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It is clear from published series that laparoscopic colectomy for cancer can be performed safely by experienced surgeons, but there is a considerable learning curve for the procedure. Although surgeons have shown that an equivalent resection can be performed, it is not clear yet that this translates into equivalent recurrence and survival rates. Most of the expected benefits of minimal access surgery are being provided by laparoscopic colectomy, although these benefits have not been as readily achievable as those seen with other procedures. Even the early results of laparoscopic colectomy for cancer are encouraging, although the fate of this procedure rests with the long-term analysis of a number of trials currently underway. Laparoscopic techniques are continuing to evolve and improve secondary not only to technological breakthroughs but also advances in basic science and clinical research. This article provides technical descriptions to illustrate key concepts in laparoscopic resection of the right colon and rectosigmoid for cancer and reviews the results of recent prospective randomized trials.

Key words: Colon cancer, laparoscopic surgery, technical aspects, review.

The laparoscopic approach has become the gold standard for cholecystectomy, Nissen's fundoplication, and adrenal surgery, which are end organ, isolated types of procedures. The application of laparoscopic techniques to the treatment of various colorectal diseases has, however, not been met with the same enthusiasm and support. Laparoscopic colorectal surgery presents greater challenges, especially in the resection of colorectal cancer, which is the leading indication for large bowel resection in the United States.[1] It requires operating over multiple quadrants, retracting the small bowel, exposing and dissecting large tissue planes, removing a large, bacteria-laden organ that may contain a malignancy, and performing a bowel anastomosis. In this chapter, we will present what we believe is a safe and systematic approach for the successful application of laparoscopic techniques in the management of colon cancer. The technical descriptions illustrate key concepts for successful laparoscopic resection of the right colon, sigmoid colon, and rectum for cancer and can be adapted virtually to all laparoscopic operations of the colon and rectum.

Summary of Key Concerns in Laparoscopic Colorectal Cancer Surgery

Controversy continues to surround the use of laparoscopic resection in cases of colon and rectal carcinoma despite the expansion in the use of laparoscopic techniques in benign colorectal surgery over the past several years.[2] This is partially because of concerns about whether patients undergoing laparoscopic colorectal surgery truly achieve benefits worth the extra expense and difficulty of this approach[3-5] and in the face of concerns about whether an adequate oncological and staging operation can be accomplished. The issue of port-site metastases also remains a major concern in the minds of many surgeons.[6,7] Laparoscopic colorectal surgery requires very advanced laparoscopic surgical skills,[8] and there is justifiable concern that even if there are significant advantages in the laparoscopic approach, this is achievable only in the hands of the few dedicated laparoscopic colorectal surgeons. Training and competency in laparoscopic colorectal surgical techniques should become less of an issue because it is being increasingly addressed with the introduction of basic and advanced laparoscopic training into general surgical and colorectal residency programs.

Operative Strategy: How can a Cancer Operation be Effectively Accomplished?

It is our firm belief that the proposed operation should never be modified just to enable its performance to be completed laparoscopically. Laparoscopic curative resections of colon and rectal cancer should be performed according to the accepted oncological principles and operative strategy established in conventional surgery.[9-11]

Although it is questionable whether a high liga-

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tion of the inferior mesenteric artery (IMA) or extended lymphadenectomies reduce recurrences and increase survival,[12,13] we define a curative oncological resection as follows[14]: proximal lymphovascular ligation and complete lymphadenectomy with (1) wide en bloc resection of tumor-bearing bowel segment with adjacent soft tissue and mesentery, (2) resection of suitable margins of the normal bowel proximal and distal to the cancer, and (3) occlusion of the bowel above and below the tumor to minimize the possibility of intraluminal tumor spread.

In addition, we consider the following to be important components of an oncological operation: (1) minimal manipulation of the tumor-bearing segment, (2) rectal washout with tumoricidal solution for rectosigmoid cancers, (3) placement of the specimen as soon as possible into an impermeable bag before delivery through the abdominal wall, (4) protection of the peritoneal cavity from contamination, (5) assessment of the liver and peritoneal cavity for metastatic disease, and (6) conditions that allow an anastomosis or a stoma to be safely performed.

We first showed the feasibility of this operative strategy in a cadaver model[15] and then applied our method to patients after extensive practice in the laboratory and in benign clinical resections.

General Preoperative Preparation

As in conventional surgery, patients should be fully investigated to exclude synchronous tumors and metastatic disease. A thorough preoperative staging work-up allows for appropriate preoperative administration of adjuvant therapy in advanced rectal cancers. It allows the surgeon to plan the operation with the patient, minimizes intraoperative surprises, and maximizes the chance for a good outcome.

Cardiac, pulmonary, renal, and hematologic status must be suitable to allow for 2 to 4 hours of general anesthesia with a reasonable expectation for postoperative recovery and healing of the postoperative wounds. Medical conditions such as cardiopulmonary disease or diabetes are evaluated before surgery with the help of appropriate medical consultation as required. Physiological parameters are optimized before and during surgery. Preoperative nutritional status should not be ignored, and patients with significant weight loss should be considered for nutritional supplementation, although rarely does this mean preoperative parenteral nutrition.

Bowel preparation, prophylaxis against deep venous thrombosis, and perioperative antibiotics are also mandatory. Furthermore, it is important to ensure that patients are fully conversant with the implications both of the disease and the operation and are prepared for stoma formation. It follows that they should be seen by an enterostomal nurse therapist before operation if there is a high probability of needing a stoma.

Our patients are strongly encouraged to accept an epidural anesthetic to supplement perioperative analgesic management. Equally important, we believe epidural anesthesia aids visualization and retraction by shrinking the small bowel diameter during operation and may reduce postoperative ileus. These effects are mitigated in epidural anesthesia, especially when placed in the thoracic region, by shortening the length of postoperative ileus via thoracic sympathetic nerve blockade.[16,17] Postoperative ileus may also be further diminished by the decreased perioperative administration of narcotic drugs, which are known to diminish bowel activity.[18,19]

Technical Considerations

Relevant Vascular Anatomy

The normal vasculature to the right colon can most accurately be described as emanating from a paracolic arcade, fed by the ileocolic and middle colic arteries, reinforced in 13% of cases by a right colic artery. The middle colic artery arises as a single vessel from the superior mesenteric artery in 46% of cases,[20] generally dividing about 2 cm from its origin into a branch for the hepatic flexure and a branch for the transverse colon. The second most common middle colic vasculature consists of 1 artery for the hepatic flexure with a separate vessel for the transverse colon. At least 5 different patterns may be seen in the middle colic system, with as many as 3 middle colic arteries possibly present. Separating the transverse mesocolon from the attachments of the greater omentum and the lesser sac and performing proximal ligation of the middle colic vessels constitute one of the most difficult steps in performing an oncological right hemicolectomy.

The IMA is a straight vessel that runs from the distal aorta to its bifurcation into 2 superior rectal arteries in the mesorectum. Its first branch is the left colic artery, which usually arises from several millimeters to several centimeters away from the origin of the IMA. An accessory left colic artery arising from the superior mesenteric artery is seen in 15% of specimens.[20] The second branch of the IMA is the colosigmoid artery, which supplies both the descending and sigmoid colonic segments. Choosing a mesenteric resection line between the left colic and the colosigmoid vessels will facilitate the mesenteric division because after IMA and vein division, only 1 or 2 mesenteric vessels need be ligated and cut. Additionally, proximal division of the IMA and vein is usually necessary to allow the mobilized left colon to reach well into the pelvis without tension. Unless there is suspicion of mesenteric insufficiency from the middle colic vessels (or an accessory left colic artery), there should be little or no risk of vascular insufficiency with this maneuver.

Instruments

Tables 1 and 2 list the minimum number and types of instruments required for laparoscopic right colectomy and proctosigmoidectomy, respectively. Our preferred energy source for dissection and tissue division is the ultrasonic shears, which generates less smoke and we believe has less potential for accidental tissue thermal damage than standard electrocoagulation.

The LigaSure (ValleyLab, Boulder, CO) is a new electrosurgery device that works by fusing the collagen in vessel walls to create a permanent seal in vessels up to 7 mm. Our initial experience shows that it may reduce cost by eliminating the use of endoscopic staplers for vascular ligations.

