LAPAROSCOPIC GENERAL SURGERY

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OVER the past five years, a revolution has taken place in general surgery requiring the retarding of tens of thousands of surgeons and the retarding of their operating rooms. This startling change has come about because of the rapid acceptance of laparoscopic techniques for therapeutic intervention, particularly removal of the gallbladder. The term "laparoscopy" (from the Greek lapar, the flank, and scope, to examine) refers to the visual examination of the abdominal cavity by means of an endoscope or telescope (the laparoscope). Laparoscopic surgery is a means of performing diagnostic and therapeutic procedures after gaining access to the abdominal cavity. Although the first reports of laparoscopy were published early in the 20th century, the use of this technique was confined to diagnosis (liver biopsy and evaluation of abdominal pain) and ligation of the fallopian tubes until recent years. Laparoscopic cholecystectomy was first performed in 1987, and since then, a variety of intraabdominal operations have used laparoscopic techniques. The rapid progress in laparoscopic surgery and its impact on general surgery are the focus of this review.

BACKGROUND

The modern era of laparoscopic surgery was ushered in when a miniature video camera was attached to the eyepiece of the laparoscope, which allowed multiple observers to view an operative field from the same vantage point. Surgeons in France first performed laparoscopic cholecystectomy in 1987, and the procedure was introduced in the United States in mid-1988. Laparoscopic cholecystectomy has been rapidly adopted by surgeons, and many large series have been reported. These series have highlighted the principal advantages of the laparoscopic approach over traditional ("open") cholecystectomy, including reduced postoperative pain, shorter hospital stays, and shorter periods of disability. The news media quickly portrayed laparoscopic surgery, with its small incisions, as a panacea ("minimally invasive," "band-aid," or "Nintendo" surgery), and the lay public demanded this form of surgery from its physicians and surgeons. As patient demand grew, so did the need to train surgeons in the new technique. Between 1990 and 1992, about 15,000 general surgeons were trained in the United States alone. Hospitals rushed to purchase the expensive laparoscopic equipment in order to be the first to offer laparoscopic cholecystectomy in their region. As surgeons became skilled in laparoscopic cholecystectomy, they began to use the laparoscope to perform other abdominal operations. Many such procedures have been described, ranging from operations on the esophagus to those on the rectum and from those involving the abdominal wall to those involving the retroperitoneum.

For an appreciation of the status of laparoscopic surgery, one must understand the basic principles of laparoscopy. A working space within the abdominal cavity is initially established. This is usually accomplished by insufflating the peritoneal cavity with carbon dioxide to a pressure of 10 to 15 mm Hg. The laparoscope is inserted into the abdomen with a trocar and hollow sheath containing a side port for continuous carbon dioxide insufflation, as well as valves and gaskets to allow the insertion and removal of the laparoscope without allowing the carbon dioxide to escape. The diameter of the laparoscope and initial laparoscopic sheath is 5 or 10 mm. In an operation, accessory sheaths are inserted to introduce laparoscopic instruments (Fig. 1). These instruments are generally elongated, narrower versions of standard surgical tools. The surgeon works with instruments inserted through one or two sheaths while the laparoscope is focused on the operative field by an assistant. The video cameras have high resolution and, when harnessed to the laparoscopic eyepiece, magnify images 5 to 15 times and provide a clear image of the operative field.

Laparoscopic surgery is currently limited by a number of factors. The video image is two-dimensional and is directed by an assistant. The laparoscopic port acts as a fulcrum that restricts the freedom of movement of the instruments. The instruments provide limited feedback about the amount of force being applied and a restricted sense of touch. Laparoscopic operations rely on high-technology equipment and generally require the assistance of one additional person (the camera operator). Because of the limitations imposed by laparoscopic optics and instruments, certain skills (such as suturing) require considerable practice to master. Adhesions or inflammation may preclude adequate visualization of the operative field and require changing to a traditional open operation. Also, the carbon dioxide pneumoperitoneum used during laparoscopic surgery can cause adverse local and systemic effects, such as gas embolism, hypercapnia, acidosis, and arrhythmias.

