Introduction

Almost 150,000 new cases of colorectal cancer are diagnosed each year in the United States, making them the fourth largest group of new cancer patients. Consequently, colorectal cancer claims 50,000 lives annually. Ninety to ninety-five percent of colon tumors are adenocarcinomas; less frequent types include carcinoids, stromal tumors (formerly leiomyosarcomas), lymphomas, and undetermined lesions. Surgery remains the cornerstone of curative therapy, with the greatest technical advances made in recent years using minimally invasive methods, including laparoscopy and robotics. Indeed, multiple randomized trials have demonstrated equal outcomes for the traditional open approach and the laparoscopic approach to colon cancer surgery.

Regardless of the type of surgical approach to colon cancer, location continues to be the major determinant of the type and extent of colon resection; the degree of resection is based on the arterial, venous, and lymphatic drainage of the affected colon segment. Furthermore, medical societies and healthcare payers are increasingly relying on the adequacy of lymph-node resection, and therefore the number of nodes examined histologically, as a benchmark of satisfactory oncologic therapy.

In this section, the surgical techniques will be outlined, but whenever appropriate, laparoscopic techniques will also be highlighted.

Colon

Surgical Anatomy

Topography

The length of the colon ranges from 120 to 200 cm in length; the luminal diameter is greatest at the cecum (7.5 cm), but gradually diminishes to 2.5 cm in the sigmoid colon. External anatomic characteristics of the colon that distinguish it from the small bowel include the taenia coli, the haustralsacculations of the bowel wall, the appendix epiploicae, and the attachment of the greater omentum to the transverse colon.

Colon surgery and lymph-node harvest are based on the vascular supply of their subsegments. The colon and rectum derive from the embryologic midgut and hindgut, with the blood supplies following the superior mesenteric artery and inferior mesenteric arteries, respectively. Derivatives of the midgut include the cecum and the right-half to two-thirds of the transverse colon. The derivatives of the hindgut are the left one-third to one-half of the transverse colon, the descending colon, the sigmoid colon, the rectum and the superior portion of the anal canal.

Cecum

The cecum is located in the right iliac fossa and is approximately 10 cm long, with the widest transverse diameter of all the colon segments averaging 7.5 cm. It is completely enveloped with the visceral peritoneum and is typically mobile. The gonadal vessels and the right ureter typically course posterior to the medial border of the cecum. The terminal ileum empties into the cecum from a medial-to-lateral direction through a thickened invagination called the ileocecal valve. The valve prevents retrograde flow from the colon into the small bowel, but in approximately 25-30% of individuals, the ileocecal valve is incompetent. The incompetent valve is most evident during colonoscopies when colonic air readily passes into the small intestines, resulting in marked abdominal distention and patient discomfort. Clinically, patients with distal colonic obstructions and functional ileocecal valves typically have colonic dilatation on radiography that mimics a closed-loop obstruction. While the cecum is quite distensible, a diameter greater than 12 cm can result in ischemic necrosis and perforation.

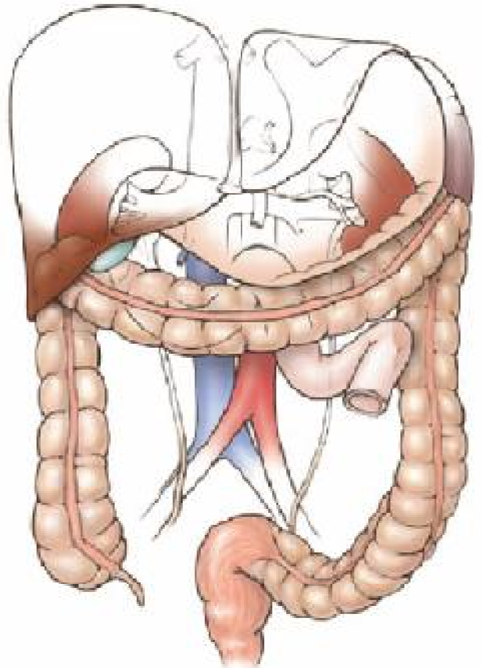

Figure 2

Ascending Colon

From the cecum, the ascending colon is the 12-20 cm segment that runs upward toward the liver on the right side. With the exception of its posterior surface, which is fixed to the retroperitoneum, the ascending colon is covered laterally and anteriorly by the visceral peritoneum.

Middle colic artery

For the surgeon, the psoas muscle, the second portion of the duodenum, the right ureter, and the inferior pole of the right kidney, all have important anatomic relationships to the ascending colon.

The ascending colon is laterally attached to the parietal peritoneum along the white line of Toldt-an area that represents an embryonic fusion plane between the visceral and parietal peritoneum. This subtle anatomic landmark is relatively avascular and serves as the classic landmark for surgical mobilization of the ascending colon away from its retroperitoneal attachments.

The hepatic flexure is the segment of the ascending colon that rests under the right liver lobe and turns medially and anteriorly into the transverse colon. The hepatic flexure can often be identified during colonoscopy by a purplish impression on the superior aspect of the colon wall when the scope reaches the right side.

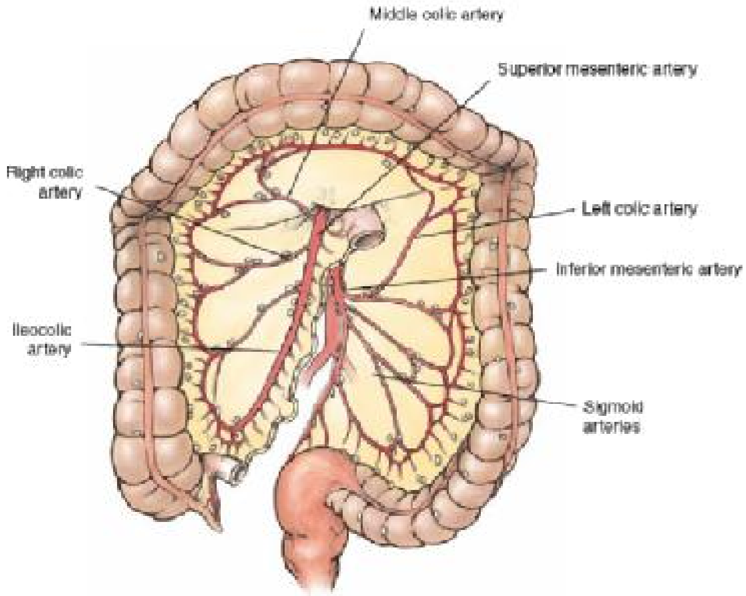

Figure 2

Transverse Colon

The transverse colon is suspended between the hepatic flexure and the splenic flexure and spans 40-50 cm, sharing important anatomic relationships with the stomach, the tail of the pancreas, the spleen, and the left kidney. It is completely invested with peritoneum and has a long mesentery known as the transverse mesocolon, referred to as the colon's most mobile portion. Indeed, it is not infrequent to find women who have transverse colons that reach into the pelvis. Anatomically, the transverse colon is attached to the greater curvature of the stomach by the gastrocolic ligament or omentum. The greater omentum descends off the inferior aspect of the transverse colon. Locally advanced tumors of the transverse colon may involve the stomach, pancreas and duodenum posteriorly, and the spleen, as well as the omentum.

Descending Colon

The descending colon extends 25-30 cm from the splenic flexure to the sigmoid colon along the left gutter of the peritoneal cavity, forming important posterior anatomic relationships with the kidney, ureter, and iliac vessels at the pelvic brim. This segment is narrower than the ascending colon, but is similar to it in that it is covered by visceral peritoneum except for its posterior aspect, where it is fixed to the fascia of the quadratumlumborum muscle. The descending colon is also fused laterally to the parietal peritoneum, forming the avascular white line of Toldt.

Sigmoid Colon

At the pelvic brim, the sigmoid colon is located at the lower end of the descending colon and usually extends to the third sacral vertebrae. The entire length is variable but averages 35-40 cm in length. Unlike the descending colon, which is thin-walled and fixed, the sigmoid colon is thicker, mobile, and completely invested in visceral peritoneum. The long floppy mesentery of the sigmoid colon enables the formation of omega loops in the pelvis. More importantly, the mesosigmoidis generally fixed to the left lateral pelvic wall and forms the intersigmoid recess (fossa) which overlies the left ureter as it courses over the iliac vessels. The sigmoid colon ends at the confluence of the teniae coli at the rectosigmoid junction. Endoscopically, because the teniae coli cannot be visualized, the National Cancer Institute defines the rectum to be the last 12 cm above the anal verge as measured by rigid sigmoidoscopy.

Blood Supply

Arteries

The right colon and up to two-thirds of the proximal transverse colon are derived from the midgut, a region supplied by the superior mesenteric artery. The distal transverse colon and left colon are derived from the hindgut, supplied by the inferior mesenteric artery. These two arterial systems arborize along the mesenteric border of the colon, forming the marginal artery of Drummond. This marginal system is formed by tributaries from the ileocolic, right colic, middle colic, left colic, and sigmoid arteries, and spans from the ileocecal valve to the rectosigmoid colon. All the terminal vessels that vascularize a limited area of bowel wall are supplied by these arteries. Collateralization is excellent along the marginal arteries, serving as an important source of a segment's blood supply when a major vessel is occluded. The presence of these marginal arteries also allows the sacrifice of major vessels, facilitating the colon's mobilization for distal anastomosis.