Positioning

The patient is installed in the extended Lloyd-Davis position with specialized padded lithotomy stirrups (OR Direct, Acton, MA) and pneumatic intermittent calf compressors (Fig 1). A moldable bean mattress (Olympic Medical, Seattle, WA) keeps the patient from sliding off the table when put in steep Trendelenburg position. It is important that the legs are not angled too steeply at the hips because this will restrict the operative field. The foot of the table is dropped and the buttocks are pulled to the end of the table so that the anus is easily accessed. A towel roll is occasionally used to elevate the sacrum. The lower extremities are abducted only enough to allow access to the perineum. A bladder catheter is placed. An orogastric tube is passed during the operation, but usually is discontinued at the conclusion of the operation.

For proctosigmoidectomy cases, a rectal washout is then gently performed using warm saline through a large mushroom catheter connected to a 3-liter irrigation bag. When the rectal effluent is clear, a final digital examination and rigid sigmoidoscopy are done to reassess the relationship of the tumor to the anal sphincters. A bag is secured to the tube, which is left in place to drain the rectum.

Table 1. Instruments Required for Laparoscopic Right Colectomy

No.	*Type*
4	Cannulas (3 × 10-12 mm, 1 × 5 mm) including anchoring devices and converters
1	Dissecting device, eg, Autosonix (USSC, Norwalk, CT)
1	Endoscopic dissector, eg, Maryland dissector
2	Endoscopic graspers (Babcock-like large and small)
1	Endoscopic Babcock clamp
1	Suction-irrigation device
1	Endoscopic clip applicator
1	Multifire endoscopic linear stapler
3	Endoscopic stapler cartridges (2 × 60-mm cartridges, 1 × vascular cartridge)
1	Linear stapler with 2 × 60-mm cartridges

Table 2. Instruments Required for Laparoscopic Proctosigmoidectomy

No.	*Type*
5	Cannulas (3 × 10-12 mm, 2 × 5 mm) including anchoring devices and converters
1	Dissecting device, eg, Autosonix (USSC, Norwalk, CT)
1	Endoscopic dissector, eg, Maryland dissector
2	Endoscopic graspers (Babcock-like large and small)
1	Endoscopic Babcock clamp
1	Suction-irrigation device
1	Endoscopic clip applicator
1	Multifire endoscopic linear stapler
3	Endoscopic stapler cartridges (2 × 60-mm cartridges, 1 × vascular cartridge)
1	Circular end-to-end anastomotic sampling device (28 or 31 mm)

Trocar Cannula Positions

Pneumoperitoneum is created using a standard technique for insufflation with a Verres needle and maintained at 12 to 15 mmHg by an automatic CO_2 insufflator at a high flow rate of 10 to 15 L/min. After the initial 10 to 12 mm cannula has been placed infraumbilically, 2 cannulas are positioned in the right and 2 in the left lateral abdominal wall outside the lateral edges of the rectus muscle, taking care to avoid the inferior epigastric vessels (Fig 2). For right colectomy, the right upper quadrant cannula may be omitted (Fig 3).

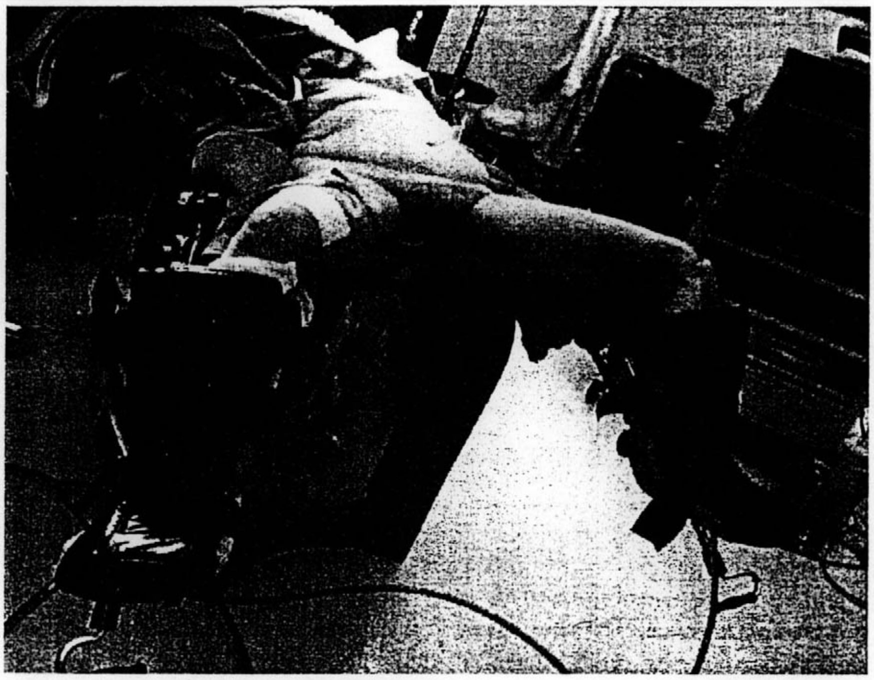

Figure 1. Lloyd-Davies position with specialized padded lithotomy stirrups (OR Direct Stirrups; Acton, MA) and pneumatic intermittent calf compressors.

Procedure

Assessment and Tumor Localization

A general assessment of the peritoneal cavity is made for any inadvertent bowel or vascular injury during access, and whether it is feasible to proceed with and complete the procedure laparoscopically. If the lesion is small or not definitely localized to the cecum or rectosigmoid region, it is best to have it positively identified and marked endoscopically before surgery[21,22] (Fig 4). Alternatively, intraoperative colonoscopic visualization, laparoscopic identification, and marking the distal resection line with a suture may be necessary. The disadvantages of intraoperative colonoscopic tumor localization are the extra time required and the gas insufflation that may distend the bowel and somewhat impair visualization. The bowel distention may be limited by the placement of a clamp across the proximal bowel during gas insufflation. Localization with intraoperative ultrasonography has also been described,[23] but we have no experience with this.

Liver Evaluation

Direct inspection. The reverse Trendelenburg (head-up) position exposes the superior liver surface maximally so that direct inspection via the laparoscope is possible. Our experience is that a flexible, self-washing laparoscope (EL2-TF 410 type 41; Fujinon Inc, Saitama, Tokyo, Japan) enables visualization

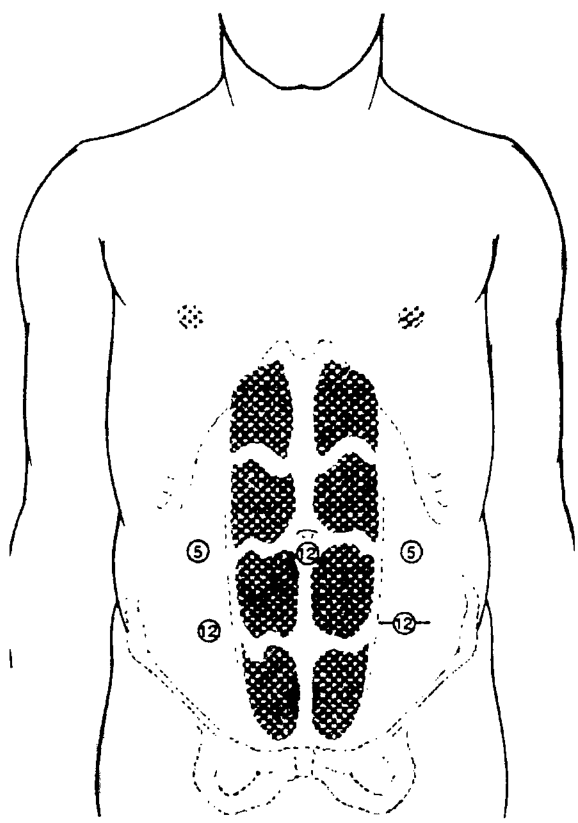

Figure 2. Position of cannulas for proctosigmoidectomy. Numbers indicate size in mm. Dotted lines indicate site of wound extension for specimen retrieval. (Modified and reprinted with permission.[46])

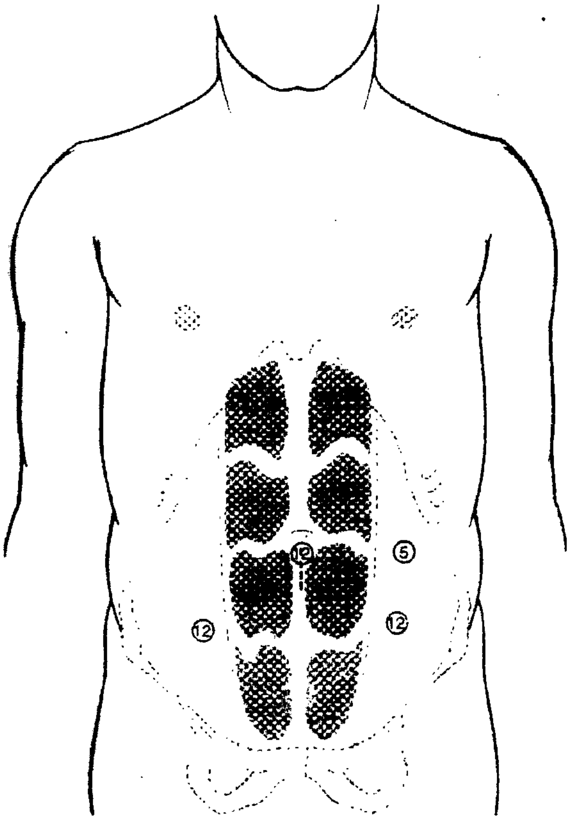

Figure 3. Position of cannulas for right colectomy. Numbers indicate size in mm. Dotted lines indicate site of wound extension for specimen retrieval. (Modified and reprinted with permission.[46])

all the way to the ligamentous attachments of the liver. Often there are benign cysts or hemangiomas that can be recognized on the surface of the liver. Likewise the whitish, desmoplastic appearance of a metastasis may be unmistakable.