The unbridled enthusiasm of the news media, the public, and some surgeons for laparoscopic proce-
niques (computed tomography, magnetic resonance imaging, and ultrasonography) for detecting abdomi
nal-mass lesions varies widely, but tumors that are less than 1 to 2 cm in diameter are frequently missed.33–35
Laparoscopy can detect lesions less than 1 mm in di-
ameter, although only the surfaces of intraperitoneal
structures are evaluated. In 36 percent of patients with pancreatic tumors, Warshaw et al.33 detected
small liver and peritoneal metastases by laparoscopy
that were not identified by preoperative investiga-
tions. For gastric cancer, up to 40 percent of patients
have unsuspected peritoneal or liver metastases (or both) discovered at laparoscopy.31 The reported ac-
curacy of laparoscopic biopsy in identifying malig-
nant liver disease is approximately 90 percent,34
and the recent development of laparoscopic ultrasound
probes may further improve the diagnostic accuracy
of laparoscopy for this disease.35–37 Other applica-
tions of laparoscopy in malignant conditions include
"second-look" procedures to assess whether there is
a recurrence of ovarian cancer after therapy,38
staging of lymphoma,39–40 and examination of the
pelvic lymph nodes for the staging of prostate car-
cinoma.40

Evaluation of Abdominal Trauma

Another diagnostic application of laparoscopy is to
evaluate blunt and penetrating abdominal trauma. The
use of laparoscopy has been reported to re-
duce the rates of unnecessary laparotomy, lessen mor-
bidity, shorten hospital stays, and decrease overall
costs.41–43 The reported diagnostic accuracy of lapa-
roscopy in abdominal trauma is over 90 percent. How-
ever, although laparoscopy effectively visualizes in-
traperitoneal organs, it does not visualize well the
retroperitoneum and the organs it contains (the du-
denium, the pancreas, and parts of the colon). Diag-
nostic laparoscopy is particularly useful to assess pen-
etration of the peritoneum following trauma, such as
stab wounds or tangential gunshot wounds, to the ab-
dom.41 Cuschieri et al.42 conducted a prospective
multicenter study comparing laparoscopy with perito-
neal lavage in patients with abdominal trauma. Both
procedures had a sensitivity of 100 percent in detect-
ing important intraabdominal injuries. The positive
predictive value for determining the need for laparot-
omy was 92 percent for laparoscopy as compared with
72 percent for peritoneal lavage. These results suggest
that diagnostic laparoscopy will be increasingly valu-
able in the evaluation of abdominal trauma by reduc-
ing the number of unnecessary abdominal explorations
and hospital costs.40

Laparoscopic Cholecystectomy

Laparoscopic cholecystectomy was adopted rapidly
by most surgeons and embraced enthusiastically by
the public. More than 85 percent of all cholecystec-
tomies in the United States were estimated to have
been performed laparoscopically in 1993. During la-
paroscopic cholecystectomy, the gallbladder is resected

Figure 1. Diagram of the Abdomen after the Creation of a Pneu-

moperitoneum and the Insertion of Laparoscopic Instruments for
the Performance of Cholecystectomy.

Accepted Procedures

Diagnostic Laparoscopy

Evaluation of Abdominal Pain

Laparoscopy is frequently used to evaluate unex-
plained acute and chronic abdominal pain. Diagnostic
laparoscopy may preclude unnecessary appendecto-
momy in 20 to 40 percent of patients with abdominal
pain and equivocal clinical presentations and may
point to other diseases requiring alternative ther-
apy.26–27 Rates of removal of noninflamed appendixes
of 10 to 40 percent27 are common with the use of
standard preoperative diagnostic tests, with the high-
est rates occurring in women of childbearing age.27
The overall diagnostic accuracy of laparoscopic exami-
nation in the evaluation of acute abdominal pain has
been reported to be 80 to 99 percent,28–31 as compared
with a 20 to 40 percent rate of unnecessary laparoto-
momy when laparoscopy is not performed in patients
with such pain.27–28

Staging of Malignant Tumors

Laparoscopy can also be used to diagnose and stage
intraabdominal tumors through direct visual assess-
ment and optically guided biopsies. Such staging may
avert an unnecessary open operation in patients with
unresectable tumors. The sensitivity of current tech-
and then removed through an umbilical incision (Fig. 2). Cholangiography may also be performed; this laparoscopic operation thereby duplicates its open counterpart.