The SMA supplies the entire small bowel with 12-18 jejunal and ileal branches to the left and three major colonic branches to the right. The ileocolic vessel is the most constant of these branches and supplies the terminal ileum, appendix, and cecum. The right colic artery is the most variable blood supply of the colon, and may be absent in up to 20% of patients. When present, the right colic artery can originate from the SMA, as a branch of the ileocolic artery or middle colic artery. The right colic artery communicates with the middle colic artery through the marginal arteries.

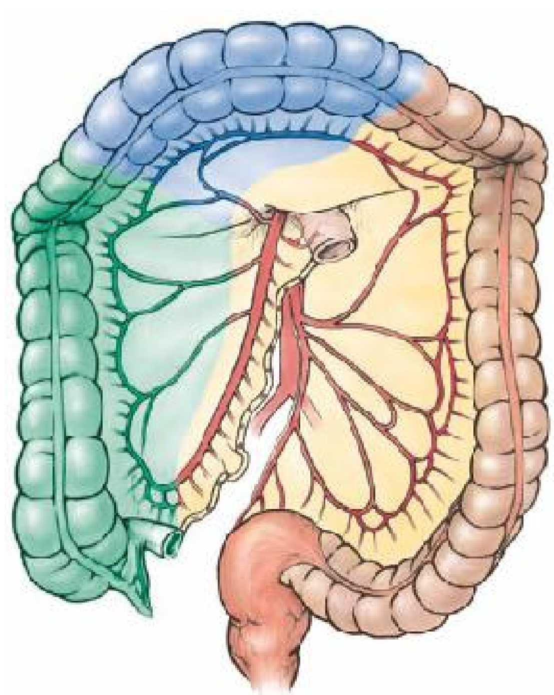

Figure 3

The middle colic artery is a major blood supply to the colon and is an important surgical landmark when planning a colon resection because it is a demarcation point for the clinical definition of a right or left hemicolectomy. This artery arises proximally as the superior mesenteric artery enters the small bowel mesentery at the inferior border of the pancreas. The middle colic artery then ascends into the transverse mesocolon, and typically divides into the right and left colon blood supplies through the marginal artery. The middle colic may also be absent in some patients and the presence of an accessory middle colic artery may be found in 10% of patients.

The left colon receives its blood supply from the inferior mesenteric artery which originates from the L3 level. Like the SMA, the IMA also gives three principle branches: the left colic, sigmoid, and superior rectal arteries. Unlike the SMA, the IMA is more constant in distribution. The first branch of the inferior mesenteric artery is the left colic artery, which divides into ascending and descending branches as it passes upward. The ascending branch anastomoses with the branches of the middle colic artery, a system that supplies the distal transverse colon and splenic flexures. After supplying the left colon, the descending branch joins branches of the sigmoid artery.

Originating from the inferior mesenteric artery, the sigmoid artery divides into ascending and descending collateral branches as it travels through the sigmoid mesocolon. The descending branch supplies the sigmoid colon; the ascending vessels merge with the marginal artery system. The terminal vessel of the inferior mesenteric artery is the superior rectal (hemorrhoid) artery.

The blood supply to the splenic flexure is most inconsistent, relying on collateral circulation supplied by the left branch of the middle colic and the ascending branch of the left colic arteries. This "watershed" area is vulnerable to ischemia during low splanchnic blood flow. In light of this, bowel anastomoses in the region of the splenic flexure is fraught with risks of leaks and breakdowns.

Veins

The colon's venous anatomy parallels the arterial supply of the corresponding midgutor hindgut-derived segments. Drainage of the midgut-derived right colon is achieved by the superior mesenteric venous system, which includes the ileocolic, right colic, and middle colic veins. This configuration forms the superior mesenteric vein and joins the splenic vein to empty into the portal venous system. Drainage of the left colon derived from the hindgut is accomplished by the inferior mesenteric venous system, which differs from the superior mesenteric venous system by joining the splenic vein before entering the portal vein. The course of the inferior mesenteric vein only courses partially with the inferior mesenteric artery, but continues in a cephalad direction to the splenic vein. Due to its proximity to the left renal vessels, the inferior mesenteric vein may be inadvertently ligated during left nephrectomy. In some instances, ligation of the IMV can be performed if additional descending colon length is necessary to reestablish colorectal continuity (i.e., allow the descending colon to reach the pelvis).

Lymphatic Drainage

The lymphatic drainage starts from the lymphatic follicles with the colonic submucosa, and drains through the muscularis layer into the epicolic nodes. From the epicolic nodes, drainage continues to the paracolic lymph nodes. The paracolic nodes drain into intermediate lymph nodes that course along the major arteries and are clustered at bifurcations. The terminal lymph node basins are the principle lymph nodes at the aorta. These principle lymph nodes are the celiac, superior mesenteric, and the inferior mesenteric lymph-node groups, which eventually drain into the cisterna chyli.

Most surgical resections for tumors should include the intermediate lymph nodes. The Intergroup 0089 trial for adjuvant chemotherapy in Stages II and III colon cancer treatment showed that the best survival is evident when greater than 20 negative lymph nodes are evaluated for Stage II cancer, and greater than 40 lymph nodes evaluated for Stage III cancer. These findings may suggest more refined staging from adequate lymph-node evaluations, rather than confer causation. For the present, the National Cancer Institute Guidelines 2000 recommends a minimum of 12 lymph nodes in the resected specimen for adequate tumor staging, which also serves as a benchmark for adequate oncologic resection.

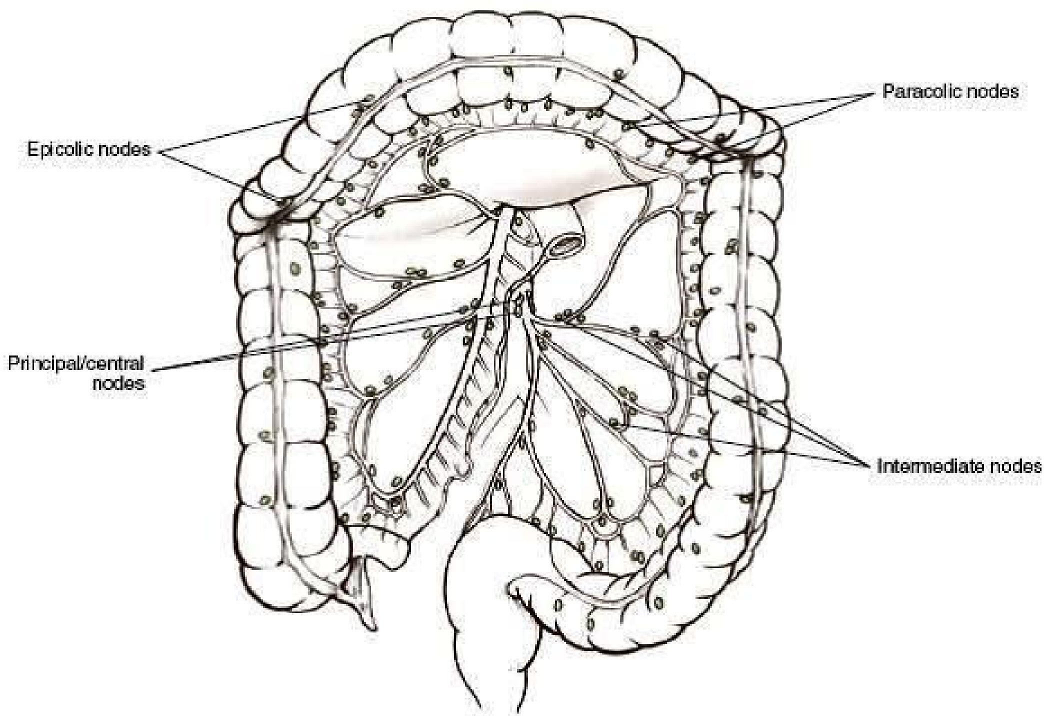

Figure 4

Nerve Supply

Just as in the small intestine, the colon contains ganglia in both the submucosa and myenteric plexi. These plexi receive extrinsic innervation from the parasympathetic and sympathetic divisions of the autonomic nervous system, and the neural supplies are thought to parallel the vascular supply.

The sympathetic nerves consist of afferent and efferent fibers originating from T6 to T12. The postganglionic efferent fibers follow the superior mesenteric artery as it branches to supply the right colon. Left colon and rectum sympathetic fibers originate from L1 to L3 and pass through the preaortic plexus located above the aortic bifurcation, and the postganglionic fibers follow the branches of the IMA, superior rectal artery to the left colon, sigmoid, and rectum.

The right and transverse colon parasympathetic supply comes from the right vagus nerve, and these fibers travel with the branches of the SMA and enter the bowel wall. The origins of the parasympathetic innervation to the left colon are less clear, but are believed to originate from the S2 to S3 spinal segments.

Surgical Applications

Surgical resection continues to be the primary therapeutic method for malignant tumors of the colon. However, screening colonoscopy and possibly CT colonography remain the most effective modalities for the detection of early or premalignant disease. In endoscopically unresectable tumors, the particular tumor's location determines the extent of resection, and the vascular supply and lymphatic drainage to the mesenteric segment define the boundaries of resection.