Laparoscopic liver ultrasonography. Liver ultrasonography is performed as a standard part of the oncological procedure. All 8 segments of the liver can be evaluated using a 10-mm laparoscopic ultrasonographic probe (UA 1402; Bruel & Kjaer Medical Systems Inc, N. Billerica, MA) passed through the right-lower-quadrant cannula, under the visual guidance of the camera from the umbilical cannula. Laparoscopic liver ultrasonography will readily characterize cysts from hemangiomas from metastases in nearly all patients.[24,25] The procedure is operator-dependent, but inexperienced surgeons may work in concert with radiologist-ultrasound specialists to achieve maximum quality procedures.

Laparoscopic ultrasound-guided liver biopsy. Laparoscopic ultrasonographic probes with a needle-biopsy channel (8666 laparoscopic probe; Bruel & Kjaer Medical Systems Inc) have just become commercially available and should significantly enhance the quality and safety of liver biopsy. It is feasible, however, to use a percutaneous needle puncture approach in the right upper quadrant, with (for deep lesions) or without (for surface lesions) ultrasound guidance when performing a liver biopsy. By holding the probe steady with the suspect lesion under surveillance, a long Tru-Cut (core biopsy) needle can be placed through the body wall in nearly the same plane as the ultrasound beam, puncturing the liver surface just adjacent to the probe. The needle can then be followed with ultrasound guidance into the suspect lesion. The biopsy site can thereafter be examined for bleeding, with the direct application of pressure on the puncture site using a gauze pad inserted into the abdomen through a lower quadrant 10- or 12-mm cannula. Persistent bleeding from the site can be further controlled with electrosurgery applied via a probe from the right-lower quadrant. Only rarely will biopsies result in any significant bleeding.

Right Colectomy

Right and left colectomy are performed in essentially the same manner, except one is the mirror-image of the other. The procedure of right colectomy is described here because it is the more commonly performed. It is our opinion that extracorporeal anastomosis gives an equivalent return of bowel function compared with a totally intraperitoneal approach (Ludwig and Milsom, unpublished data in a canine model, June 1995), and that is what will be described herein.

Vascular ligation and retroperitonel mobilization. Right colectomy for colon cancer should include en bloc resection of the right colon with wide mesenteric clearance, near complete lymphadenectomy of the right colon vascular supply with proximal ligation of ileocolic, right colic, and middle colic vessels. If a cecal or proximal ascending cancer is resected, performing mesenteric transaction with division of the ileocolic vessels and vessels for the hepatic flexure of the middle colic artery may be sufficient.

The patient is placed in the Trendelenburg position and tilted left-side down so that the small intestine falls toward the left upper quadrant. The surgeon stands between the legs with both assistants standing on the left, all looking at a monitor placed at the right shoulder of the patient. The mesentery of the terminal ileum is grasped dorsally with graspers and is placed under tension. In general, the distal

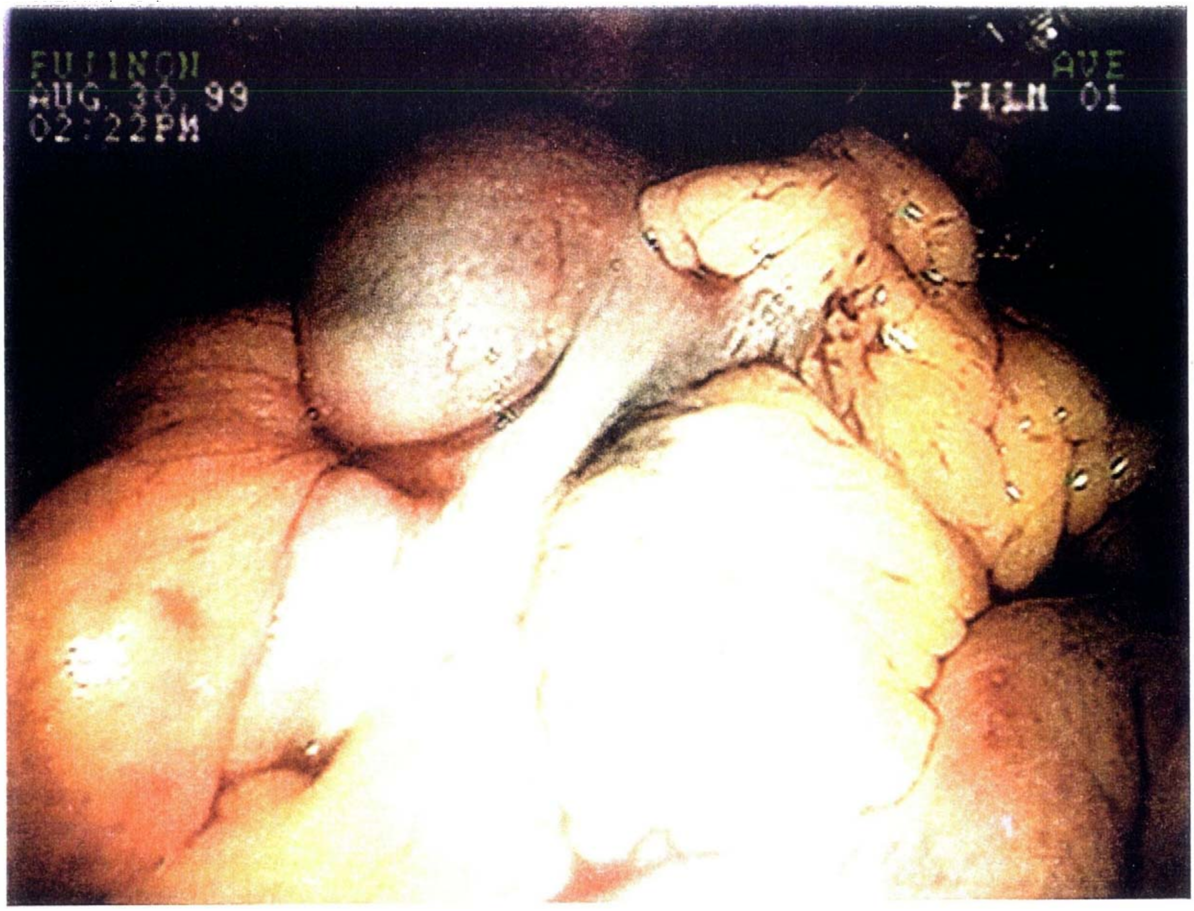

Figure 4. Hepatic flexure tumor marked by preoperative colonoscopic injection of India ink.

part of the ileal mesentery (dorsal aspect) is grasped with a grasper inserted through the left-upper quadrant cannula and the medial portion of the ileal mesentery is held with a smaller grasper through the left-lower quadrant cannula so the graspers do not cross and do not block access for the surgeon's scissors and dissector. Dissection of the mesentery is begun just medial to the base of the appendix and is carried cephalad, medially, and to the left toward the inferior edge of the duodenum. The peritoneum is incised and the right colonic mesentery is completely freed retroperitoneally, creating a tunnel beneath the ileal mesentery in an avascular plane. This tunneling maneuver can be accomplished almost entirely by blunt dissection with sharp transaction of some of the connective tissue fibers between the dorsal aspect of the mesentery and its attachments to Gerota's fascia and the duodenum. For accurate dissection, the assistant must consistently place satisfactory tension on the tissue. When this tunneling is created beneath the mesocolon, the duodenum, the right ureter, the gonadal vessels, and Gerota's fascia become clearly visible and may be swept posteriorly away from the dorsal aspect of the right mesocolon (Fig 5). Blunt dissection may be carried out in a cephalad direction over Gerota's fascia to the inferior edge of the liver and to the second portion of the duodenum.