A number of retrospective studies reported that laparoscopic cholecystectomy causes less postoperative pain, involves shorter periods of postoperative hospitalization, and allows a more rapid return to full physical activity than open cholecystectomy. Because of the perceived improvement in outcome, the prospect of conducting a randomized trial of laparoscopic as compared with open cholecystectomy in this country quickly became an unrealistic goal. Results of a small prospective, randomized trial from Canada were published recently and confirmed that laparoscopic cholecystectomy led to an earlier resumption of a full diet, more rapid hospital discharge, and a shorter convalescence than open cholecystectomy. These advantages result in lower costs in most cases.

Experience with laparoscopic cholecystectomy has now been reported in many large series (Table 1). Death is rare (<1 percent) and is usually due to unrelated causes. However, death has been caused by iatrogenic injuries to the bile duct or intestine. The introduction of laparoscopic instruments through the abdominal wall may injure major blood vessels or the bowel. The rate of conversions from laparoscopic operations to open operations ranges from 1.8 to 8.5 percent and tends to be highest early in a surgeon’s experience. However, not every patient with symptomatic cholelithiasis is a candidate for laparoscopic cholecystectomy. Inability to tolerate a general anesthetic, uncorrectable coagulopathy, and concurrent diseases requiring laparotomy are considered absolute contraindications to the laparoscopic approach.

Certain hepatobiliary diseases (e.g., acute cholecystitis) and nonbiliary conditions (such as adhesions from prior abdominal operations) increase the likelihood of conversion from a laparoscopic to an open approach. Major complications are unusual, and the rate of bile-duct injury has generally been 0.5 percent or less in these series — a rate only slightly higher than that after open cholecystectomy. Most bile-duct injuries have occurred early in a surgeon’s experience.

Despite favorable reports from centers performing many laparoscopic cholecystectomies, anecdotal observations suggested that complications were occurring at a higher rate than was being reported. In addition, several tertiary care centers noted an increased number of referrals of patients with bile-duct injuries for definitive therapy. The New York State Department of Health received reports of increased complications related to laparoscopic cholecystectomy and estimated the frequency of bile-duct injury to be seven to eight times higher with laparoscopic than with open cholecystectomy. Iatrogenic damage to the bile duct is a devastating complication that mandates further intervention to establish biliary patency and may lead to stricture with choledochal jaundice or, ultimately, biliary cirrhosis. Owing in part to these issues, but also because of the rapid implementation of laparoscopic cholecystectomy, the National Institutes of Health held a consensus development conference in September 1992 entitled “Gallstones and Laparoscopic Cholecystectomy.” The consensus statement indicated that laparoscopic cholecystectomy had become the treatment of choice for many patients, decreasing pain and disability and potentially reducing the cost of treatment. Since the outcome of laparoscopic cholecystectomy is greatly influenced by the training, experience, skill, and judgment of the surgeon performing the procedure, it was recommended that strict guidelines for training laparoscopic surgeons, determining

Table 1. Results of Laparoscopic Cholecystectomy.

