Conferences and Reviews

Endoscopic Laser Therapy in Gastroenterology

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Endoscopic laser therapy has become an important and widely used tool in gastroenterology. It has become important for outpatient palliative therapy for ablating obstructing gastrointestinal neoplasms. This method has often circumvented the need for major palliative surgical resections. Caution must be applied to laser therapy for potentially curable malignant neoplasms because, with vaporization of the target tissue, no tissue specimen is available to assure that local or invasive residual carcinoma is excluded. Therefore, in good surgical candidates, surgical resection of potentially curable cancers is always recommended. In the future, however, the combination of refined endoscopic ultrasonography and laser fluorescence techniques may lead to earlier detection, more precise localization, and even curative ablation of gastrointestinal malignancy.

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Over the past ten years, the use of endoscopic laser in clinical gastroenterology has flourished.* In 1981 there were 12 laser units in the United States. Now more than 300 medical centers provide endoscopic laser therapy.[1] It is therefore timely to review the clinical developments in this field. Although laser therapy is used in many different areas of medicine and surgery, we will discuss its use only in gastroenterology.

Historical Considerations

Einstein's theory of relativity laid the theoretic groundwork for Maiman's development of laser technology in 1960.[2] As early as 1963, several investigators had already explored the possibility of using the laser to treat gastrointestinal neoplasia.[3-6] The application of laser to clinical gastroenterology was not practical, however, until Nath and co-workers developed a thin, flexible quartz wave guide or probe in 1973. This probe can conduct the laser beam through the biopsy channel of a conventional endoscope, providing multiple diagnostic and therapeutic uses.[7] Soon thereafter, Frühmorgen, Dwyer and associates published their results with argon laser-induced hemostasis of hemorrhagic gastritis and gastric ulcers in humans.[8,9] Endoscopic laser therapy has since been successfully applied to many gastrointestinal disease processes.

Basic Principles

When an atom is exposed to a sufficient amount of external electromagnetic energy, the electrons of that atom are excited to a higher energy state. With return of the electrons to their initial resting state, energy is released in the form of photons. The released photons then randomly collide with neighboring atoms, resulting in electron excitation that will release additional photons of the same wavelength. This stimulated emission of photons produces laser light. The continuously emitted photons can be directed and amplified by a set of two mirrors producing a laser beam; thus the acronym LASER, from *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation. Unlike sunlight, the beam of light is monochromatic (composed of one wavelength), extremely intense, and easily focused. When absorbed by biologic tissue, the laser energy becomes thermal energy, and, if sufficient temperatures are reached, tissue damage occurs.[10,11]

There are a variety of commercially available lasers. Their names reflect the mediums used to emit photons. The Nd-YAG—neodymium-yttrium-aluminum-garnet—laser, the dye laser, and the argon or carbon dioxide laser use solid, liquid, and gas mediums, respectively. Each laser medium produces a laser beam with a unique wavelength resulting in different absorption properties and tissue effects.[10,11] For example, the argon laser's wavelength is well absorbed by hemoglobin, usually resulting in a 1- to 2-mm depth of tissue penetration. It is therefore useful for photocoagulating superficial blood vessels. The Nd-YAG laser, in contrast, is poorly absorbed by hemoglobin and water but well absorbed by tissue protein, thus making it a better choice for both photocoagulation of deeper vessels and tumor ablation (Tables 1 and 2).[12,13]

TABLE 1.—*Commonly Used Commercially Available Lasers*

Type of Laser	*Usual Wavelength, microns*	*Depth of Tissue Penetration, mm*	*Able to Use in Flexible Endoscope*	*Visible to Human Eye*
Argon	0.51	1-2	Yes	Yes
CO_2	10.60	1	No*	No
Dye	0.54	0†	Yes	Yes
Nd-YAG	1.06	<4	Yes	No

Nd-YAG = neodymium-yttrium aluminum garnet

*A flexible probe that can be used in an endoscope is now available in Japan but not yet in the United States.
†The dye laser has a photoacoustic effect rather than thermally destroying tissue.

Endoscopic Laser Techniques

Most currently used laser endoprobes require a noncontact technique in which the probe tip and the lesion are sepa-

*See also "You Light Up My Life . . . and Liver—Gastroenterologic Laser Therapy in the 1990s" by R. A. Kozarek, MD, on pages 83-84 of this issue.