Most patients undergoing elective colon resection for tumor have had cancer screening to determine distant metastasis or synchronous colonic lesions. Currently, this screening includes biochemical evaluations, positive emission tomography-CT scan, possibly MRI and additional colonoscopic evaluations. Aside from the cecum and rectum, the accuracy of exact tumor location cannot always be ascertained by colonoscopy. Surgical strategy can be anticipated if precise tumor localization can be marked preoperatively by double contrast colonography when feasible or endoscopic ink tattooing or clip marking. Intraoperative colonoscopy to localize the tumor is time-consuming and may unnecessarily induce bowel distention.

An important component of preoperative preparation is mechanical bowel preparation, which classically consists of administration of a polyethylene glycol electrolyte solution, oral nonabsorbable antibiotics, intravenous antibiotics. Alternatives to colon cleansing may be used as long as they can effectively decrease contamination and bacterial load. One should be mindful that left colon tumors are more likely to cause obstruction than right colon tumors due to the smaller lumen size. In order to prepare the obstructed left colon, diverting loop colostomies followed by resection is an option. If a diverting colostomy is to be performed, it is advisable to plan the ostomy at or near the area of planned resection so that the ostomy can be incorporated in the specimen at a later resection. Another option for temporarily relieving the obstruction is to place a colonic stent and allow the bowel to decompress while preparing the patient for elective surgery over the ensuing 2 weeks.

The major surgical procedures for the colon include right hemicolectomy, extended right hemicolectomy, extended left hemicolectomy, left hemicolectomy, rectosigmoid resection. Three main considerations increase anastomotic complications in reestablishing intestinal continuity; lack of demonstrable pulsatile arterial blood flow, tension between the two ends of colon, and perianastomotic hematoma or contamination. Other issues that may increase anastomotic complications include sepsis, circulatory shock, carcinoma at the anastomosis, preoperative radiation.

Standard resections for colon tumors	
Tumor location	Resection
Cecum/appendix	Right hemicolectomy
Ascending colon	Right hemicolectomy
Hepatic flexure	Extended right hemicolectomy
Transverse colon	Extended right hemicolectomy
Splenic flexure	Left colectomy and distal transverse colon (or extended left hemicolectomy)
Descending colon	Left hemicolectomy
Sigmoid colon	Rectosigmoid resection

Right Hemicolectomy

Tumors located in the appendix, cecum, or ascending colon often require a righthemicolectomy, the anatomic boundaries of which span the cecum to the proximal half of the transverse colon.

An extended right hemicolectomy includes the transverse colon to the splenic flexure that includes the left branch of the middle colic artery. This procedure is appropriate for tumors at the hepatic flexure and the transverse colon. Many surgeons avoid isolated transverse colon resections because a hepatic flexure to splenic flexure anastomosis is a problematic one in terms of tension and uncertain blood supply.

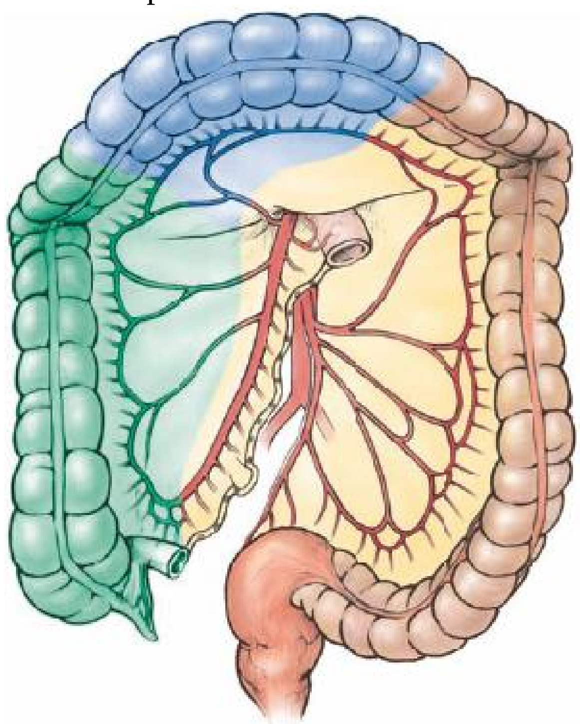

Figure 5

Abdominal incisions used to perform a right hemicolectomy may vary, with choices including a midline, paramedian, transverse supraumbilical, or even a Pfannestiel incision. The peritoneal cavity is inspected for gross metastasis. A solitary hepatic metastasis may be resected at the same time, but with appropriate presurgical evaluations, this occurrence is generally anticipated rather than unexpected.

The planned resection for right hemicolectomy includes the final 6 cm of the ileum and the proximal transverse colon. Tumors of the cecum should include 10-15 cm of the ileum. The ileocolic, right colic, and right branch of the middle colic vessels are ligated at their origins and the mesentery removed with the colon. For tumors located in the transverse colon, the middle colic vessel should be ligated before the bifurcation at the inferior border of the pancreas. It is probably best to avoid direct manipulation of the tumor during the dissection, but this is more a surgeon preference.

Mobilization of the right colon begins from the cecum toward the hepatic flexure. The colon is retracted medially so that electrocautery can be used to release the lateral peritoneal attachments along the line of Toldt. This can be accomplished by placing the left index finger behind the peritoneal attachments while using electrocautery above the finger.

Mobilization of the right colon is completed when the hepatic flexure is freed from the liver superiorly and from the duodenum posteriorly. The renocolic ligament that anchors the hepatic flexure may be thick and should either be tied with 2-0 suture ligation, divided with ultrasonic shears or electrothermal bipolar device (LigaSure, Covidien, Boulder, CO). The gastrocolic ligament can be divided just below the gastroepiploic arcade of the stomach using the same energy sources. The omentum attached to the resected colon can also be taken with the specimen. There are three areas of caution during cephalad mobilization of the right colon: (1) excessive mobilization deep to the mesentery and entering Gerota's fascia, (2) avulsion of a collateral venous branch between the inferior pancreaticoduodenal and middle colic veins, and (3) injury to the second and third portion of the duodenum.

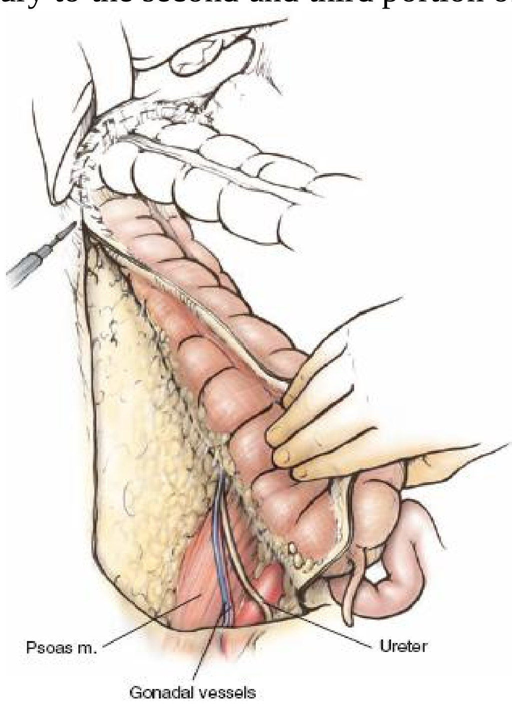

Figure 6

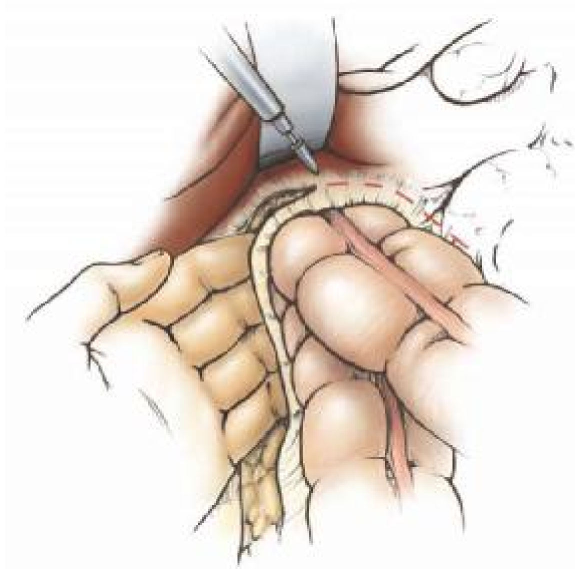

Figure 7

The transverse colon can be divided with GIA cutting staplers, usually a blue load cartridge. Similarly the appropriate site of the ileum is divided with the same GIA stapler. The result is that the entire right colon is now attached only to its mesentery. The two major lymphovascular pedicles are the ileocolic and the middle colic vessels. The mesenteric peritoneum can be outlined by electrocautery from the cut end of the transverse colon to the ileum, much like a wedge.