<table>
<thead>
<tr>
<th>Study</th>
<th>Year of Study</th>
<th>No. of Patients</th>
<th>Procedures Converted to Open Operations</th>
<th>Mortality</th>
<th>Major Complications</th>
<th>Common Bile-Duct Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larson et al. 10</td>
<td>1992</td>
<td>1763</td>
<td>4.5</td>
<td>0.1</td>
<td>2.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Southern Surgeons Club 3</td>
<td>1991</td>
<td>1518</td>
<td>4.7</td>
<td>0.07</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Cuschieri et al. 8</td>
<td>1991</td>
<td>1236</td>
<td>3.6</td>
<td>0</td>
<td>1.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Soper et al. 6</td>
<td>1992</td>
<td>618</td>
<td>2.9</td>
<td>0</td>
<td>1.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Spaw et al. 3</td>
<td>1991</td>
<td>500</td>
<td>1.8</td>
<td>0</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>Lillehoj et al. 12</td>
<td>1992</td>
<td>400</td>
<td>4.0</td>
<td>0</td>
<td>5.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Wolfe et al. 9</td>
<td>1991</td>
<td>381</td>
<td>3.0</td>
<td>0.9</td>
<td>3.4</td>
<td>0</td>
</tr>
</tbody>
</table>

*These include myocardial and cerebrovascular events, pneumonia, hemorrhage, bile leakage, and iatrogenic injury to the bile duct or bowel.
their competence, and monitoring their ability "to develop and implemented promptly."

Operations Gaining Acceptance

Appendectomy

Open appendectomy has been the accepted therapy for acute appendicitis for over a century. In 1983, the German surgeon Kurt Semm described a laparoscopic appendectomy. A number of subsequent reports documented the feasibility and safety of the procedure. However, the proposed advantages of laparoscopic as compared with open appendectomy are less compelling than those for cholecystectomy, since postoperative pain and disability after open appendectomy are already minimal. Two small prospective, randomized trials from the United Kingdom have compared laparoscopic appendectomy with open appendectomy. In both series, the laparoscopic approach resulted in a shorter period of postoperative hospitalization, less pain, and fewer wound infections. Perhaps more important, laparoscopic appendectomy may result in fewer postoperative adhesions than open appendectomy.

Exploration of the Common Bile Duct

Although choledocholithiasis occurs in up to 15 percent of patients undergoing elective cholecystectomy, it was initially thought that there was no laparoscopic access to the common bile duct. Therefore, most surgeons combined laparoscopic cholecystectomy with endoscopic retrograde cholangiopancreatography in patients suspected of having choledocholithiasis, adding sphincterotomy and stone extraction when stones were identified. It has now become apparent that stones of the common bile duct can often be removed with laparoscopic techniques. Most such stones can be extracted through the cystic duct with a stone basket or by dilating the cystic duct to allow the insertion of a 10-French (3-mm) choledochoscope into the common bile duct. The stones can be removed under direct vision with a basket placed through the biopsy channel of the choledochoscope. The results of a few small series suggest that such techniques can clear the common bile duct of stones in about 90 percent of patients.

In patients with large stones of the common bile duct or in those in whom the cystic duct cannot be used to gain access to the common duct, alternative strategies are necessary. The anterior wall of the common bile duct can be incised directly to allow the insertion of a larger choledochoscope into the duct. The proximal part of the biliary tree can also be evaluated by this method, since the transcytic technique preferentially directs endoscopes toward the duodenum. After the ductal stones are removed, the choledochotomy is closed over a T tube with fine, absorbable, monofilament suture. These maneuvers require excellent suturing skills to prevent postoperative stricture and mandate the placement of drains and a T tube, which results in longer hospital stays.

Laparoscopic choledocholeithotomies have been done, as they should be performed only by experienced laparoscopic surgeons. The appropriate current management of common bile-duct stones in the era of laparoscopic cholecystectomy is unclear and depends on the skills of the surgeon and the endoscopist. When successfully performed, transcytic exploration of the common bile duct is followed by a recovery similar to that following laparoscopic cholecystectomy alone and eliminates the need for a second procedure (endoscopic retrograde cholangiopancreatography) and its risks.