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rated by approximately 1 cm and the probe tip is aimed as directly or *en face* as possible for maximum effect. The noncontact approach prevents tissue contact with the probe tip that could result in tip heating and damage to the probe. A continuous flow of gas is also delivered coaxially through the probe tip to further prevent tissue adherence and to cool the probe tip. Newer commercially available laser probes, such as the contact endoprobe with a sapphire tip, have been designed for a direct contact approach.[14] This technique can be used with more tangentially located lesions that are not as readily accessible to the en face endoscopic approach of the noncontact laser technique.

TABLE 2.—*Relationship Between Temperature and Tissue Effects in Laser Therapy**

Critical Temperature, °C	*Histologic Event*	*Endoscopic Appearance*
45	Cell death, edema, endothelial damage, vasodilation	Erythema, edema cuff
60	Protein coagulates	Tissue turns white, blood turns black
80	Denatured collagen contracts, blood vessels constrict	Tissue puckers
100	Tissue water boils	Vaporization causes a divot
210+	Dehydrated tissue burns	Blackened tissue disappears or glowing embers appear

*Adapted from Waye et al.13

TABLE 3.—*Clinical Applications of Endoscopic Laser Therapy in Gastroenterology*

Application	*Procedure Setting*	*Usual Laser Type*
Tumor ablation		
Esophageal cancer	Outpatient	Nd-YAG
Gastric cancer	Outpatient	Nd-YAG
Colorectal cancer	Outpatient	Nd-YAG
Photodynamic therapy	Inpatient	Argon dye laser
Hemostasis		
Bleeding ulcers	Inpatient	Nd-YAG or argon
Angiomas	Outpatient	Nd-YAG or argon
Radiation proctitis	Outpatient	Nd-YAG or argon
Biliary diseases		
Bile duct stones	Inpatient	Dye laser
Miscellaneous		
Pseudocyst drainage	Inpatient	Nd-YAG
Stricture	Outpatient	Nd-YAG

Nd-YAG = neodymium-yttrium aluminum garnet

Clinical Applications

Endoscopic laser therapy has many therapeutic applications. The clinical problem and desired effects determine the type of laser used. Most treatments are safely done on an outpatient basis without much more discomfort than with routine endoscopies (Table 3).

Tumor Ablation

Endoscopic laser treatment is useful for the palliative treatment of incurable gastrointestinal malignancy and in those patients who are poor surgical candidates. Laser therapy has also been successfully used to remove large benign gastrointestinal neoplasms with high malignant potential.[15,16] Its use, however, as a primary curative therapy for early localized malignant neoplasms is still under investigation.[17,18]

Esophageal carcinoma. In the United States, patients who present with esophageal cancer are generally incurable with all conventional therapies. Therapeutic goals are the relief of obstruction and bleeding. Since Fleischer and Kessler first used the laser endoscopically to treat esophageal carcinoma in 1982, laser ablation has become a major tool for tumor palliation.[19]

Laser therapy can usually be done on an outpatient basis. Preparation is the same as for an upper endoscopy. As with other endoscopic procedures, patient comfort is maintained with intravenous sedation and topical pharyngeal anesthesia.

Laser treatment is preferentially performed in the distal to proximal direction to maximize visualization and minimize the risk of perforation. Thus, a strictured esophageal lumen must be wide enough to accept the endoscope. If luminal stenosis does not allow free passage of the endoscope, mechanical dilation of the narrowed area is required before successful laser treatment. The laser probe is then inserted through the biopsy channel of the endoscope and aimed at the malignant tissue under direct visualization. The laser coagulates and vaporizes the obstructing tissue, creating a wider lumen (Figure 1).