The ileocolic artery and vein can usually be identified dorsally in the mesentery and may be traced to their origin from the superior mesenteric artery and vein. The right colic vessels, which in only 13% of patients originate directly from the superior mesenteric artery just proximal to the ileocolic artery,[20] are usually found after the mesentery is mobilized from the duodenum and the caudal portion of the pancreas. If the right colic vessels are not present, the surgical team should proceed with the dissection and the ligation of the ileocolic vessels. All vessels are carefully dissected at a safe distance (10 to 15 mm) from the superior mesenteric artery and vein, sweeping any lymph nodes distally to be transected later

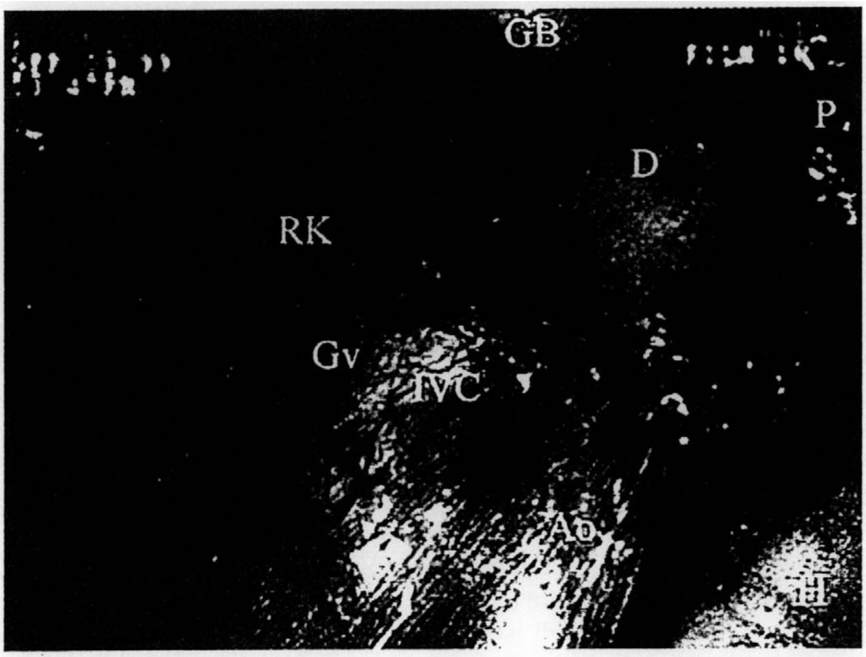

Figure 5. Anatomic relations of the hepatic flexure appreciated during mobilization of the right colon. Ao, aorta; D, duodenum; GB, gallbladder; Gv, gonadal vein; H, hepatic flexure; IVC, inferior vena cava; RK, right kidney; P, pancreatic head.

with the pedicle. A window is made on both sides of the vessels either from the ventral or dorsal aspect. The ileocolic vascular pedicle must be traced distally to the cecum before it is divided so it can be correctly distinguished from the superior mesenteric vessels; these vessels can easily be mistaken for the ileocolic pedicle. Usually, before division, we flip the ileocolic mesentery and the ileum caudally, then carefully examine the vessels from their ventral aspect. The pedicles are then transected with an endoscopic vascular stapler.

Dissection is next carried cephalad from the ventral aspect of the right colonic mesenteric root, continuing medially until the peritoneal reflection of the middle colic vessels is seen. This reflection is divided sharply and the underlying tissue is bluntly dissected to isolate the middle colic vessels. If the right colic vessel has not previously been identified and divided, dissection in the direction of the middle colic vessels should be carried out carefully. Because the middle colic vessels have a high degree of anatomic variability, care in their dissection is essential. By carefully separating the middle colic vessels from the retroperitoneal structures and from the lesser omental sac, the surgeon often will see a cluster of sizeable middle colic vessels arising from the superior mesenteric artery and vein, which may be divided with a 30-mm endoscopic vascular stapler or individually clipped and divided.

Mesenteric and bowel transection. Subsequently, just to the left of the middle colic pedicle, the mesenteric edge of the transverse colon is grasped, the peritoneum is incised from the middle colic pedicle up to the bowel edge, and then the mesentery is divided to this point. Marginal vessels are divided between clips as needed. The greater omental attachments to the transverse colon are then dissected from the colonic edge and the omentum is completely cleared off the transverse colon at the proposed distal resection line. Vessels of the omentum are electrocoagulated or clipped, and divided as necessary. Triangulating tension applied by the assistant throughout this stage is crucial. The transverse colon is then transected with the application of 1 or 2 cartridges of a 30-mm endoscopic stapler, or a single application of an EndoGIA II 60-mm cartridge (United States Surgical Corp, Norwalk, CT).

Next, the terminal ileum is grasped and the proximal resection line is identified. The ileal mesentery is completely dissected starting from the ileocolic pedicle, and any marginal vessels are clipped and divided. Ileal transection is similarly accomplished with an endoscopic stapler. The ileal and transverse colonic ends are tagged together by placement of laparoscopic sutures to facilitate exteriorization later for anastomosis.

Attention is now turned to complete the mobilization of the transected specimen. Because most of the mobilization has been performed dorsally, only the peritoneal attachments of the lateral and posterior abdominal wall will need to be divided. The mobilization starts at the cecum, rolling it in the direction of the splenic flexure so the dorsal and lateral attachments of the right colon up to the hepatic flexure can be divided. Sometimes a thin membrane of connective tissue between the flexure and the superior portion of Gerota's fascia is the last layer of tissue and prevents the hepatic flexure from coming completely free. In these cases, it is sometimes better to complete the mobilization from beneath the mesocolon because the edge of the colonic attachments to the retroperitoneum is easier to visualize from this aspect. The terminal ileum and the cecum are flipped superiorly in the direction of the liver, the duodenum is identified, and the membrane, which may also be attached to the second portion of duodenum, is simply transected until the colon is completely free up to the distal resection line.

Specimen retrieval. An impermeable endoscopic bowel bag, such as the EndoCatch II (United States Surgical Corp), is brought into the abdominal cavity through the left-lower quadrant cannula and the specimen is placed immediately in the bag. The umbilical cannula site is first widened to 15 mm for the introduction of the bag and then further widened with a 3- to 5-cm fascia-cutting incision to remove the bag containing the specimen. The specimen is opened to ensure the tumor-bearing segment has been excised with adequate margins.

Anastomosis. The sutured ends of the terminal ileum and proximal transverse colon are then exteriorized via the extended umbilical wound through a wound protector (Dexterity Protractor, Dexterity Surgical Inc, Rosewell, GA), and a functional end-to-end anastomosis is performed with staplers (GIA 60; United States Surgical Corp).

This technique differs from others that laparoscopically mobilize the right colon first and then ligate the vessels intracorporeally or extracorporeally. We believe our technique as described may have the following advantages:

(1) Manipulation of the tumor-bearing segment is minimal because the colon will be mobilized only after complete mesenteric division. The free-floating mobilized colon is far less manageable in laparoscopic surgery than in conventional surgery, and this practice of leaving the colon in situ until after mesenteric division may lessen the risk of intraperitoneal dissemination of malignant cells.

(2) The named arteries of the right colon are clearly visible posteriorly at their origin from the superior mesenteric artery so an early and proximal ligation can be safely performed. This retromesenteric approach also serves to keep the small intestine out of the operative field, thus facilitating exposure.

(3) Wide mesenteric clearance is easily achieved because the arteries are proximally ligated and maintaining the lateral attachments helps to exert tension on the mesentery during dissection. As long as the right colon is fixed at the lateral wall, countertraction can be applied to the mesentery, which facilitates mesenteric dissection.

(4) Proximal and distal bowel transection with endoscopic staplers before completing the mobilization of the tumor-bearing segment occlude the intestinal lumen, which may minimize the possibility of contamination by intraluminal exfoliated malignant cells.

(5) The specimen can be immediately placed in a bag and can be safely delivered with little risk of spilling intestinal contents or tumor cell dissemination into the peritoneal cavity or the abdominal wound.