Repair of Inguinal Hernia

Approximately 500,000 patients undergo repair of inguinal hernias in the United States each year, making it one of the most common operations. The conventional surgical approach to groin hernias has been to ligate or reduce the hernia sac and perform suture reconstruction of the inguinal floor through an open incision. Although this operation can usually be performed as an outpatient procedure with the use of local anesthesia, it has been associated with considerable postoperative pain and a delayed return (four to six weeks) to full physical activity and employment. The rates of hernia recurrence after open repair are low (0 to 2 percent) in specialized centers, but rates in regionalized studies of heterogeneous populations have averaged 5 to 10 percent for primary hernias and 5 to 30 percent for recurrent hernias. These trends with conventional herniorrhaphy along with the success of laparoscopic cholecystectomy provided the impetus to develop a laparoscopic approach to hernia repair.

Several techniques for laparoscopic herniorrhaphy have been used, including closure or plugging of the hernia, and various types of patch repairs. The latter is currently the most common method, an entails placing a large prosthetic patch internally to cover the hernia and inguinal floor. Conceptually, this operation is similar to the open preperitoneal approach advocated by Stoppa et al., who use a large "tension-free" patch to cover the entire inguinal floor, with a subsequent recurrence rate of 1.4 percent.

Laparoscopic repair of inguinal hernias is performed with the use of general anesthesia and three laparoscopic ports. After the hernia is visualized (Fig. 3), the peritoneum overlying the inguinal floor is incised and, along with the hernia sac, is elevated from the underlying structures (Fig. 4). A large sheet of prosthetic mesh is placed over the entire myopectineal orifice and secured with sutures or staples. The peritoneum is then closed to reduce the frequency of postoperative adhesions to the mesh. Recently, a similar operation has been performed with an entirely extraperitoneal approach, confining carbon dioxide insufflation and the placement of laparoscopic ports to the preperitoneal space. Although technically more difficult, this method...
tentially avoids the risks to intraabdominal organs associated with laparoscopy.

The safety and efficacy of laparoscopic inguinal hernia repair have recently been evaluated in two multi-institutional reports. MacFadyen and associates analyzed data from 16 surgeons who reported 847 laparoscopic herniorrhaphies in 752 patients (some repairs were bilateral). Four types of operation were used (Table 2). The various plug techniques were quickly recognized to have high rates of recurrence and have been abandoned. The rate of recurrence of hernia was lowest in the patients treated by placement of a large prosthesis over the inguinal floor. The morbidity rates ranged from 4.4 to 19.8 percent, but most complications were minor and transient. In a separate multi-institutional trial, Fitzgibbons et al. reported on 597 patients who underwent 736 hernia repairs (some were bilateral) made by a prosthetic-patch procedure. After a mean follow-up of six months, there were 16 (2.2 percent) definite recurrences of hernia and 9 (1.2 percent) possible recurrences. The one postoperative death was due to a myocardial infarction. Long-term thigh pain or hypoesthesia was seen in three patients (0.5 percent) and occurred most commonly in the distribution of either the femoral branch of the genitofemoral nerve or the lateral cutaneous nerve of the thigh.

Unlike other laparoscopic procedures that duplicate traditional open surgical approaches, laparoscopic hernia repair represents a departure from standard herniorrhaphy. Furthermore, the variety of techniques that have been used in the early phase of laparoscopic herniorrhaphy prevents definitive conclusions regarding the operation’s value. It appears, however, that laparoscopic hernia repair is associated with less postoperative pain and an earlier return to full physical activity than conventional herniorrhaphy. Despite the favorable early results, the procedure is controversial. Although the operation is similar to the repair described by Stopa et al., the different method for fixation of the mesh laparoscopically adds an element of uncertainty to long-term stability and security. To date, recurrence rates with the preperitoneal prosthetic-patch operation have been low, but the follow-up has been short (<6 months). Since most recurrences after conventional herniorrhaphy develop five or more years after the original operation, the long-term rates of recurrence may
Figure 4. Laparoscopic Transperitoneal Repair of Indirect Left Inguinal Hernia.
First, the peritoneum overlying the left internal ring is divided above (dotted line, Panel A) the hernia orifice. Then peritoneal flaps are made, exposing the structures of the inguinal floor (Panel B), and polypropylene mesh is stapled into place over the entire floor (Panel C). Finally, the peritoneum is closed over the prosthetic mesh (Panel D).
prove unacceptably high, especially when the procedure is performed by an inexperienced surgeon. Further evaluation in controlled clinical trials is therefore needed before laparoscopic herniorrhaphy is more widely implemented.