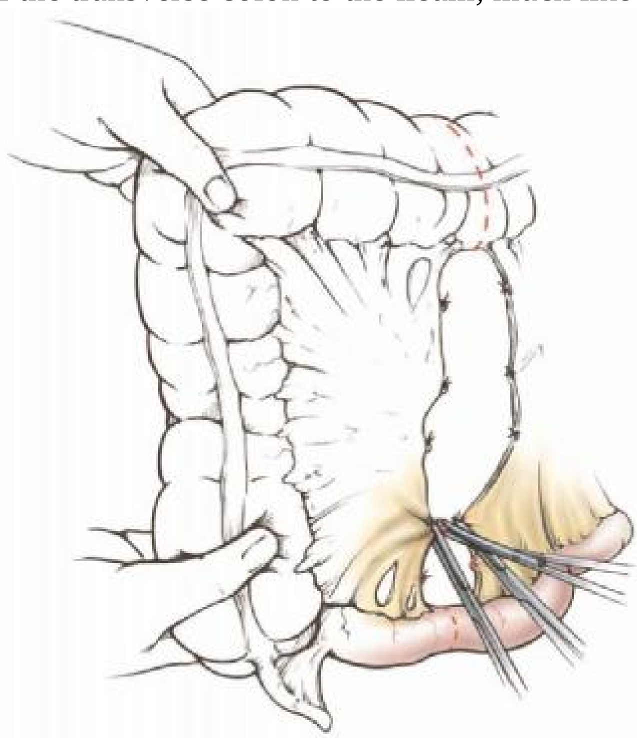

Figure 8

The apex of this wedge is the base of the ileocolic pedicle, which can be doubly ligated with 2-0 ties. The branch of the middle colic is also divided using similar technique. Once the vascular pedicles are divided, the remaining mesentery is divided by a series of double clamping and mesentery ligation using 2-0 or 3-0 ties. An alternative, but very efficient, method of dividing the mesentery is to ligate the lymphovascular pedicles and then divide the mesentery along the previous cautery outline using the LigaSure device. The LigaSure device is effective for sealing and dividing vessels that are up to 7 mm in diameter.

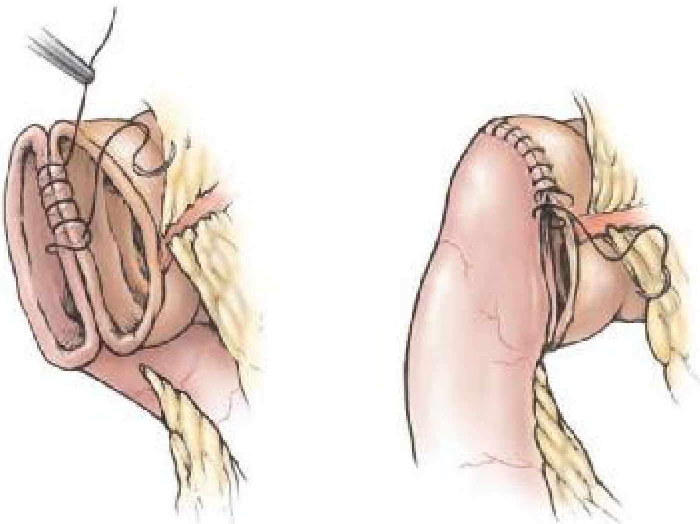

Figure 9

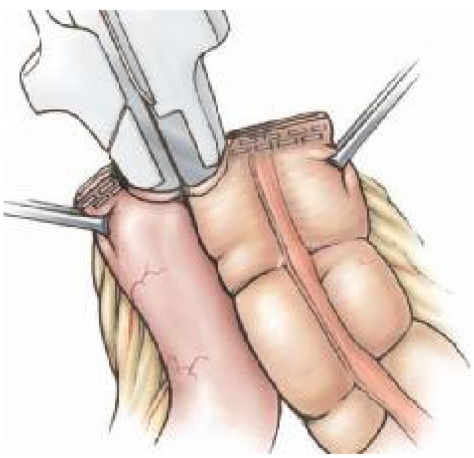

Figure 10

Intestinal continuity can be restored by hand-sewn (oneor two-layer) or stapled technique with equivalent functional results, but the stapled technique does save some time.

The stapled anastomosis begins by aligning the two ends of the bowel along the end of the antimesenteric borders. For the most part, spillage of bowel content is minimal during this procedure and therefore, it is not often necessary to place bowel clamps proximal and distal to the anastomosis. The antimesenteric corner of the staple line is excised on both bowel ends, and the forks of the blue-cartridge GIA instrument are inserted into the ileum and colon. On firing the instrument the internal staple line is checked for bleeding, and the resultant ileocolostomy edges are aligned using Allis clamps or anchored with stay sutures.

The opening of the ileocolostomycan be closed with a TA-55 stapler or simply with another blue-cartridge linear GIA. It is also acceptable to close the common opening using interrupted 2-0 or 3-0 sutures. The merits of closing the mesenteric defect are unknown, but a running 2-0 suture should suffice.

Laparoscopic Approach to Right Hemicolectomy

There are several variations to performing a laparoscopic right hemicolectomy. The peritoneal cavity is entered most commonly through the umbilicus, and the videoscope placed through the umbilical port. A l0-mm port is placed in the midepigastrium and a 5-mm port is placed midway between the umbilicus and the pubic symphesis. Essentially, there are three trocars placed along the midline, or paramedian. The patient is supine, but the table is turned in the right-side-up position. The surgeons stand on the left side of the patient. One of the most certain methods to assure adequate lymphovascluar isolation is to divide these pedicles first a method commonly referred to as medial-to-lateral approach.

To identify the ileocolic pedicle, the right colon is retracted away from the midline and the ileocolic pedicle becomes visible as a pulsatile ridge. The mesenteric window at the vascular base is opened to either side of the pedicle and a white vascular endoscopic GIA stapler is used to divide the pedicle.

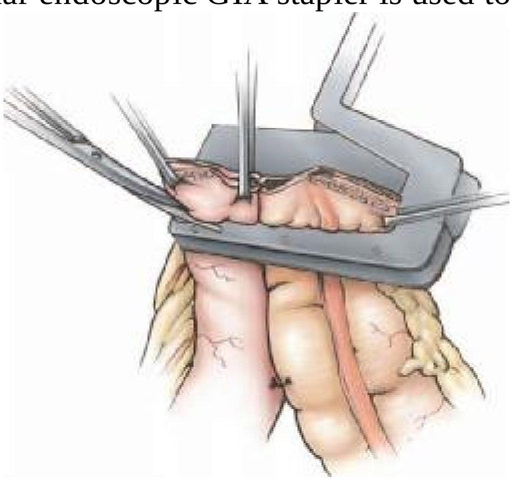

Figure 11

Once divided, the ileocolic pedicle is lifted anteriorly like a handle, and blunt dissection along the avascular retroperitoneal plane is achieved by lifting the mesentery, while simultaneously sweeping the retroperitoneum posteriorly. This can be accomplished without any energy source. The ultimate landmark of the cephalad dissection is to identify the duodenum and remain anterior to the duodenum. By heeding this landmark, the duodenum and the ureter posterior to it remain safe. The right branch of the middle colic or the root of the middle colic can be divided at this juncture using vascular staplers. Again, if the vessels are less than 7 mm, the LigaSure device may be used. The transverse colon can be divided by an endoscopic GIA stapler. The caudal dissection is performed by the same technique towards the ileum, staying in the avascular plane. By using the lymphovascular pedicle as a handle and sweeping the retroperitoneum down and posterior, the ureter and gonadal vessels remain in the retroperitoneum. The remainder of the mesentery can be divided using the LigaSure device from the middle colic pedicle down to the ileum. The ileum is divided using an endoscopic GIA stapler. The remaining attachments of the colon are the gastrocolic ligaments and the lateral peritoneal attachments. It is advantageous to leave these attachments until the final stages because they hold the colon in position while focus is on the lymphovascular pedicles. (NOTE: If the laparoscopic approach began by mobilizing the lateral attachments, it becomes difficult to identify the base of the vascular pedicles as the colon collapses over its mesentery.)

The resected colon can be removed at any time through the umbilical port, which is extended to approximately 3 cm and a wound protector is placed within it. To create the ileocolic anastomosis, it is possible to bring both barrels of the bowel out through the protected umbilical port and perform the anastomosis as in the traditional open technique. However, an intracorporeal anastomosis results in the least manipulation and especially when the transverse colon or the descending colon (in the case of an extended right hemicolectomy) cannot be exteriorized.

For an intracorporeal anastomosis, the terminal ileum is placed side-by-side in isoperistaltic fashion. A stay suture can be used to align the two barrels of the bowel. Small enterotomiesare made with electrocautery in the ileum and the adjacent colon to accommodate the white-cartridge endoscopic GIA that forms the common ileocolostomy. It is advisable to use a 45-mm or 60-mm long endoscopic stapler for maximum stomal diameter. The opening of the ileocolostomy may be closed by another endoscopic GIA either in transverse fashion or longitudinal fashion. Alternatively, the opening can be closed with single-layer interrupted or double-layer running sutures.

For extended right hemicolectomy, we prefer to bring the ileum directly to the proximal descending colon and not to the splenic flexure to avoid the risk of involving the watershed area.

Left Hemicolectomy

Whether to close the mesenteric defect or not remains a topic of debate, but should be managed the same way as one would for open surgery.

Tumors of the distal transverse colon, splenic flexure, descending colon require a left hemicolectomy. The left hemicolectomy specimen includes the distal transverse colon and the descending colon down to 2-3 cm above the sacral promontory. No presacral elevation of the rectal stump is necessary and the anastomosis is intraperitoneal. The standard vertical midline incision from the epigastrium is most commonly used, which also facilitates splenic flexure mobilization.