Proctosigmoidectomy

Vascular ligation. The patient is placed in a steep Trendelenburg position tilted right-side down so that the small bowel falls into the right upper quadrant. The surgeon and the second assistant stand on the patient's right side looking at a monitor placed near the patient's left knee while the first assistant stands on the patient's left side looking at a monitor placed near the patient's right knee. The camera is placed through the umbilical port and the first assistant holds the mesosigmoid ventrally and to the left under tension using a Babcock-like grasper through the left-upper cannula and a smaller grasper through the left-lower quadrant cannula. The retroperitoneum is incised immediately to the right of the IMA starting at the sacral promontory. Using blunt dissection, a window is created by sweeping the inferior mesenteric artery and vein ventrally and the preaortic hypogastric neural plexus dorsally to prevent injury to them. Dissection is continued from medial to lateral beneath the IMA and vein as the left ureter and the gonadal vessels are identified and swept posteriorly (Fig 6). Holding the sigmoid mesocolon under constant tension is essential; this can be achieved if the assistant grasps the cut edge of the incised peritoneum together with the IMA. Once the origin of the IMA is identified, the peritoneum is incised anteriorly over this pedicle and to the left toward the inferior mesenteric vein. This proximal

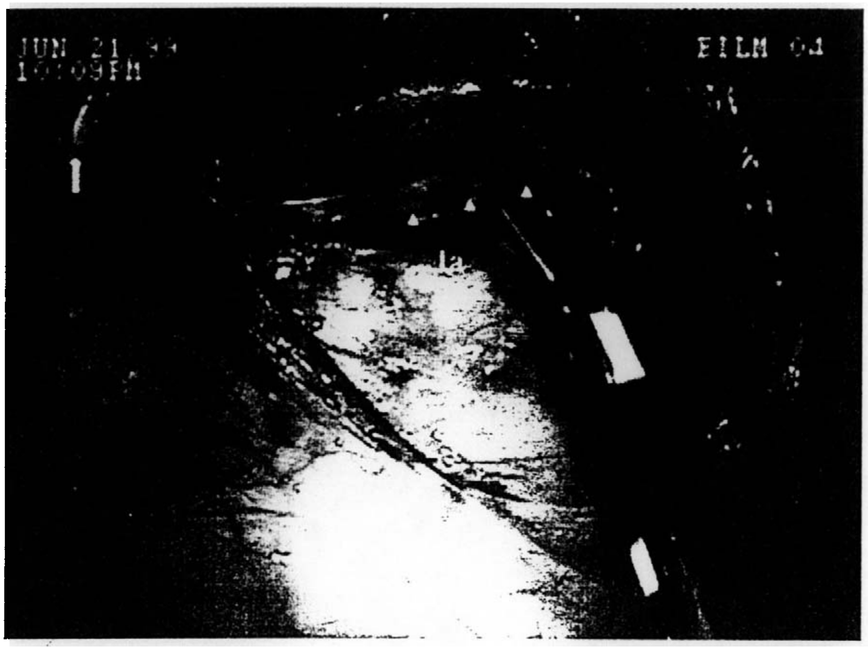

Figure 6. Left ureter (arrowheads) as it crosses the left common iliac artery (Ia). Arrow shows inferior mesenteric artery.

pedicle of the IMA is divided using an endoscopic vascular stapler only if the left ureter can be clearly identified and retracted to avoid injury. Occasionally, the lateral sigmoid attachments may need to be divided and the ureter identified from the lateral side. As in open surgery, we go from "normal to abnormal," "known to unknown," and "easy to difficult." After division, the cut ends of the IMA are held to check for hemostasis and the IMA stump may be additionally secured with an EndoLoop ligature (United States Surgical Corp) as required. Because we skeletonize the IMA pedicle in cancer surgery, the inferior mesenteric vein is usually clipped and divided separately at the inferior pancreatic border.

Mobilization. The dissection is continued in the retroperitoneal plane in a cephalad manner and from medial to lateral, with the assistant lifting the mesentery of the sigmoid and descending colon while the surgeon sweeps the Gerota's fascia (which has a purplish hue) down and away from the posterior surface of the colonic mesentery. Constantly, in the course of this dissection, the surgeon must remain in the correct plane, which is close to the bowel edge laterally and between Gerota's fascia and the colonic mesentery. All medial mesenteric attachments are divided as far cephalad as possible, in a line parallel to and just to the left of the inferior mesentery vein. Occasionally, a left colic or splenic flexure venous branch must be isolated and divided (Fig 7). It is important to stay in the correct plane just anterior to the Gerota's fascia and identify the precise anatomy, especially in thin patients, so that the splenic vein will not be mistaken for the left colic vein (Fig 8). Extreme care must be taken in detaching the posterior mesenteric attachment of the splenic region, because the marginal vessels of the left colon are at risk for injury during this dissection. These vessels are the lifeline of the mobilized bowel, bringing blood from the middle colic vasculature to the left colon.

After the posterior surface of the mesocolon cephalad has been dissected as far as possible, the lateral attachments of the colon are revealed and cut to

Figure 7. DJ, duodenojejunal junction at the ligament of Treitz; LK, left kidney; P, pancreatic body. Arrow shows junction between left colic vein (concave arrowhead) and inferior mesenteric vein (arrowheads).

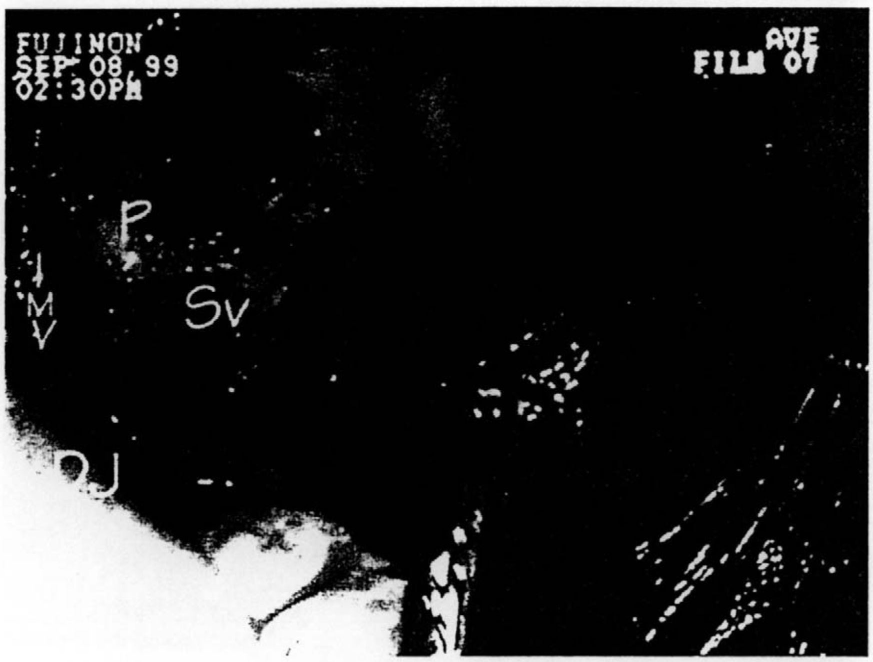

Figure 8. DJ, duodenojejunal junction at the ligament of Treitz; IMV, inferior mesenteric vein; P, pancreatic body; Sv, splenic vein. Note, by comparing with Figure 7, how the splenic vein may be mistaken for the left colic/inferior mesenteric vein, especially in thin patients.

meet up with the medial front of the retroperitoneal dissection. This medial to lateral retroperitoneal approach allows early identification of the left ureter and obviates the loss of domain by keeping the colon attached laterally, thus providing important countertraction as the mesentery and bowel are mobilized.

For the splenic flexure mobilization, the monitor at the left knee is moved up to the patient's left shoulder. The surgeon now stands between the patient's legs, using both cannulas on the left side, while both assistants stand on the patient's right side. At this point, the entire team looks at the monitor at the patient's left shoulder. The splenic flexure should initially be dissected from its posterior and lateral aspect, which expedites complete mobilization of the flexure. In this region, the greater omentum gradually appears and is distinguished from the epiploic appendices by its more lobulated fatty texture. Carefully applied traction and countertraction is essential to reveal the plane between the omentum and the colon. Once the flexure is dissected from the most cephalad attachments of the lienocolic ligament, the omentum is freed from the transverse colon edge toward the midline as far as is required for the descending colon to reach into the pelvis for a tension-free anastomosis.

Mesenteric transection. Using a triangulation method that allows for excellent exposure as well as good tissue tension, the mesocolon is divided up to the colonic edge at the proposed proximal resection line by a combination of blunt and sharp dissection, coagulation of smaller vessels, and clipping of larger vessels.