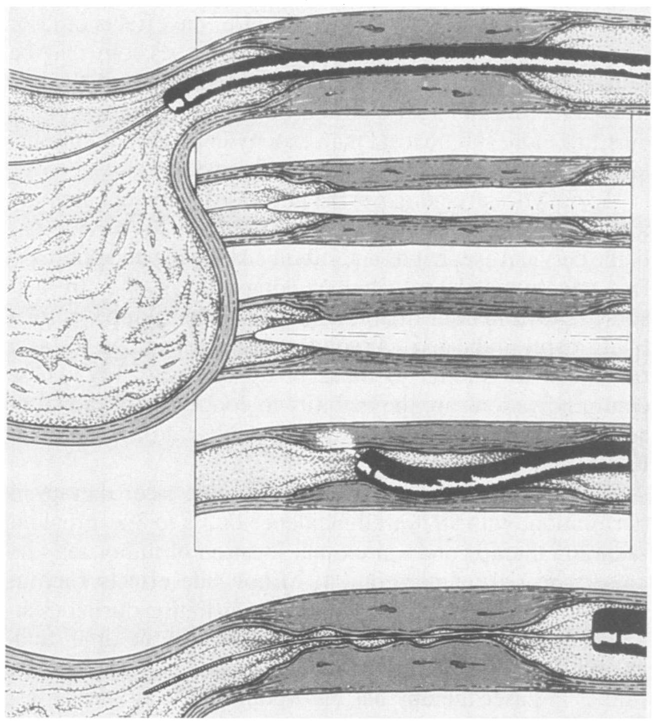

Figure 1.—The tumor shown is partially occluding the esophageal lumen. Although the endoscope can pass through the strictured area, it cannot be maneuvered effectively to allow for laser treatment of the tumor mass. With mechanical dilation **(inset)**, the endoscope with laser probe can now be used to fulgurate the tumor in a distal to proximal direction (from Waye et al[13]).

Contact endoprobes, noncontact endoprobes, and even nude fibers (laser fibers whose distal ends are progressively destroyed as they are used) have been used successfully to ablate esophageal tumors. Contact coagulation can be useful in a very stenotic or completely occluded lumen in which target tissues cannot be approached en face with the endoscope.[20(p143)] A small prospective study comparing the efficacy of contact with noncontact Nd-YAG laser therapy found no difference between the two methods in the number of treatment sessions required, the relief of dysphagia, or the occurrence of complications. The esophageal lumens of both groups were relatively patent, however, so an advantage may not have been elicited.[14] Further study of the potential benefits of the contact endoprobe technique is needed.

The number of sessions required to provide adequate palliation depends on the severity of the stenosis. Although there are proponents of only a single session of treatment, generally two or three sessions, each session scheduled every two to three days, are required.[21]

More than 90% of patients who are treated with laser therapy have a marked abatement of dysphagia. Although the result is best in those patients with tumors that are less than 5 cm long and located in straight segments of the mid and distal esophagus,[22] technical success in achieving luminal patency does not always correlate directly with the patient's overall clinical state. Because of refractory dysphagia, odynophagia, and anorexia, 10% of these patients will be unable to maintain their weight.[22-24] Furthermore, the effects of laser therapy may be short-lived, and follow-up sessions may be required. These sessions may consist of additional laser treatments, mechanical dilation, or both.[24] If the tumor recurs in a more submucosal than exophytic pattern, additional laser therapy is increasingly less effective.[25]

Exophytic carcinomas of the mid and distal esophagus are ideally suited to laser ablation. Laser therapy for carcinomas of the cervical esophagus and submucosally located tumors is less effective and has a higher complication rate. In fact, some think that laser treatment of these latter tumors is relatively contraindicated. Absolute contraindications to laser treatment are similar to those of upper endoscopy. These contraindications are the inability to cooperate, a known or suspected perforated viscus, and unstable cardiac or pulmonary conditions.[22,26]

The major complication of endoscopic laser therapy is perforation, with an overall incidence of 5% to 8%. Previous radiation therapy and a proximal location of tumor may increase the risk of perforation. Minor side effects such as abdominal distension caused by air insufflation during treatments and transient chest pain occur 10% of the time. Substantial bleeding, sepsis, and systemic side effects are rare.[27-29] Laser therapy has an overall mortality rate of less than 1%.[22-24,26]

Other accepted palliative treatments of esophageal cancer include the endoscopic placement of endoprostheses, surgical resection, and radiation and chemotherapy. Comparisons of laser treatment with intraesophageal prostheses suggest that both methods are equally effective in lessening dysphagia in the straight segments of the esophagus. The prosthesis is slightly better at resolving dysphagia when the tumor is located at the gastroesophageal junction.[30] Endoprosthesis placement across the gastroesophageal junction, however, is associated with significant reflux complications.[31] Because endoscopic treatment of the upper esophagus is technically difficult, neither laser treatment nor prostheses are particularly effective at providing symptom relief for obstructive tumors in the cervical esophagus.