A mechanical retractor such as the Thompson or Bookwalter greatly enhances exposure, particularly for splenic flexure mobilization. The small intestines are exteriorized and wrapped in moist laparotomy pads. The left colon is reflected medially, exposing the white line of Toldt. This lateral peritoneal fold is sharply incised using an electrocautery or scissors, and the opening is extended from the sigmoid colon to the splenic flexure. At the splenic flexure, mobilization should follow the edge of the colon and its curve to avoid injury to the spleen. For all practical purposes, the renocolic, splenocolic, and pancreaticocolic attachments are bundled into one avascular structure that makes up the anchor of the splenic flexure. Blunt dissection of the renocolic ligament often avulses the veins on the surface of Gerota's fascia. The left colon is distracted inferiomedially and any attachment divided using cautery or scissors. Free the omentum from the distal 8-12 cm of the transverse colon.

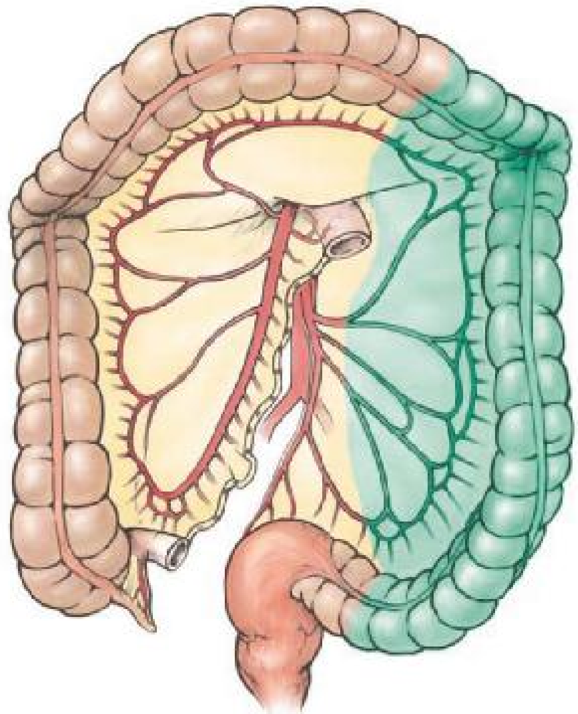

Figure 12

If the tumor is at the splenic flexure or the distal transverse colon, the omentum can be incorporated in the specimen. Once the splenic flexure is mobilized from the direction of the paracolic gutter, the gastric colic ligament is divided toward the splenic flexure to free the distal transverse colon. The final aspect of freeing the splenic flexure from the posterior attachments is most easily accomplished with one surgeon placing the splenic flexure of the colon between the left thumb and index finger and thinning out the tissues while the assistant uses cautery to divide the attachments. Once the splenic flexure is mobilized, the retroperitoneal attachments from the sigmoid colon to the transverse colon can be swept posteriorly, giving view of the ureter and gonadal vessels.

The medial aspect of the mesocolonis marked by cautery from the level of the duodenum down to the sacral promontory. The inferior mesenteric artery is skeletonized and ligated with 2-0 ties and divided, leaving a stump off the aorta of approximately 1.5-2.0 cm to avoid injury to autonomic nerve fibers. The inferior mesenteric vein is ligated near the ligament of Treitz. The transverse colon and descending colon are divided using blue-cartridge GIA cutting staplers. The mesentery between the two cut ends of colon are divided to include the marginal arteries using standard clamp-and-tie techniques, having constant awareness of the course of the ureter. The

LigaSure device can be used to divide the mesentery in place of the clamp-and-tie technique.

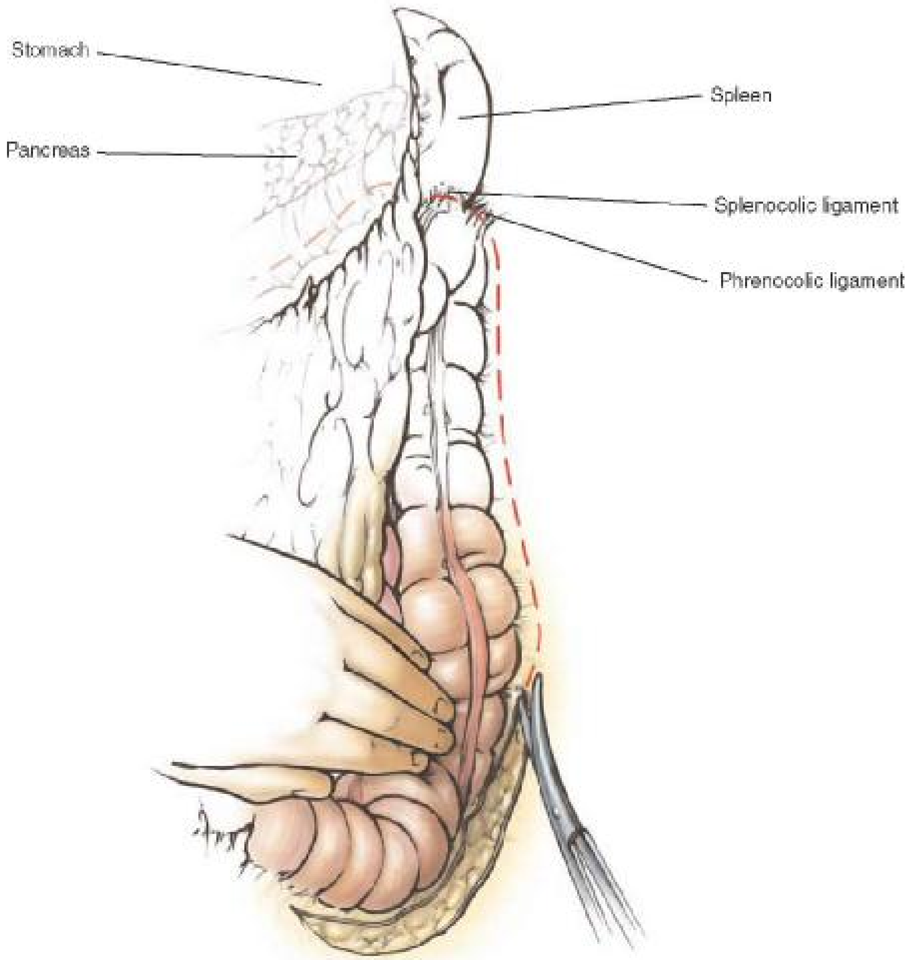

Figure 13

An anastomosis between the transverse and sigmoid colons can be stapled or hand-sewn. At the outset of stapling, the two ends of the bowel lumens are aligned along the antimesenteric border using stay sutures. The antimesenteric corners of the GIA staple lines are removed with scissors, and the forks of the GIA are inserted into the bowel lumen and the instrument fired. After inspection of the anastomosis the ostomy is closed with another GIA cutting stapler.

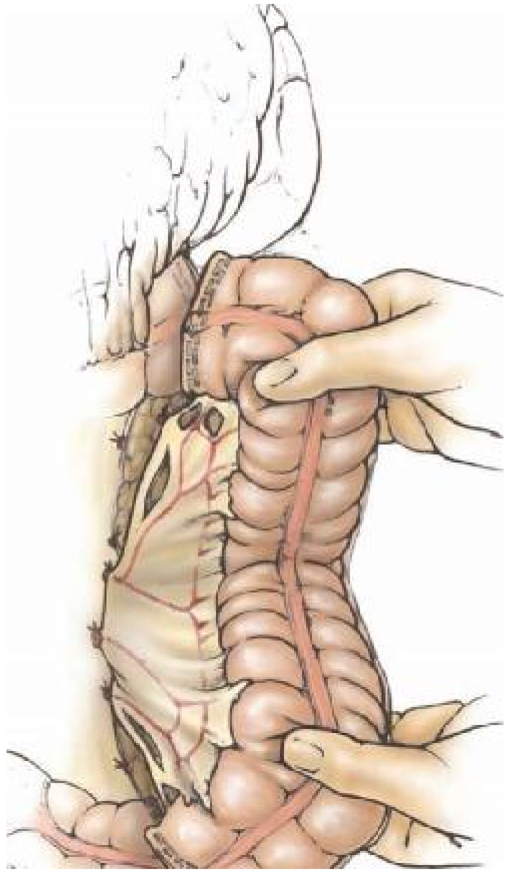

Figure 14

Rectosigmoid Colectomy

Alternatives to stapling can include a single-layer interrupted end-to-end or sideto-end (Baker's) anastomosis using 3-0 sutures. A two-layer anastomosis is sometimes used.

While left colon resections usually encompass portions of the sigmoid colon, lesions amenable to sigmoid resection, which extend from the lower portion of the descending colon to the level of the sacral promontory, are located at the proximal two-thirds of the sigmoid colon. When a sigmoid tumor crosses the pelvic brim, additional challenges can arise involving the bladder, ovaries, uterus, or distal ureter. Typically, lesions of the proximal sigmoid would require an anastomosis between the descending colon and the distal sigmoid. Lesions of the distal sigmoid would require an anastomosis between the proximal sigmoid and the upper rectum. Lesions of the middle sigmoid would depend on the redundancy of the colon.