Laparoscopic hernia repair also requires a general anesthetic, with its associated risks, for a procedure that can be done conventionally with local anesthetics. There is a small but finite risk of serious injury to intraabdominal organs that is not associated with traditional inguinal herniorrhaphy. Also, costs may be higher because of the need for expensive equipment and other supplies related to laparoscopic instrumentation. Unlike those for laparoscopic cholecystectomy, these increased costs are not offset by decreased hospital charges, since hernia operations are routinely outpatient procedures regardless of the method of repair. A recent comparison of conventional with laparoscopic herniorrhaphy indicated an average increase in cost of 135 percent with the laparoscopic approach. Whether these direct costs may be partially offset by an earlier return to employment is not known.

Laparoscopic Colon Resection

It is a challenge to apply laparoscopic surgery to resection of larger organs such as the colon. Some of the technical difficulties encountered in laparoscopic intestinal surgery result from the need for complete mobilization of bowel segments of variable lengths and locations, the requirement of a watertight anastomosis of the remaining bowel, and in cases of cancer, the need to obtain adequate resection margins and to remove mesenteric lymph nodes. Two main types of laparoscopic bowel resection are performed depending on whether portions of the operation are performed outside the abdominal cavity (extracorporeal, laparoscopic-assisted bowel resection) or within the cavity (totally laparoscopic, intracorporeal methods).

For laparoscopy-assisted colectomy, laparoscopic techniques are applied to the initial steps of bowel resection (lysis of adhesions, intestinal mobilization, and division of mesenteric blood vessels with or without bowel transection), whereas the final stage of the operation — removal of the specimen and reanastomosis of the remaining colon — is performed extracorporeally. A relatively small (3 to 7 cm) incision is made at one port entry or directly over the area of the planned anastomosis. The rationale for the extracorporeal portion is that reanastomosis of bowel segments can be performed in the same fashion and with the same speed and reliability as in open surgery. It has been assumed that the primary benefits of laparoscopic surgery (less pain, shortened hospital stay, and faster convalescence) will still be maintained with laparoscopy-assisted colectomy because there is minimal manipulation of the intraabdominal contents and the incision is smaller than that used for the standard operation. However, there is no clear evidence that this assumption is true. Resection and reanastomosis of the colon with totally intracorporeal techniques have been complicated by the need to remove large specimens through small incisions, technical problems in performing the anastomosis, and prolonged operating times. Unlike the laparoscopic removal of a kidney affected by a benign disease, which may be facilitated by morcellation within a nylon bag, intact removal of the resected colon is of particular importance in cases of malignant disease, since precautions must be taken to avoid the spread of the tumor while providing adequate histologic evaluation and tumor staging. There have already been reports of recurrences of colon cancer at the trocar site in the abdominal wall following laparoscopy-assisted colectomy. With totally intracorporeal procedures, the specimen has generally been removed transrectally or through a very small incision.

In addition to many case reports, three larger series of laparoscopic colectomy (≥40 cases) have been reported. In two of these studies, most patients underwent laparoscopic-assisted resection, although Phillips et al. 19 used an intracorporeal technical approach in 40 of 51 patients (78 percent). In 8 to 41 percent of the patients in these series, the laparoscopic approach was unsuccessful and the operation was converted to a standard open colectomy. Postoperative complications occurred in 8 to 20 percent of the patients, and two patients died (1.3 percent) in the perioperative period. The hospital stay after successful laparoscopic colectomy averaged five to eight days. Patients returned to work one week after the operation in the study by Phillips et al. 19 Falk and coworkers compared outcomes in patients undergoing laparoscopic colectomy, operations converted from laparoscopic to open procedures, and traditional open colectomies (historical controls). Although the patients who had laparoscopic colectomy were sent home sooner than those in the other groups, the total hospital costs were similar in all three groups. This finding was presumably due to the higher costs of laparoscopic instruments and operating-room fees. The number of lymph nodes available for examination was also similar in the three groups.