Although prostheses have greater procedure-related morbidity than laser treatment, there is no significant difference in procedure-related mortality and overall survival. Complications of endoprosthesis placement include tube migration, blockage, pressure necrosis, erosion into adjacent structures, and death.[24-26,31,32]

Both laser treatment and surgical resection of incurable esophageal carcinoma result in equally favorable symptomatic relief. Surgical treatment is associated with a substantially higher perioperative death rate, ranging from 10% to 30%.[27] Endoscopic laser therapy has a less than 1% mortality and offers the additional advantage of an outpatient setting.[31] Despite successful laser treatment requiring multiple endoscopic sessions, its overall cost is still much less than the cost of a palliative operation.[26]

There are no studies that compare the efficacy of laser therapy with that of radiation and chemotherapy. Laser therapy, however, may have more immediate results, may require fewer treatment sessions and hospital visits, and is probably less expensive. The morbidity and mortality of radiation therapy and laser therapy are probably comparable.[26] There are no effective chemotherapeutic regimens for adenocarcinoma of the esophagus, but several drug regimens have produced partial and complete responses in patients with squamous cell esophageal cancer.[33(p859)]

In conclusion, laser therapy for the relief of malignant esophageal obstruction is as effective as surgical therapy and endoprosthesis placement. Laser therapy has low procedure-associated morbidity and mortality compared with these other methods. There is no evidence that any therapy prolongs survival.

Gastric carcinoma. Endoscopic laser therapy is used primarily as a palliative treatment to relieve obstruction and to prevent recurrent bleeding in patients with gastric cancer. Most gastric carcinomas that are amenable to laser therapy are located near the gastroesophageal junction and present with obstructive symptoms. One to three sessions of endoscopic laser therapy may lead to notable symptomatic improvement.[28]

Contraindications to and complications of laser therapy for gastric cancer are similar to those previously described for esophageal cancer. Although direct comparisons are not available, laser therapy is probably less expensive and has less morbidity than palliative surgery.[28,34]

Japanese investigators are studying the use of endoscopic laser therapy for the curative treatment of localized mucosal gastric carcinoma. They have reported 74% to 85% five-year survival in a highly selected group of patients treated with the laser alone.[17,18,35] These results are similar to those of conventional surgical therapy, although comparative trials are lacking.

Colorectal carcinoma. Laser therapy for colorectal cancer provides relief of obstruction and bleeding in patients who are poor surgical candidates.[36-38] Although treatment is traditionally reserved for patients with rectal cancer because of easy endoscopic access and its purported safety, the treatment of more proximal lesions is now being reported.[39,40]

About two to five outpatient sessions are required to create a lumen large enough to allow the passage of feces and gas. To maintain luminal patency, follow-up sessions are usually required every four to eight weeks. Despite successful laser treatment requiring multiple endoscopic sessions, the overall cost is considerably less than that of surgical palliation.[41]

Complications of rectal laser therapy include perirectal abscess formation, anal stenosis, with incidences of 2% to 3% and 2% to 5%, respectively, and perforation. Rectal perforation is usually contained in the perirectal space and can often be managed with intravenous antibiotic therapy and bowel rest. Perforations in the more proximal colon (above the peritoneal reflection) result in soilage of the free peritoneal space and often require surgical intervention. Overall reported colorectal perforation rates range from 3% to 10%. The mortality of colorectal laser therapy is less than 1%.[39,42]

In addition to palliative treatment of colorectal cancer, the Nd-YAG laser has been used to vaporize large, sessile, benign polyps, which have a high malignant potential and are technically difficult to remove with endoscopic polypectomy techniques. A recent study showed a negligible incidence of malignant occurrence and no difference in life expectancy with laser treatment of these lesions as compared with surgical resection.[15] An equally large study, however, demonstrated a significant incidence of malignant occurrence in those patients who underwent endoscopic laser treatment alone.[36] Currently, polyps not amenable to endoscopic polypectomy should be surgically resected in all suitable surgical candidates.