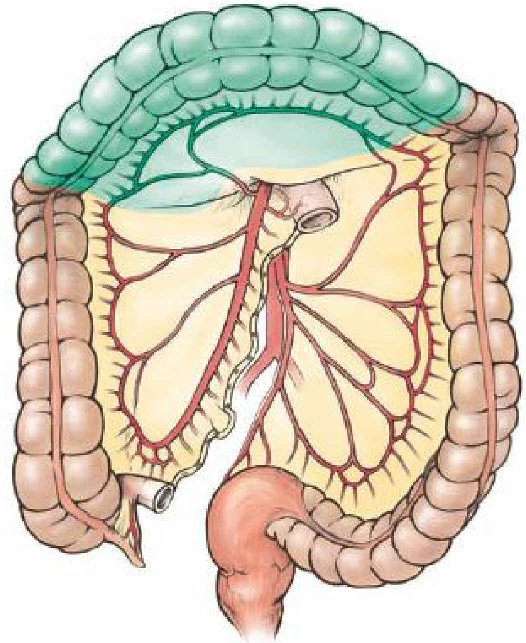

Figure 15

Sigmoid colon tumors can be approached through a standard midline incision, being ready to mobilize the splenic flexure if necessary. Whenever it is anticipated that the anastomosis will approach the pelvic brim, it is advisable to place the patient in the supine modified lithotomy position with Allen stirrups so that the anal canal is accessible for possible circular stapled anastomosis or proctosigmoidoscopy.

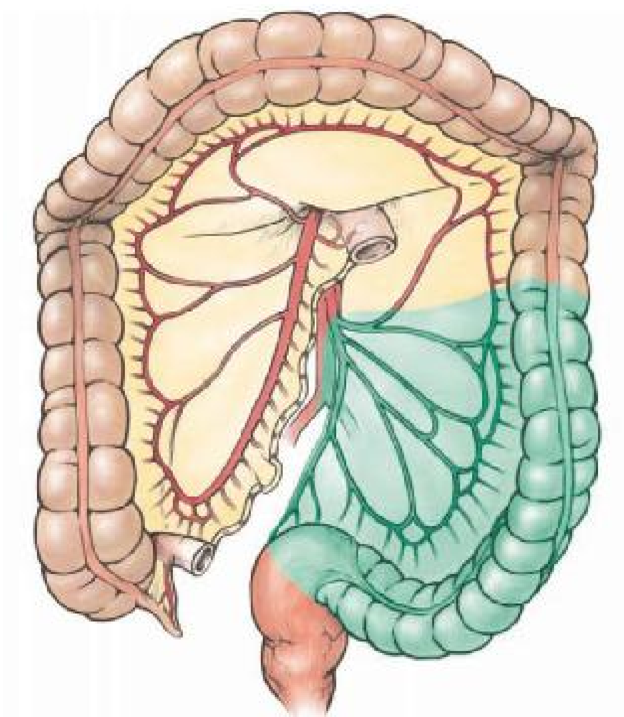

Figure 16

Mobilization of the left colon and splenic flexure from the lateral peritoneal wall is accomplished by medial retraction of the colon and a combination of blunt finger dissection and sharp dissection with an electrocautery or scissors. The sigmoid colon is retracted medially and mobilized from its lateral attachments down to the rectosigmoid junction. The ureter is identified as it courses over the iliac vessels along the pelvic wall.

The lymphovascular pedicles that are divided as part of a rectosigmoid colectomy depend on the portion of the sigmoid colon involved. Lesions at the proximal sigmoid colon may require ligation at the root of the inferior mesenteric artery. Middle or distal sigmoid lesions may be treated by ligating the inferior mesenteric artery distal to the left colic artery. Obviously, ligation of the main trunk of the inferior mesenteric artery would make splenic mobilization necessary and absolute confirmation of pulsatile blood supply of the descending colon prior to anastomosis.

Restoration of bowel continuity is undertaken with an end-to-end or side-to-end anastomosis using either a hand-sewn or stapled technique. The hand-sewn technique involves either one or two layers. If there is adequate redundancy, a side-to-side stapled anastomosis can be performed as described for left hemicolectomy.

In cases where the anastomosis is being formed with the rectum, a circular stapled technique with a 29-mm or 31 mm EEA may be appropriate. However, when the rectal stump is long and the presacral space is still undisturbed, it is difficult to pass the EEA stapler to the level of anastomosis. In such instances, primary hand-sewn anastomosis or intra-abdominal stapling techniques are more appropriate.

The mesocolic defect may be closed with running sutures, but this may not be an easy task. In several hundred cases of left and sigmoid colectomy without mesocolic closure, we have not encountered any bowel obstructions from internal hernias.

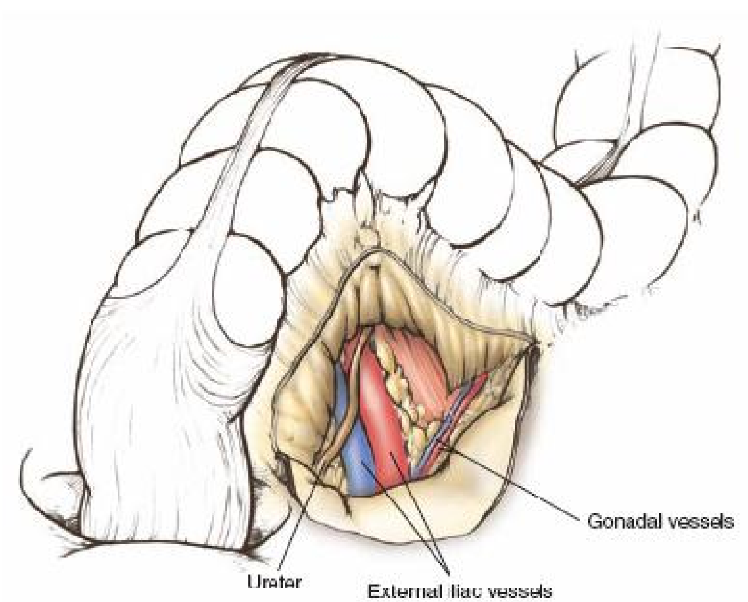

Figure 17

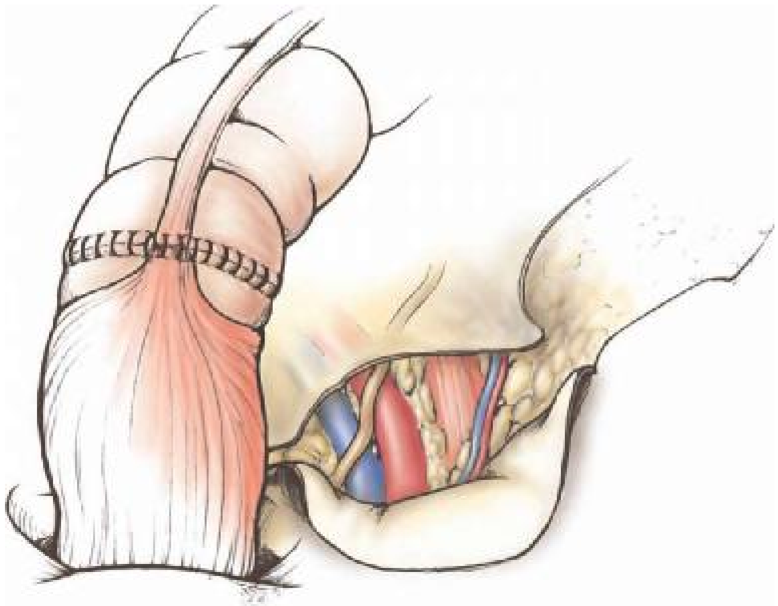

Figure 18

Technical pitfalls that are more relevant to left and sigmoid colectomy include splenic capsule avulsion, ureteral injury and anastomotic failure secondary to tension or poor blood supply.

Laparoscopic Left and Sigmoid Colectomy

There are variations to laparoscopic left and sigmoid colectomy, but the setup is similar. The techniques for distal descending and sigmoid tumors are the same. A commonly used approach is the hand-assisted technique with a hand-assist port placed through a midline periumbilical incision. The patient is in the modified lithotomy position with Allen stirrups. The other laparoscopic approach performs the entire dissection, resection, and anastomosis intra-abdominally with the videoscope placed through the umbilicus and operating ports placed to each side of the patient's abdomen. An angled videoscope is used. A mechanical arm is of value in holding the videoscope. The left side of the table is turned up. When the dissection is in the pelvis, the patient is in the steep Trendelenberg position, but reversed when the dissection is toward the splenic flexure.

As with right hemicolectomies, one technique to assure adequate lymphovascular pedicle ligation is to perform a medial-to-lateral ligation of the inferior mesenteric artery branches. The divided pedicle is lifted up away from the retroperitoneum and another dissecting instrument is used to sweep the retroperitoneal structures away. This dissection occurs in an avascular plane toward the pelvis. The ureter and the gonadal vessels will come into view. For tumors of the sigmoid colon, the retroperitoneal dissection is performed toward the pelvis once the inferior mesenteric artery is ligated distal to the left colic artery with a vascular load endoscopic stapler. The proximal portion of the rectum is mobilized and the distal colon is transected at that level with blue-load endoscopic GIA staplers. The proximal aspect of the sigmoid colon is divided with endoscopic GIA staplers at the descending colon. The lateral attachments of the sigmoid colon are avascular and divided using cautery scissors. Virtually all sigmoid colectomies require mobilization of the descending colon, but not all will require splenic flexure mobilization.