Proximal bowel transection. This is accomplished by the application of 1 or 2 cartridges of a 30-mm endoscopic stapler, or a single application of an EndoGIA II 60-mm cartridge (United States Surgical Corp). The colon is then tested for reach into the pelvis and further mobilized as required. Occasionally, proximal bowel transection is done early to aid splenic flexure mobilization; the divided proximal bowel is grasped and reflected by applying medial, cephalad, and anterior traction to expose the posterolateral attachments of the left colon. If there is any question about vascular insufficiency, a careful judgment regarding viability of the colon will need to be made when the left colon is exteriorized for placement of the center rod and anvil of the circular stapler (to be described later). Further mobilization of the left colon must be performed as needed until there is no question about viability or tension.

Exposure of pelvic operative field. In general, adequate exposure of the operative field can be achieved by a combination of positioning and retraction with an EndoPaddle retractor (United States Surgical Corp). During pelvic dissection, we have found several additional simple maneuvers that improve retraction and exposure. In a woman, it may be valuable to place a rubber dilator or another rigid instrument intravaginally to elevate the vagina anteriorly to achieve the proper tissue tension and define the rectovaginal plane. A standard uterine manipulator used routinely in gynecologic laparoscopic surgery to manipulate the uterus anteriorly out of the operative field may also be of help when extensive anterior dissection is required. Passing a suture through the uterine fundus and bringing it out through the anterior abdominal wall does just as well in retracting the uterus anteriorly (Fig 9).

A cotton tape encircling the rectosigmoid and clipped to itself can be used for firm but safe rectal retraction during mobilization.[26] Substituting the cotton tape with suture loops passed directly through and then clipped against the anterior abdominal wall externally serves just as well while freeing up one access port. Exposure and dissection down to the pelvic floor in both sexes may be aided by perineal pressure in a cephalad direction to elevate the pelvic floor.

Pelvic dissection. For the pelvic dissection, the surgical team and the monitors assume the original position. The rectum is completely mobilized as far distally as required by the tumor location and toward the pelvic floor using standard open technique of sharp dissection, starting with posterior mobilization, then dissecting posterolaterally to the right and to the left of the rectum, and finally anteriorly. If the proper plane is entered posteriorly, no bleeding will occur and the connective tissue between the fascia propria of the rectum and the presacral fascia can be separated easily by sharp dissection. Division of the lateral ligaments is readily performed under direct laparoscopic vision. Posteriorly, the pelvic nerves are identified (Fig 10) and preserved by keeping the dissection plane anterior to them. The close-up and magnified views of the mesorectum provided by the laparoscope (10 to 20× magnification) ensure the correct planes of dissection with minimal bleeding. This magnified view, in our opinion, allows for better and more precise surgery.

Distal occlusion and rectal wash-out. The distal resection line, optimally at least 2 cm, is precisely identified using intraluminal inspection with a proctoscope and subsequently marked by a laparoscopically placed suture on the bowel wall. The mesorectum is sharply dissected and divided transversely with the ultrasonic shears, clipping any large vessels encountered. It may be most expeditious to divide the mesorectum with an endoscopic vascular stapler after creating a plane between the posterior wall of the rectum and the anterior portion of the mesorectum. Once the distal resection line has been freed of the mesorectum, we achieve distal occlusion by the application of EndoTA staplers or EndoGIA staplers (United States Surgical Corp) from which the cutting knives have been removed. A distal rectal wash-out is then performed transanally with 4% povidone-iodine, which we believe is important in reducing the risk of implantation of exfoliated tumor cells.[27]

Rectal transection. The rectum is transected at a level just below the occluding stapler line with 2 or 3 applications of the 30-mm endoscopic stapler that

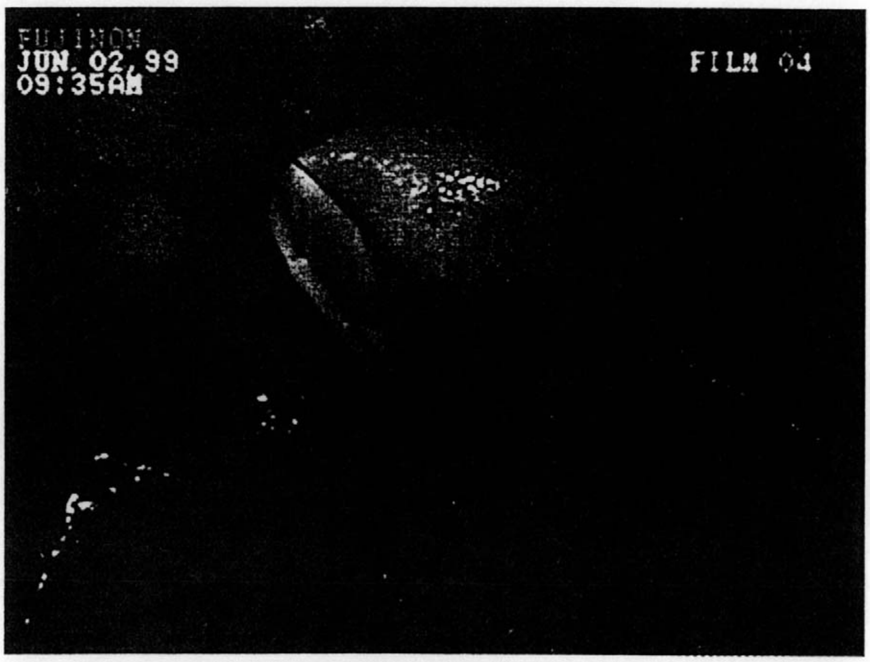

Figure 9. Uterus retracted anteriorly by sutures brought out through the anterior abdominal wall.

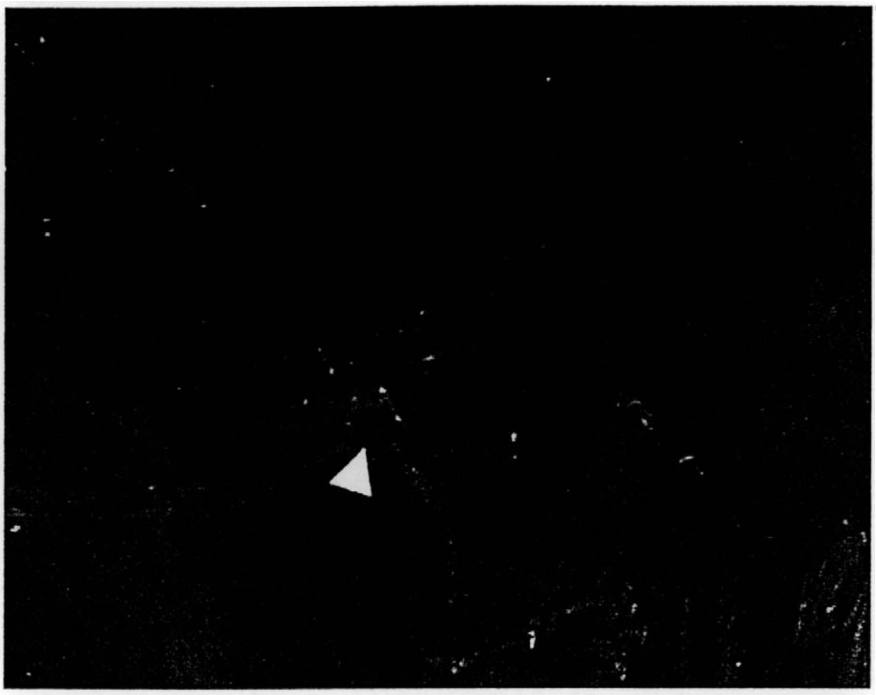

Figure 10. Arrowhead shows hypogastric plexus as seen under magnified laparoscopic view.

has been passed through the right-lower quadrant cannula as perpendicular to the bowel as possible. It is also important to keep the transection line as straight as possible when the multiple cartridges are applied.

Specimen retrieval. The left-lower quadrant cannula site is first widened to 15 mm for the introduction of the bag and then further widened with a 3- to 5-cm muscle-splitting incision to remove the bag containing the specimen.