In summary, laser therapy is particularly useful in recanalizing obstructive malignant rectal and colonic lesions and in removing large sessile polyps in poor surgical candidates. Patients with a reasonable surgical risk, however, should have their carcinomas or large polyps removed surgically. Possible advances in endoscopic ultrasonography may eventually determine if residual neoplastic tissue is present after laser treatment, thus providing a potentially curative role for laser therapy alone.

Photodynamic therapy. Although still experimental and in its infancy, laser photodynamic therapy has been used to treat thousands of patients with various types of cancer.[43] The basic principles and techniques of photodynamic therapy are simple. An exogenous photosensitizer, which is administered intravenously, is selectively retained by malignant target tissues. A laser with a specific wavelength is then applied to the sensitized tumor tissue by a diffuser fiber that distributes the beam over a wide surface area.[44] With exposure to the laser light, intracellular photochemical reactions are initiated, resulting in fluorescence of and damage to (including cell lysis) the sensitized tissues. The theoretic result of this therapy is the selective destruction of malignant tissue with sparing of the surrounding normal tissue. Current clinical protocols use hematoporphyrin derivatives as photosensitizing agents and the argon dye laser as the source of the laser light.[43]

Although photodynamic therapy is an increasingly popular technique for skin, bronchial, and bladder carcinomas, its use in gastrointestinal malignancy has been limited. The Japanese with their aggressive esophagogastric carcinoma screening program have applied these techniques to the treatment of superficial localized tumors. Some endoscopists are using a contact probe that buries the laser fiber in the mucosa to increase treatment effectiveness.[17] Their success rates in these small case series vary, with cure rates of 0% to 80%.[45,46]

Photodynamic therapy has also been used as a palliative treatment of patients with obstructing esophagogastric and colonic tumors. The obstruction can be relieved in 50% to 100% of cases, but no direct comparisons with standard laser ablation therapy are currently available.[29,47,48]

The most common complication of photodynamic therapy with hematoporphyrin derivatives is skin photosensitivity that resembles the skin manifestations of porphyria. Patients may need to avoid excessive sun exposure for as long as 12 weeks after therapy.[47] Severe cutaneous sunburns are reported in 3 of 54 patients (6%) in one study.[49] Serious complications including mediastinitis, stricture formation, bronchoesophageal fistula, and perforation may occur in as many as 22% of patients treated.[49,50] These complications are more frequently encountered when photodynamic therapy is applied to obstructing lesions.[45,46,49,50]

The currently used technique of photodynamic therapy has several limitations. The available hematoporphyrin derivatives are not as selectively retained in tumor tissue as once thought. Nor is the ideal dosing of these photosensitizing agents known. Furthermore, their specific light absorption spectrums mandate the use of lasers that can produce only superficial tissue ablation.

In summary, photodynamic therapy for gastrointestinal tumors is currently an experimental tool and cannot be recommended as a routine palliative or curative therapy. With the refinement of laser delivery systems and the type and dosing of photosensitizing agents, photodynamic therapy may soon play an active role in treating early and advanced gastrointestinal malignancy.

Hemostasis

To establish the efficacy of a specific therapy for gastrointestinal bleeding, it is important to know the natural history and prognosis of the lesions that are to be treated. For example, in 80% of cases, upper gastrointestinal bleeding stops spontaneously; hence, establishing the efficacy of a specific therapy is difficult, often requiring a large number of patients from multicenter trials to minimize type II errors. It is also particularly important to identify the subgroup of high-risk patients who are likely to continue to bleed and who have increased morbidity and mortality if early therapeutic intervention is not provided.[51] With these epidemiologic considerations in mind, we address the efficacy of lasers in the management of gastrointestinal bleeding.

Endoscopic laser therapy was the first and most extensively studied thermal hemostatic procedure. Initial emphasis was placed on the argon laser because it is absorbed primarily by hemoglobin and has a shallow 1- to 2-mm depth of effect. The argon laser, therefore, seemed perfectly suited for coagulating a superficial blood vessel without perforating the thin underlying viscera. The Nd-YAG laser, on the other hand, because of its greater depth of penetration was feared to have an unacceptably high perforation rate.[51] Data from subsequent clinical studies suggested similar safety and efficacy, however.[52-54] The argon laser is more difficult to use in a bloody field because its energy is often absorbed by overlying blood clots and not the deeper target vessels. The Nd-YAG laser is now generally preferred by most endoscopists.[1]