A much-needed multi-institutional prospective, randomized trial comparing laparoscopic with open colectomy for colon carcinoma has recently begun and
should answer many questions about the value of laparoscopic surgery for this indication.

**Operations for Gastroesophageal Reflux**

A recent randomized, prospective trial comparing medical therapy with open surgical therapy for complicated gastroesophageal reflux demonstrated that surgery (the Nissen fundoplication, a 360-degree wrapping of the gastric fundus around the distal esophagus) more effectively improved the symptoms and endoscopic signs of complicated esophagitis for up to two years. Because of the perceived morbidity of the open Nissen fundoplication (owing primarily to the large upper-abdominal incision required) and the availability of powerful antisecretory drugs, few patients are now treated by operative correction of gastroesophageal reflux. Recently, a number of centers have used laparoscopy for antireflux operations.

An antireflux barrier can be reestablished with the use of methods similar to those applied in open procedures. This method uses five ports in the upper abdomen. These operations include the Nissen fundoplication and a 270-degree partial fundoplication (the Toupet technique). Although these procedures require dexterity with suturing and therefore must be performed by a surgeon with advanced laparoscopic skills, no tissue is removed, making them ideally suited to the laparoscopic approach. Two large series of the laparoscopic Nissen fundoplication have now been described. Other surgeons have selectively applied the Nissen and Toupet procedures, on the basis of the size of the gastric fundus and the amplitude of proximal esophageal peristalsis. Early postoperative results have been excellent in these series. The average postoperative hospital stay has been two to four days, complete relief of preoperative symptoms has been achieved in more than 90 percent of patients, and the rates of postoperative dysphagia and the gas bloat syndrome have been acceptably low. The long-term outcome of laparoscopic antireflux operations is not yet known but is expected to be similar to that of its standard open counterparts.

**Operations for Peptic Ulcer Disease**

Elective surgery for uncomplicated peptic ulcer disease is rarely necessary because modern antisecretory therapy is highly effective and because peptic ulceration is often caused by agents that can be eliminated (i.e., Helicobacter pylori and nonsteroidal antiinflammatory drugs). Nonetheless, several laparoscopic variations of highly selective vagotomy for the treatment of peptic ulcer disease have been described. The technique has been used in two small series of patients with chronic duodenal ulcers. No complications were reported in either of these studies, acid secretion was reduced in patients who were studied postoperatively, and recurrent ulceration was not observed during brief periods of follow-up.

Bailey and Zucker reported early results in 30 consecutive patients undergoing laparoscopic posterior or truncal vagotomy and anterior, highly selective vagotomy. Ulceration recurred in two patients, both of whom had prepyloric ulcers. Katkhouda and Mouiel described 60 patients with duodenal ulcers refractory to medical therapy who were treated with laparoscopic posterior truncal vagotomy and anterior gastric seromyotomy. An 80 percent reduction in acid production was observed one month after surgery, and complete healing of the ulcers was documented in 57 patients (95 percent) six months after surgery.

Emergency laparoscopic treatment of a perforated duodenal ulcer has been reported by several centers. The most common approach has been to combine simple closure of the perforation with the use of an omental patch. Some patients who have had surgery within a few hours of the onset of symptoms have also been treated with simultaneous laparoscopic highly selective vagotomy. Vereecken described 30 patients with perforated ulcers who were treated laparoscopically. The procedure was converted to an open operation in two patients, and one patient died of multisystem organ failure. On average, oral intake of food and drink was resumed on postoperative day 4, and patients were sent home on the ninth postoperative day. No patients required a second operation or had recurrent ulceration during a mean follow-up of five months.