Anastomosis. The mobilized descending colon is next delivered through the left-lower quadrant wound using the right-upper quadrant grasper that has been used to hold it before the release of pneumoperitoneum. A purse-string (size 0 polypropylene) suture is placed around the cut edge of the proximal colon after excising the previously placed staples. The anvil of a 31-mm circular stapler (Premium CEEA; United States Surgical Corp) is placed into the descending colon lumen and the purse-string suture is tied around the center rod in the usual manner. This end of the bowel is carefully returned to the peritoneal cavity without twisting its mesentery. The abdominal wound is closed with interrupted size 0 polyglycolic acid sutures through all layers of the fascia, using Rumel tourniquets (Fig 11) to tighten them around the left-lower quadrant cannula that is reintroduced. Pneumoperitoneum is reestablished and the anastomosis is then created. A size 2-0 braided suture is loosely tied through the plastic stapler trocar tip. The stapler is inserted transanally and, under laparoscopic guidance, passed to the rectal staple line directed toward the left pelvic side wall to face in the direct line of approach of the center rod coming from the left-lower quadrant. Next, the plastic tip is protruded through the rectal wall just adjacent to the staple line aided by countertraction applied with an endoscopic Babcock instrument. With a grasper in the right-lower quadrant cannula, the thread is pulled to safely dislodge the plastic trocar tip from the center post and to remove it through the cannula under direct vision. A standard double-stapling technique is used to form the colorectal anastomosis by grasping the groove in the center rod with an endoscopic Babcock instrument, through the right-lower-quadrant cannula, then locking the center rod into the center post of the circular stapler. The free edge of the mesentery is followed to ensure hemostasis and no tension or torsion. The small bowel is swept away to the right to prevent obstruction under the free mesenteric edge of the descending colon. Excellent visualization of the anastomosis all around is mandatory before the stapler is fired.

To test the anastomosis for leak, the pelvis is filled with saline to submerge the anastomotic line, and air insufflation of the rectum is performed with a proctoscope while the proximal colon is occluded with a clamp. The tissue donuts created with the circular stapler are checked for completeness and are sent for routine pathological analysis. We believe routine

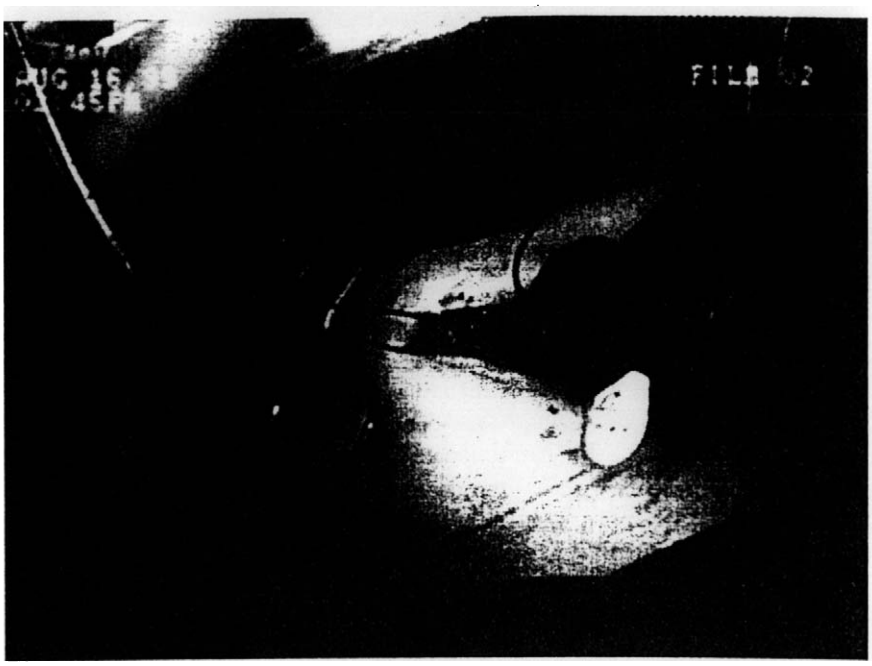

Figure 11. Rumel tourniquets used to tighten sutures around cannulas during fascial closure.

pelvic drainage is not necessary,[28] but if required, a Jackson-Pratt drain may be inserted through the right-lower quadrant cannula site.

Wound Closure

At the completion of the procedure, irrigation and a final examination of the peritoneal cavity is carried out to ensure hemostasis. Cannulas are removed under direct laparoscopic inspection for hemostasis. All 10- to 12-mm sites are closed using conventional techniques or with transabdominal sutures with the cannulas in situ, using the EndoClose suture passing device (United States Surgical Corp).

Specific Considerations and Problems

Hemorrhage

Intra-abdominal hemorrhage is dealt with in a deliberate, systematic way. If a moderately sized or large mesenteric vessel is bleeding, it should be precisely grasped at the site of bleeding. This action usually stops the hemorrhage so clips may be safely and accurately applied on both sides of the vessel. Occasionally, if the puncture site cannot be located precisely, the bleeding vessel is grasped, and a gentle twisting of the tissue about the long axis of the grasping instrument may result in hemostasis. Further dissection can then be carried out and the vessel can then be clipped or coagulated. The suction-irrigation instrument and a piece of gauze inserted via one of the cannulas can be extremely useful in clearing the field during hemostasis. It may sometimes be safer and more efficacious to suture ligate bleeding mesenteric tears than repeated attempts at electrocoagulation. After successful hemostasis, the field is irrigated and suctioned before proceeding with further dissection. Always, a precise definition of vital structures in the operative area must be achievable during laparoscopy, or the procedure should be converted to an open one.

Conversion to Open Procedure

The decision to convert to an open procedure is based on judgment and experience. Very often, this can and should be made early in the operation by an accurate assessment of the tumor factors and peritoneal conditions, rather than after a tedious trial of dissection. Dense adhesions, poor visualization of tissue planes (usually from bowel distention, gross obesity, or inflammation), and inability to control hemorrhage and identify the relevant anatomy are common reasons for conversion. When a solitary liver metastasis is visible on the surface and may be resectable (small peripheral lesion) at the same time as the colorectal cancer primary, the surgeon must consider whether to convert to an open procedure so as to perform the 2 resections in the most efficacious manner. In instances of multiple hepatic lesions, with no other sign of metastasis, it may be feasible laparoscopically to insert a catheter into the common hepatic artery for chemotherapy, but we have no experience with this and would proceed to an open operation.

Measures to Prevent Port-Site Recurrence

The wide variation in port-site metastasis previously reported likely relates to surgical technique. Even in conventional colectomy, the experience of the surgeon performing the operation seems to influence development of local recurrence and survival.[29] Franklin et al[30] recommended the following: (1) suture all trocars to prevent their dislodgment and sudden desufflation during pneumoperitoneum; (2) use endoscopic bag for extraction of the specimen; (3) wash trocars with 5% povidone-iodine before removal; (4) remove intra-abdominal fluid before trocar removal to prevent wound contamination; (5) close all trocar sites including fascia, muscle, and peritoneum; (6) avoid direct handling of the tumor; and (7) irrigate all skin and subcutaneous sites with povidone-iodine solution before closure. Although there is no evidence that these steps will prevent port-site metastasis, we believe they may be important in standardizing techniques that surgeons should be cognizant of in laparoscopic oncological resections.

Mesorectal Excision With Autonomic Nerve Preservation

During radical high ligation of the IMA, hypogastric nerve damage is most frequently encountered over the front of the aorta and below the sacral promontory.[31,32] Special care should, therefore, always be taken not to injure the hypogastric nerves during high ligation of the IMA. On the basis of the anatomic relationship among hypogastric nerves, splanchnic nerves, the middle rectal artery, and the pelvic fascial planes, Havenga et al[33] reported that total mesorectal excision is compatible with autonomic nerve preservation. We believe laparoscopy provides better visualization of the operative field in a deep and narrow pelvis, and that better visualization for the surgeon and his assistants is the first step towards doing a better cancer operation. In addition, the magnified view provided by laparoscopic surgery may offer better precision in performing high ligation of the IMA and mesorectal excision with autonomic nerve preservation. It is, however, crucial to operate with good hemostasis because blood can seriously obscure laparoscopic views. We have recently assessed the feasibility of laparoscopic techniques for mesorectal excision using a human cadaver model with very positive results with regards to nerve preservation and completeness of mesorectal excision.[34]

Postoperative Care and Complications

Postoperative care and management do not differ from conventional surgery. There are, however, a few complications that are specific to laparoscopic surgery that can occur. Patients should be checked routinely for subcutaneous emphysema and reassured that the apparent deformities will usually disappear within about 24 hours. Referred pain to the shoulder tips occurs commonly in the early postoperative period and does not indicate a catastrophic event in the absence of other corroborating clinical signs. Anastomotic leaks and small bowel obstruction are managed in the same way as after conventional surgery. Contrast-enhanced CT scans are helpful in the evaluation of such cases and can diagnose a Richter's hernia at a port-site that mimics a wound hematoma. Any reoperation that may be required is best done as an open procedure.