Peptic ulcer disease. Patients admitted to hospital with bleeding peptic ulcers generally have a fairly benign course with almost no mortality. Patients who rebleed during their initial hospital stay, however, may have a mortality as high as 22%.[51] This grim prognosis has led to intensive attempts to differentiate prospectively those patients who are more likely to rebleed. Several endoscopic criteria that convey an increasing risk of rebleeding have now been identified. The main criteria established at the time of the initial endoscopy are the presence of an ulcer with active bleeding and the presence of a nonbleeding visible blood vessel in the ulcer base. If actively bleeding, as many as 85% of patients may rebleed during the initial hospital stay. If visible nonbleeding vessels are present, there is a 50% or greater incidence of rebleeding.[55]

Prospective randomized studies of laser therapy for upper gastrointestinal tract bleeding have generated conflicting data,[52-54,56-59] but if these data are analyzed by patient subgroups according to their potential rebleeding risk, the efficacy of laser therapy can generally be demonstrated in the high-risk group. In addition to successful initial hemostasis with laser therapy in these patients, most studies show a significant reduction in the incidence of rebleeding, the number of units of blood required, and the need for emergent surgical intervention.[52-54,56-58] In contrast, no favorable effects of laser therapy can be shown in patients without visible vessels or active bleeding, presumably because their risk of rebleeding and death from bleeding is so low.[52-59]

The role of laser therapy for bleeding ulcers is now less clear with the introduction of two portable bedside endoscopic techniques: injection therapy and electrothermal coagulation. Endoscopic injection therapy is an increasingly popular, technically easy procedure. Epinephrine or hypertonic saline or ethanol solution is administered into the bleeding target vessel and surrounding tissues under direct endoscopic vision. The required accessories for this technique are few, mobile, and inexpensive. Electrothermal coagulation therapy uses contact thermal probes such as the multipolar and heater probes to simultaneously tamponade a bleeding vessel and deliver thermal coaptive energy.[55] Although direct comparisons of laser therapy with these devices are few, injection therapy and thermal probe approaches appear as, if not slightly more, effective than the laser.[55,60,61] Injection therapy offers the additional advantage of few technical failures, whereas the laser and thermal probes cannot be used in about 10% of lesions because of an inability to approach the target lesion with the probe.[1,56,59]

Complications of laser therapy for bleeding ulcers include a 0% to 2% perforation rate in controlled studies with experienced endoscopists.[51,59] Laser-induced massive bleeding has been reported but is only a rare complication of this procedure.[51]

In conclusion, endoscopic laser therapy effectively provides acute hemostasis for patients with actively bleeding ulcers and decreases the number of units of blood required and the need for emergent surgical repair. The more portable, less expensive, and less technically demanding nonlaser electrical thermal probes and, more recently, injection therapy have, however, essentially replaced the laser in the current management of patients with bleeding ulcers.

Gastrointestinal vascular malformations. Gastrointestinal vascular malformations—that is, angiomas, arteriovenous malformations, angiodysplasias, vascular ectasias, and "watermelon" stomach—are a diverse group of lesions with poorly defined natural histories. They make up a small but substantial percentage of all causes of gastrointestinal bleeding.[62] Several uncontrolled studies have generally reported efficacy of both argon and Nd-YAG lasers in decreasing short-term transfusion requirements and the incidence of recurrent bleeding in these disorders.[63-71] Until, however, the natural history of vascular malformations is better defined with well-designed controlled prospective studies comparing endoscopic laser therapy with other treatment modalities, including medical therapy and surgery,[72] laser therapy's short- and especially its long-term efficacy should be accepted with caution.