If the tumor is in the proximal descending colon or splenic flexure, the left colic vessel is divided first with hemoclips, bipolar electrocautery or a vascular stapler. The pedicle is lifted up away from the retroperitoneum and a blunt dissecting instrument sweeps the retroperitoneal attachments posteriorly in a cephalad direction. This maneuver will lead directly to the distal half of the transverse colon, to the left of the duodenojejunal junction. A window is made in the transverse mesocolon and blueload endoscopic GIA staplers are used to divide the distal transverse colon. The distal descending colon can be divided with the same stapler. The base of the mesentery and the inferior mesenteric vein can easily be divided using the LigaSure device. The lateral attachments of the bowel and the splenic flexure are mobilized using cautery scissors and the LigaSure device in a manner very similar to the open technique. Awareness of the course of the ureter and gonadal vessels are important.

Common pitfalls that increase the complexity of a laparoscopic operation include undermobilizing the lateral and splenic flexure attachments resulting in anastomotic tension or inadequate oncologic margins, and entering a deeper retroperitoneal plane and encountering bleeding from retroperitoneal veins and lumbar vessels. (NOTE: This approach for oncologic laparoscopic left colon and sigmoid colectomy is very different from the approach for benign diseases such as diverticulitis.)

Colon continuity is typically restored using either a side-to-side intracorporeal anastomosis or by circular EEA staplers. The side-to-side anastomosis is suitable for transverse or descending colon to sigmoid anastomosis. To augment the length of the colon, the gastrocolic ligaments will need to be divided. Stay sutures are used to bring the two barrels of the bowel in antemesenteric alignment. Cautery is used to make small colotomies in each barrel of the bowel so that blue-load endoscopic cutting GIA staplers can be used to form the common channel. The ostomy is closed using running sutures or another GIA stapler.

For descending colon to rectum anastomosis, the umbilical port is enlarged to 3 cm and the descending colon exteriorized through a wound protector. The transected edge of the distal colon is opened and the anvil of the EEA stapler is inserted into the opening. A purse-string suture using 3-0 PDS is used to close the colotomy around the spike of the anvil in preparation for an end-to-end stapled anastomosis. The colon with the anvil is returned to the abdominal cavity. The resected bowel specimen can also be brought out of the abdominal cavity at this time. The stapler is introduced in the rectum by the assistant and the spike introduced through the rectal stump. The anvil and the stapler are engaged, closed and fired. The anastomosis is tested by insufflation and direct inspection with a proctosigmoidoscope. Drains are not necessary when the presacral space remains undisturbed.

The extended umbilical fascial incision is closed with heavy absorbable sutures such as running Number-1 PDS.

A subtotal colectomy for cancer consists of removal of the entire intraperitoneal colon, and is often required for multiple polyps that are not amenable to endoscopic resection or the presence of synchronous tumors. A standard midline incision initiates the subtotal colectomy. The operation commences usually with mobilization of the lateral attachments beginning at the cecum. The lateral peritoneal attachments of the right colon are mobilized. The colon itself is mobilized from the duodenum at the level of the hepatic flexure, and the hepatocolic ligament is sharply divided. The omentumis usually taken with the specimen by dividing the gastrocolic ligaments along the length of the transverse colon. The mobilization continues around the splenic flexure and along the lateral peritoneal reflections of the descending colon and is completed at the rectosigmoid junction. However, in order to use the circular EEA stapler for anastomosis, the proximal rectum needs to be mobilized off the presacral space.

Subtotal Colectomy

The margins for bowel transection are determined after complete mobilization. A GIA cutting stapler is used to divide the terminal ileum 4 cm proximal to the ileocecal valve; the distal point of transection is usually at the proximal rectum with a TA-55 stapler. To assure adequate lymph-node harvest, the named segmental arteries are ligated at their origins. Mesenteric ligation is best accomplished with an assistant holding the bowel segment anteriorly while the surgeon divides the mesenteric vessels with suture ligation, or with the LigaSure. The same technical pitfalls for right and left colectomy described previously apply.

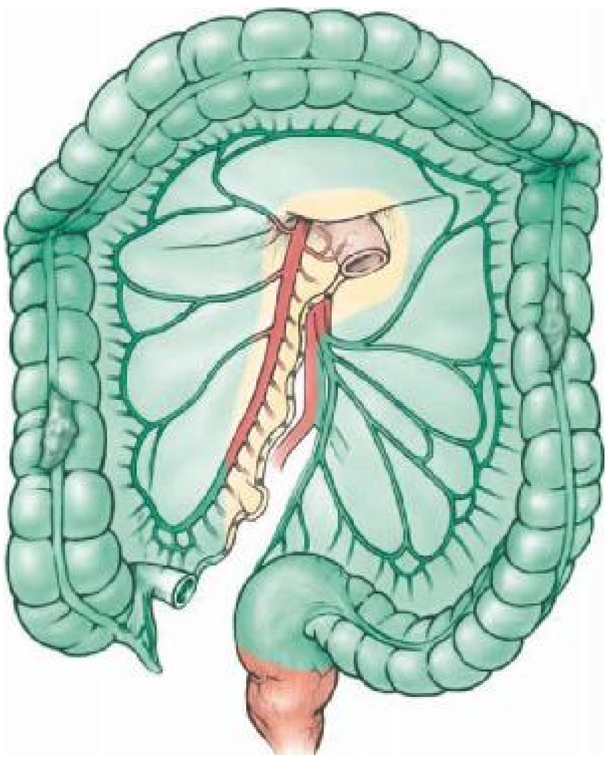

Figure 19

Restoration of gastrointestinal continuity requires an anastomosis between the ileum and the rectum, completed with a hand-sewn technique in single layer using interrupted 3-0 or 4-0 sutures. However, a side-to-end anastomosis using the circular EEA stapler is an excellent method of creating an anastomosis. A side-to-end anastomosis is preferable to compensate for the lumen disparity between the ileum and the rectum.

Laparoscopic-Assisted Subtotal Colectomy

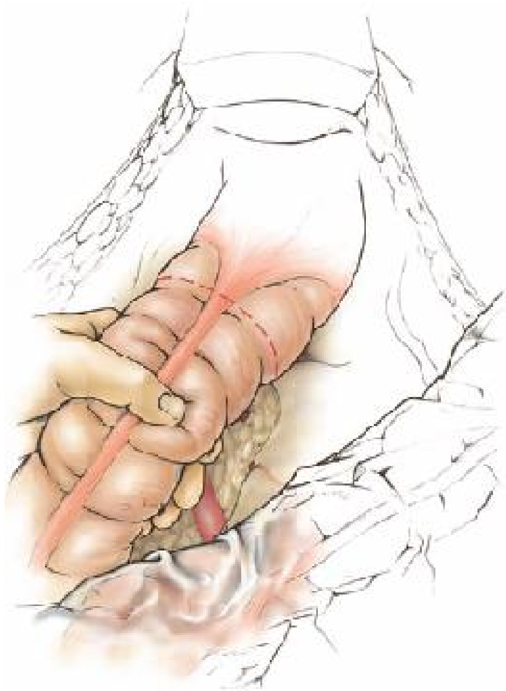

Figure 20

Laparoscopic subtotal colectomy for oncologic therapy can be cumbersome given the multiple quadrants that the colon resides. It is probably more practical and time-saving to use a hand-assist port. In patients without extensive intra-abdominal fat, it is more feasible to laparoscopically divide the three main vascular pedicles; ileocolic, middle colic, and inferior mesenteric arteries followed by dividing the ileum and rectosigmoid junction, LigaSure applied to the base of the mesentery and finally, divide the lateral attachments. In patients with significant intraabdominal fat, we have used laparoscopic methods to mobilize the splenic flexure, transverse colon, and hepatic flexure followed by extending the midline incision to complete the remainder of the procedure with a smaller abdominal incision.

To restore intestinal continuity, we prefer the side-to-end anastomosis between the ileum and the rectum.

Figure 21

Appendix Surgical Anatomy

Topography

The appendix extends from the base of the cecum as a long tube with varying length, but averages about 9-10 cm. While the base of the appendix emerges at the convergence of the teniae coli, the tip of the appendix can be found in various positions. The retrocecal location is the most commonly encountered position of the appendix. The appendix is typically located inferior and posterior to the fold of Treves, a triangularly shaped antimesenteric epiploic appendage that marks the junction of the ileum and the cecum. The fold of Treves is useful in identifying the appendix when using small-incisions, and can frequently be used to locate the appendix on computer tomography.

Blood Supply

The appendiceal artery is a branch of the ileocolic artery that runs through the mesoappendix.

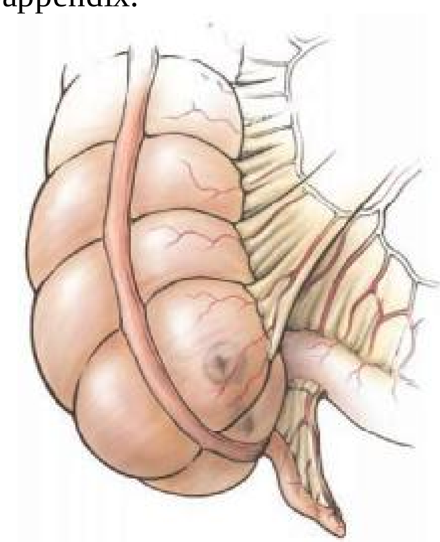

Figure 22

Nerve Supply

The appendix is innervated by both the parasympathetic and sympathetic divisions of the autonomic nervous system, duplicating the innervation of the cecum.

Lymphatic Drainage

Lymphatic drainage from the appendix is encompassed in the right colon distribution.

