/kg and delivered light doses of 100-200 Joules/linear cm of diffuser at 630 nm (*e.g.*, an endobronchial lesion) to 2.0 mg/kg and 15 Joules/cm^2 for whole bladder treatment of carcinoma-*in-situ*. Skin lesions (*e.g.*, basal cell carcinoma and metastatic breast cancer on the chest wall) appear to respond best to 0.75-1.0 mg/kg Photofrin and 180-220 Joules/cm^2 of 630 nm light.

In earlier studies, most patients were treated by PDT only after extensive traditional treatments, and most had advanced disease. However, for those patients who were treated by PDT before the disease was out of control, even though extensively pre-treated by other modalities, PDT was found to be curative or at least offered long-term tumor control.[1] Some patients with early stage endobronchial cancers who were not amenable to other treatments have survived nearly 10 years following PDT alone.[2] Recent reviews have covered the extensive phase I and phase II clinical trials on several thousand patients receiving PDT for cancers of the bladder, lung, head and neck, genital tract, esophagus, stomach, brain, eye, and skin.[3] Newer phase I/II protocols involve PDT as adjunct to surgery in tumors of the peritoneum (pancreatic and ovarian studding—T. DeLaney and H. Pass, NIH), intrapleural treatment following resection of mesothelimoma (T. DeLaney and H. Pass, NIH; H. Takita, Roswell Park), treatment of refractory basal cell carcinoma (B. Wilson and T. Mang, Roswell Park), and treatment of AIDS-related Kaposi's Sarcoma (Z. Bernstein, T. Dougherty, and T. Mang, Roswell Park).

PDT with Photofrin is currently undergoing extensive trials for regulatory approval in the U.S., Canada, Europe, and Japan. Emphasis is on comparative trials in bladder, esophagus, and lung. However, in Japan, certain trials for early stage stomach and gynecological tumors are also underway. Regulatory approval is expected over the next one to three years. While some have noted that PDT has been around for a long time and question why regulatory approval is taking so long, it must be kept in mind that drug approval in the U.S. can cost over $100 million and takes an average 10-12 years from inception. The first properly designed phase III clinical trials in PDT were initiated only in late 1988 by Quadra Logic Technologies (QLT) of Vancouver, British Columbia, in collaboration with American Cyanamid/Lederle Laboratories of Pearl River, N.Y.

TREATMENT EXAMPLE

An example of the treatment method for an endobronchial tumor by PDT is as follows. The patient is injected intravenously with Photofrin at a dose of 2.0 mg/kg. No pharmacological effects of the photosensitizer occur except for enhanced cutaneous photosensitivity generally lasting four to six weeks (exceptions to several months have been noted in a few cases)