Chronic radiation proctitis. Recurrent lower intestinal bleeding due to chronic radiation injury occurs in 2% to 11% of patients who have received abdominopelvic radiation therapy.[73] More than 90% of all gastrointestinal radiation injuries involve the rectum and rectosigmoid colon.[73] Patients with chronic radiation proctitis present with tenesmus, crampy abdominal pain, and bloody diarrhea, usually 6 to 24 months after receiving radiotherapy.[73,74] Those patients in whom anemia develops from severe recurrent bleeding rarely respond to traditional medical therapy. Traditional therapy has included the empiric use of steroid enemas and sulfasalazine. Although the use of these anti-inflammatory agents is appropriate for inflammatory mucosal lesions such as ulcerative proctitis, the characteristic lesion of chronic radiation proctitis has essentially no active inflammation and often fails to respond to these medications. In fact, chronic radiation "proctitis" is a misnomer. The mucosa is actually often atrophic and fibrotic and contains many fragile bleeding neovascular lesions.[74] Patients for whom medical therapy fails are often treated with diverting colostomy or proctosigmoid resection. Unfortunately, these surgical procedures may fail to prevent recurrent bleeding and are associated with high morbidity and mortality.[75-77]

The use of the argon and Nd-YAG lasers for the treatment of severe chronic radiation proctitis has been reported in several case series. These series showed a decrease in both transfusion requirements and the incidence of rebleeding, with only minor complications.[73,78-81] Laser therapy appears promising for the treatment of chronic refractory radiation proctitis. These early positive results await confirmation with further clinical experience.

Biliary Disease

About 90% of common bile duct stones can be successfully removed endoscopically. The remaining 10% of stones are often technically too difficult to extract endoscopically because of their large size.[82] In the past few years, several techniques including extracorporeal shock wave lithotripsy, solvent dissolution, and electrohydraulic lithotripsy have been developed to fragment these large stones, facilitating their endoscopic removal.[83,84]

A recent entry into this field is the flash-lamp dye laser.[85,86] Its laser beam can be transmitted by a quartz fiber that is placed through the duodenoscope in direct contact with the common bile duct stone. Because of the differences between the light absorption properties of stones and tissue, fragmentation of stones can usually be achieved without simultaneously damaging the surrounding duct. This method should theoretically be effective for all types of common bile duct stones, including those that are calcified. This technique has also been applied successfully to gallbladder stones and intrahepatic stones through a percutaneous tract. Experience with endoscopic and percutaneous laser lithotripsy is, however, still limited. Its efficacy compared with that of other existing procedures and its potential complications will require further study.[82,85-88]

A few case reports describe the endoscopic laser treatment of malignant and benign biliary tract strictures and tumors of the ampulla of Vater. A few endoscopic sphincterotomies have also been done with the laser. The patients, however, were generally either poor surgical candidates or more conventional endoscopic and surgical treatments had failed.[89-94]

Miscellaneous Disorders

Multiple reports from small case series have described interesting but not generally accepted laser applications. These include the treatment of duodenal and esophageal webs and short benign gastrointestinal strictures.[95] The drainage of pancreatic pseudocysts through a laser-induced fistulous tract from the gastric or duodenal wall to the underlying adherent pseudocyst has also been reported.[96-99]

New Directions

Attempts are now under way to develop less expensive, smaller, and more portable laser units. If successful, lasers will become more suitable for emergency bedside use.

With the introduction of high-resolution endoscopic ultrasonography, the ability to detect small curable malignant lesions noninvasively may be within reach. The combination of this technique with photodynamic therapy is currently under investigation and has the potential to both detect and treat these tumors.

Other exciting developments are new laser probe delivery systems. Sapphire-tipped and ceramic endoprobes that use a contact approach are now available and may facilitate both tumor debulking and hemostasis.[14,100] New lateral-aiming probes are now being developed.[101] These probes will be ideal for eccentrically located lesions that cannot be approached in the traditional en face manner. Another possible advance is the use of the laser balloon that when inflated conforms to a stricture and allows for a circumferential dispersion of laser energy and the destruction of tissue.[102]

Low-volume water infusion rather than high-flow gas has been used successfully to maintain a clean field during noncontact laser application.[66] The benefits of this new approach are not only the ability to clean a bloody field more effectively but also the avoidance of gaseous overdistension during the procedure.

A flexible probe for the carbon dioxide laser is now available for endoscopic use in Japan. The carbon dioxide laser's local superficial cutting and coagulating effects, which simulate those of a surgical scalpel, may be used for small superficial lesions such as arteriovenous malformations of the cecum with less fear of perforation. Other lasers that simulate a surgical scalpel are also now available. Examples of these include the erbium-YAG and the holmium-YAG lasers. The limiting factor in the erbium-YAG laser's development has been and remains the inability to design a durable fiber for endoscopic use.[66,95]

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