Surgical Applications

Malignant tumors arising from the appendix are rare. Carcinoids are the most common appendiceal neoplasm, and are often found incidentally during appendectomy for acute appendicitis. When carcinoids exceed 2 cm in size, malignancy risk increases and a formal right hemicolectomy is indicated. In carcinoid tumors smaller than 2 cm and localized, only a simple appendectomy is needed.

Adenocarcinomas are more inclined to produce symptoms than carcinoids are. The common histologic variants of adenocarcinoma are well-differentiated or mucinproducing tumors (malignant mucocele) or poorly differentiated adenocarcinomas. Both of these lesions can metastasize to regional nodes and distant sites. Adequate treatment requires a mesenteric resection encompassing the primary nodal drainage system. If the diagnosis of an adenocarcinoma is made incidentally, as in an appendectomy specimen, subsequent right hemicolectomy offers the greatest curative potential.

In summary, right hemicolectomy is indicated if the appendiceal tumor is an adenocarcinoma, mucin-producing tumors, has lymphatic invasion or direct invasion of the serosa or mesoappendix.

Incision for Appendectomy

The terms Rockey-Davis and McBurney's incisions are probably of historical interest, with most surgeons describing their technique as some variation of a right lower quadrant incision (e.g., curvilinear, transverse, oblique). Classically, a transverse incision of approximately 6 cm is made at one-third the distance from the anterior superior iliac spine to the umbilicus. Obviously, in very obese patients, this landmark is not feasible and for such patients, a laparoscopic appendectomy may be desirable. The dissection is carried down through the subcutaneous fat until the external oblique aponeurosis is identified and an incision is made along the grain of its fibers. The underlying muscle layers are split (without cutting) using two Kelly clamps alternatingly opened in perpendicular directions until the peritoneum is visible. The peritoneum is incised with Metzenbaum scissors to enter the abdominal cavity.

In cases where malignancy or perforation is suspected, a wound protector may be advantageous to reduce surgical site infections, and the theoretical possibility of tumor implants within the incision.

After the peritoneum is opened, the appendix is identified by following the cecaltaenia distally, and the cecum and appendix are delivered into the wound by gentle traction. Occasionally the lateral peritoneal reflection of the cecum is divided to improve exposure. These maneuvers should bring the cecum and appendix to the anterior abdominal wall, facilitating removal without vigorous retraction. Freed from any attachments, the mesoappendixcan be identified, divided between clamps, and ligated to control the appendicular artery.

In perforated appendicitis, when the wound is contaminated, it is still best to leave a portion of the skin wound open for secondary closure. Most appendectomies do not require postsurgical drainage.

Appendectomy

Once the appendix is delivered out of the abdominal cavity, the base of the mesoappendix can be ligated using a clamp and dividing between 2-0 or 3-0 silk or absorbable ties. It is also possible to ligate the mesoappendix using bipolar energy sources such as the LigaSure device (Covidien, Boulder, CO). Once the appendiceal mesentery and artery are ligated, the appendix can be divided.

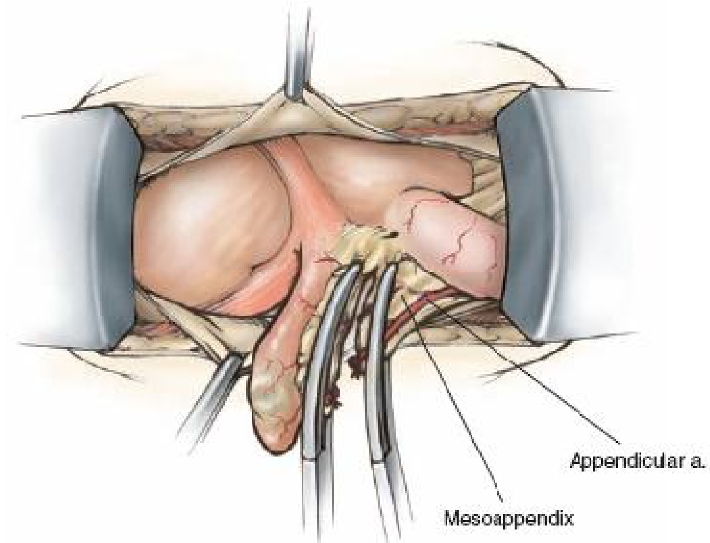

Figure 22

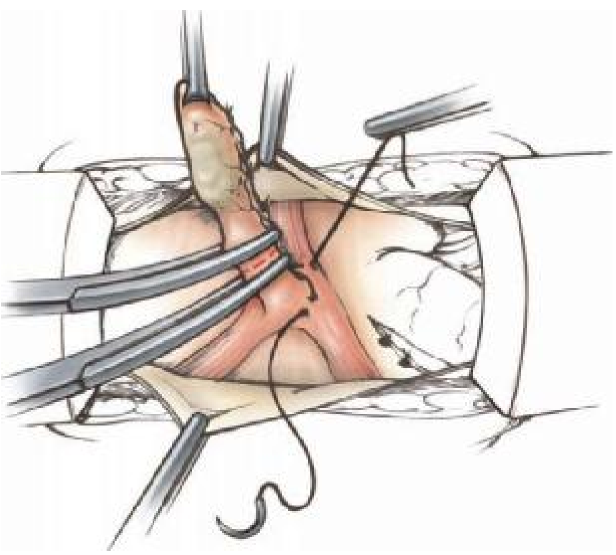

Figure 24

To divide the appendix, a straight hemostat can be applied to its base 5-10 mm from the cecum. The appendix can be transected with a blade above the hemostat, and 2-0 silk or absorbable ties applied below the hemostat. We prefer a double tie in case one tie slips. Some surgeons advocate applying cautery to the appendiceal stump mucosa to mitigate risks of mucocele formation.

If the surgeon wishes to invert the appendiceal stump, a Z-stitch is then placed as a Lembert suture in the cecum, around the base of the appendix. Prior to tying the suture, the appendix is inverted into the cecum with a clamp or forcep, and the suture is tied down, leaving the stump inverted. An alternative to the Z-stitch is to perform a purse-string suturing around the base of the stump.

There is no proven advantage or disadvantage to stump inversion or cauterizing the mucosa, and the divided appendix can simply be left alone. Pitfalls and dangers to appendectomy are the finding of inflamed cecum, possibility of cecal Crohn's disease, and poor vascular control in edematous mesoappendix. In cases where the bleeding vessel is not visible, it is advisable to perform suture ligature.

Laparoscopic Appendectomy

Laparoscopic appendectomy can be performed by multiple trocars or through a single incision in the umbilicus. The patient is positioned supine, with the operating table oriented partially in Trendelenberg and right-side up. At least one trocar should be a 10-mm trocar. The base of the appendix is identified and a window is made at the base of the mesoappendix adjacent to the appendix using dissecting forceps. The window should be large enough to accommodate a blue endoscopic cutting stapler to divide the appendix at its base. The mesoappendix can be divided with a vascular-load endoscopic cutting stapler, the Ligasure bipolar cautery, or a preformed tie.

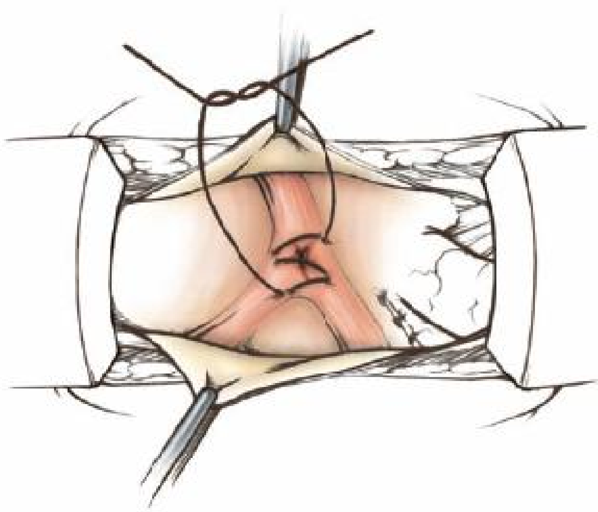

Figure 25

The specimen can be retrieved lengthwise out of the 10-mm trocar or with a specimen retrieval bag.

A pitfall of laparoscopic appendectomy, especially when a retrocecal appendix is encountered, is leaving a residual appendical stump that is too long, or encountering inflammation close to the base of the appendix. With the use of endoscopic cutting staplers, it is appropriate in the latter circumstance to divide a cuff of healthy cecum along with the appendix specimen.

Anatomic Basis of Complications

Right colectomy

- Injury or inadvertent ligature of superior mesenteric vessels.
- Injury to the retroperitoneal duodenum, for both laparoscopic and open approaches.
- Injury to the right ureter if dissection of the mesentery is deeper than the avascular plain.
- Avulsion of venous branch between inferior pancreaticoduodenal and middle colic veins, particulary in aggressive medial retraction during open colectomy.
- Lateral colon mobilization enters retroperitoneal fat and the kidney.

Left colecotmy

- Excessive traction on the descending colon before dividing the lineocolic ligaments can cause splenic capsule laceration.
- Inadequate mobilization of colon length creates tension at an anastomosis and increases the risk of leakage.
- Injury to the left ureter if dissection is carried deeper than the avascular plain.
- Laparoscopic dissection deep into lumbar vessels.

Rectosigmoid colectomy

- Presacral hemorrhage
- Injury to ureters as they cross over the ileac vessels.
- Anastomotic tension from failure to mobilize splenic flexure.

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