**Procedures Under Development**

Many other laparoscopic operations have been described and reported anecdotally. Some apply standard open surgical principles and will probably be adopted, including esophageal myotomy for achalasia, splenectomy, adrenalectomy, unroofing of simple hepatic cysts, and palliative bypass techniques for obstructing lesions in the head of the pancreas (gastrojejunosotomy and cholecystectomy). Other operations may represent a triumph of technical ability over common sense, such as ligation of teres cardiophysi for hiatal hernia repair or the Whipple pancreaticoduodenectomy (Gagner M: personal communication).

Laparoscopic general surgery has not developed in a vacuum. Surgical specialists in other fields have simultaneously recognized the potential advantages of minimal-access surgery with endoscopic visualization. These include thoracic surgeons, pediatric surgeons, gynecologists, and urologists, who have expanded the applications of laparoscopic and endoscopic surgery in their own fields.

**Problems and Challenges**

Technical limitations currently imposed on laparoscopic surgeons are being addressed by a number of investigators and surgical-instrument manufacturers. First-generation systems employing three-dimensional optics and enhanced video resolution have been developed. Laparoscopic instruments are being devised that offer a greater range of motion, more force feedback and tactile discrimination, and variable de-
grees of shaft curvature. Laparoscopic "sewing machines" are being developed to facilitate intracorporeal suturing capabilities. Investigators are assessing the use of other insufflation gases to minimize the systemic effects of carbon dioxide, and abdominal-wall retractors are being developed to eliminate the need to use an insufflating gas to create the laparoscopic working space.

As with all areas of medicine, the issue of the expense of laparoscopic surgery will be increasingly important, especially as compared with the costs of traditional open operations. Measuring direct costs alone may not reflect a main benefit of laparoscopic operations — that is, that it decreases indirect costs to society by returning patients to the work force more rapidly. The issue of reusable as compared with dispos-able laparoscopic instruments is important in the evaluation of cost factors and in considerations of waste management and sterility. Disposable instruments appear to increase the direct costs of laparoscopic surgery, but it is unclear whether they enhance patient safety enough to justify their routine use. Likewise, early experience with many laparoscopic operations suggests that operative time may be greatly prolonged as compared with conventional operations; at a cost of $1,200 per hour for the use of an operating room, the total costs may increase tremendously.

Training, furnishing credentials, and granting privileges to surgeons to perform laparoscopic operations remain hotly debated issues. The traditional system of surgical education was not prepared to train thousands of surgeons in laparoscopic techniques within a brief period. Most surgeons are now familiar with basic laparoscopic procedures — that is, cholecystectomy, appendectomy, and diagnostic procedures. Since hospitals traditionally have been the final arbiters in deciding which surgeons can perform specific procedures, they must insist on minimal criteria for training and furnishing credentials to their surgeons, such as the criteria suggested by the Society of American Gastrointestinal Endoscopic Surgeons.

More advanced laparoscopic procedures require additional training to enhance the surgeon's dexterity in performing more complicated techniques. However, some surgeons have difficulty mastering surgery in a remote, two-dimensional world requiring nonintuitive "video—eye—hand" coordination, and they will need to receive repeated training sessions or they will abandon their attempts to use laparoscopic surgery. Academic centers must develop regional training centers to allow practicing surgeons to improve their skills and prevent an upsurge in complications from these newer laparoscopic operations. General surgical residency programs must insist that their trainees are adequately exposed to the various laparoscopic operations to ensure their proficiency before their training programs are completed. Innovative training methods may also be required, such as those involving "virtual reality" systems (similar to the three-dimensional simulators used by fighter-jet pilots), to enhance a surgeon's mastery of video—eye—hand coordination. The future of laparoscopic surgery appears bright, since it potentially decreases pain, allows a more rapid recovery, and decreases costs to society. Most operations performed to a body cavity should ultimately be amenable to laparoscopic or other minimally invasive surgical techniques.

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