Surgical Anatomy

Topography

The stomach is the first abdominal organ of the digestive tract and acts as a reservoir for ingested food to begin both mechanical and chemical digestion. It lies principally in the left upper quadrant of the abdomen but terminates across the midline and frequently descends below the plane of umbilicus. The position of the stomach is variable, depending on body position, contents, and respiratory movements.

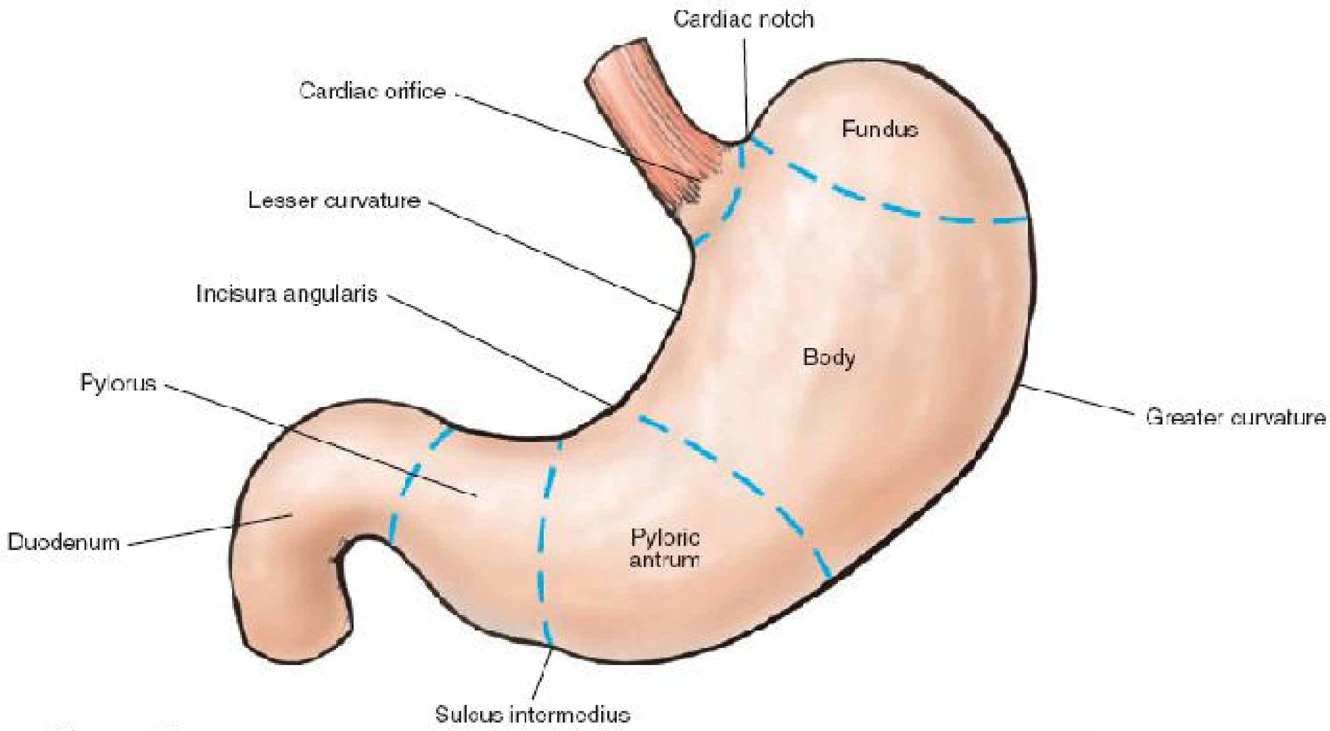


Figure 1

The anatomic regions of the stomach are divided into the cardia, fundus, body, and pylorus. The cardiac orifice marks the transition from the esophagus to the stomach. The cardia of the stomach is the portion immediately surrounding the esophageal opening and has a relatively stable location due to the esophageal attachments of the diaphragm and the peritoneal reflections (gastrophrenic ligament). At the esophagogastric junction a deep notch, defined as the cardiac notch, separates the esophagus and the fundus. The cardiac notch, together with decussating fibers of the diaphragm and circular fibers of the lower esophagus, forms a lower esophageal sphincter that prevents esophageal reflux under normal conditions. The fundus of the stomach expands upward, filling the dome of the diaphragm on the left side, and is limited below by the horizontal plane of the cardiac orifice. The incisura angularis, a sharp indentation about two-thirds of the distance along the lesser curvature, marks a vertical separation between the body of the stomach to its left and the pyloric portion of the stomach to its right and is used surgically as the proximal