Contraindications

Laparoscopic curative resection of colorectal cancer has 3 major contraindications: (1) infiltrating, (2) large and bulky, and (3) obstructing or perforated tumors. Infiltration of adjacent structures by a cancer is an indication for an open procedure because currently an en bloc multivisceral resection cannot be managed laparoscopically, although in selected cases of small bowel, bladder, uterus, fallopian tubes, and ovary involvement, en bloc resection (with EndoGIA staplers) may still be feasible without compromising curative intent. We avoid laparoscopic resection of any tumor larger than 8 cm in diameter because controlling a large mass in the peritoneal cavity using laparoscopic techniques is difficult. In any case, such a lesion would require a long abdominal incision to remove intact. Obstruction leading to significant bowel distention makes for difficult overall visualization and exposure of the mesentery for proximal lymphovascular ligation and is best managed with conventional open techniques.

Results

Most published series conclude that the laparoscopic technique is promising and may be used for benign colorectal diseases,[35,36] having shown laparos-

Table 3. Published Prospective Randomized Trials Comparing Laparoscopic Versus Open Surgery for Colon Cancer: Operative Details

Author	*Origin*	*Year*	*Follow-Up (months)*	*Number*		*Conversion (%)*	*Blood Loss (mL)*		*Op Time (min)*		*Lymph Nodes*	
				Lap	*Open*		*Lap*	*Open*	*Lap*	*Open*	*Lap*	*Open*
Lacy[39]	Spain	1995	6.5 (1-12)	25	26	4/25 (16)	107 ± 104	217 ± 268*	148.8 ± 45.5	110 ± 49.3†	13 ± 5.4	12.5 ± 7.7*
Stage[4]	Denmark	1997	14 (7-19)	18	16	3/18 (16.7)	275 (50-2100)	300* (50-2150)	150 (60-275)	95 (40-195)†	7 (3-14)	8 (4-15)*
Milsom[40]	USA	1998	20 (1.5-48)	42	38	4/42 (9.5)	252 ± 222	344 ± 626*	200 ± 40	125 ± 51†	19 (5-59)	25 (4-74)*

Abbreviations: Lap, laparoscopic surgery; Op, operative.
*Not significant.
†Significant.

copy to be accompanied by fewer complications, shorter hospital stay, more rapid convalescence, and less immunosuppression.[37,38] These trials, however, included selected patients and have been mainly uncontrolled, nonrandomized clinical series. Additionally, there are several recent reports that question whether there are any quantifiable advantages of laparoscopic compared with conventional open surgery.[3-5]

In several controlled studies, however, laparoscopic resection of primary colorectal cancers has been reported to be technically feasible and safe.[4,39,40] Histopathologic comparisons of cancer clearance between laparoscopic and open resections in controlled studies have also shown no difference in surgical margins, lymph node clearance, and tumor stage.[4,39,40] In addition, these studies report similar or reduced number of complications in the laparoscopic resection group compared with conventional open surgery.[4,5,39] In a recent prospective randomized study comparing laparoscopic versus open conventional resection of colorectal cancers, we found that at least in the short term (with median follow-up of 1.5 years for laparoscopic resection and 1.7 years for open resection), there was no statistically significant difference in survival and recurrence between the 2 groups. In that controlled study, there was no port-site recurrence at a median of 2 years in the 42 patients who underwent laparoscopic resection of colorectal cancers.[40] Based on more recent reports of larger operative series, the incidence of port-site metastasis seems to be only 0% to 1.1%. This figure approximates the results of wound metastasis after conventional open surgery.[41] It would seem from current data that port-site recurrence occurs as an early but rare phenomenon and is not unique to laparoscopic surgery.[42]

Although 2 recent prospective randomized trials have shown laparoscopic colorectal surgery to result in earlier discharge and less pain[4] and faster recovery of pulmonary and gastrointestinal function[40] with no apparent short-term oncological disadvantages, their numbers were small and longer follow-up is required to fully assess oncological outcomes.

The key features of the few published prospective randomized trials[4,39,40] comparing laparoscopic versus open surgery for colorectal cancers are summarized in Tables 3 and 4.

Future Developments

Multicenter Prospective Randomized Trials

Some of the strongest statements about outcomes of laparoscopically assisted colectomy versus open colectomy for colon cancer will lie with the reporting

Table 4. Published Prospective Randomized Trials Comparing Laparoscopic Versus Open Surgery for Colon Cancer: Results

Author	*Passage of Flatus*		*Length of Stay (days)*		*Morbidity (%)*		*Mortality (%)*		*Port Site Recurrence*
	Lap	*Open*	*Lap*	*Open*	*Lap*	*Open*	*Lap*	*Open*	
Lacy[39]	35.5 ± 15.7 h	71.1 ± 33.6 h†	5.2 ± 1.2	8.1 ± 3.8†	2 (8)	8 (30.8)	1 (4)	0 (0)	Nil
Stage[4]	—	—	5 (3-12)	8 (5-30)†	2 (11)	0 (0)	0 (0)	0 (0)	Nil
Milsom[40]	3 days (0.8-8)	4 days (0.8-14)†	6 (3-37)	7 (5-24)*	8 (15)	8 (15)	1 (1.8)	1 (1.8)	Nil

Abbreviation: Lap, laparoscopic surgery.
*Not significant.
†Significant.

of at least 3 large multicenter prospective randomized trials that are well under way: the NCI/NCCTG-934653 Phase III study[43] with 1,200 patients to be entered, the Colon cancer laparoscopic or open resection (COLOR) trial[44] with 1,500 proposed patient accrual, and the MRC Conventional versus laparoscopic-assisted surgery for colorectal cancer (MRC-CLASICC) trial with 1,200 patients to be accrued. Although these multicenter trials can tell us about the efficacy (the extent to which an intervention does more good than harm under ideal circumstances—'Can it work?'), they may not quite elucidate the effectiveness (whether an intervention does more good than harm when provided under usual circumstances of health care practice—'Does it work in practice?') and efficiency (the effect of an intervention in relation to the resources it consumes—'Is it worth it?') of laparoscopic techniques applied to the management of colonic malignancy. This is so because there are strict patient selection criteria, and it is difficult to standardize operative techniques, both in laparoscopic and conventional surgery. Nonetheless, these trials will hopefully answer questions of safety and equivalency with respect to oncological end points.

Advances in Perioperative Care

Although much effort and attention are focused on basic science research and technological advances, it must not be forgotten that the perioperative management of surgical patients, both laparoscopic and conventional, can continue to improve, eg, with techniques such as integrated multimodal rehabilitation programs that have enabled the performance of the 48-hour colectomy.[45]

Advances in Technology, Instrumentation, Documentation, and Surgical Education

Better pelvic retractors, alternative energy sources for tissue dissection and approximation, angulating endoscopic staplers, multipurpose instruments and monitors, innovations in optics, view-enhancing devices and 3-D imaging, advances in robotics technology, and laparoscopic instruments that offer tactile feedback (Ohgami M, Watanabe M, personal communication), among others, will advance laparoscopic bowel surgery and are either already available or on the horizon. We believe that, although much progress has already occurred, much more development in these procedures lies ahead in the next 5 to 10 years.

We have found that a unified team approach is especially helpful for maximizing outcome and decreasing the overall operative time, and we believe that laparoscopic instrumentation development will herald an exciting future in video-documentation of operative records while enhancing the learning experience of the entire surgical team.

Conclusion

Laparoscopic colectomy for cancer seems safe when performed by experienced surgeons, although there is a considerable learning curve for the procedure. The expected benefits of minimal access surgery are being shown by laparoscopic colectomy, although these benefits have not been as readily demonstrable as those seen with other procedures. It is clear that an equivalent resection can be performed, but it is not clear yet that this translates into an equivalent recurrence and survival rate because 5- and 10-year outcomes are needed to prove this. Early results of laparoscopic colectomy for cancer are encouraging. While the results of large multicenter trials are being eagerly awaited, laparoscopic techniques are continuing to evolve and improve as a result of technological breakthroughs and advances in basic science and clinical research.

We are in the midst of a slow "laparoscopic revolution" in treating colon and rectal diseases. We believe that laparoscopic techniques are evolving but currently enhance patient outcomes and allow us to do better surgery. We eagerly await outcome validation of the expected better results compared with conventional surgery and anticipate further definite advances that will benefit patients with colon and rectal cancers.

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