line of transection for antrectomy. The pyloric portion of the stomach consists of the pyloric antrum, the pyloric canal, and a markedly constricted terminal pylorus, composed of a greatly thickened muscular wall constituting the pyloric sphincter. The thickened sphincter marks the termination of the stomach and its transition to the retroperitoneal duodenum, which is fixed to the posterior body wall.

Curvatures and Surface

The axis of the stomach is oblique and extends from the fundus downward to the right sand ventral. The lesser curvature marks the right border of the stomach and extends from the esophagogastric junction along a concave curve to the right, terminating at the pylorus. The greater curvature is the left and inferior border of the stomach.

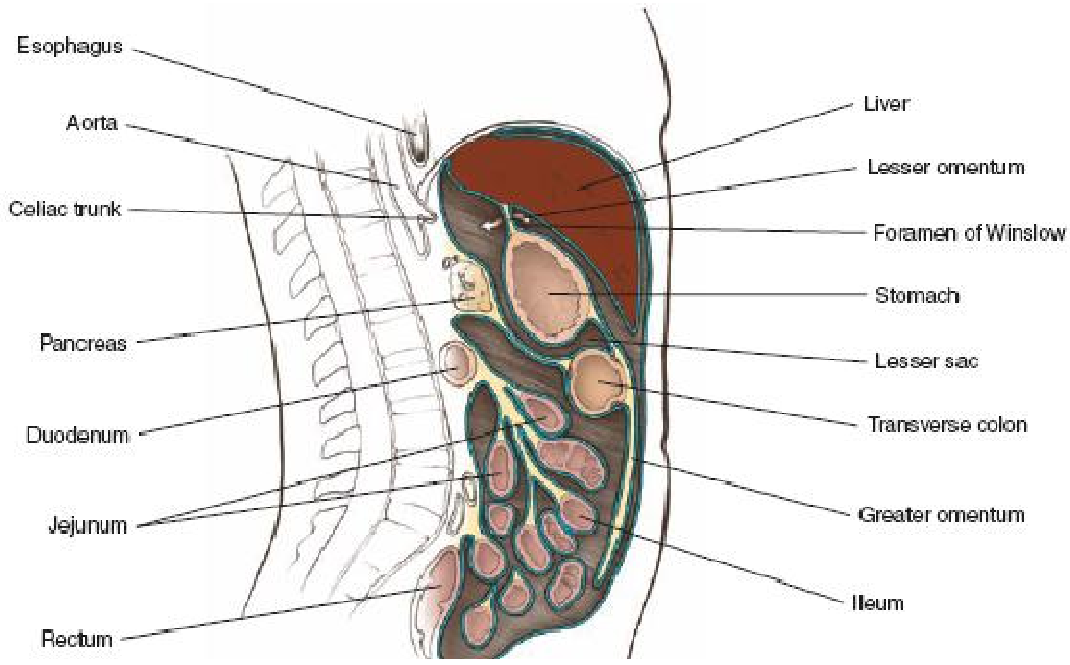


Figure 2

It begins at the cardiac notch, follows the superior curvature of the fundus, and then the convex curvature of the body down to the pylorus. The greater curvature is four or five times longer than the lesser curvature.

The rotation of the stomach during embryologic development creates a space, known as the lesser sac or omental bursa, between the stomach and the posterior abdominal wall. This space is bounded anteriorly by the stomach and lesser omentum, superiorly by the liver, inferiorly by the greater omentum (and its fusion to the transverse colon), and to the left by the spleen and its ligaments. On the right, the lesser sac opens into the greater sac through the epiploic foramen (of Winslow). The greater sac of the abdomen fills the remaining space within the peritoneal cavity.

Peritoneal Relations

The stomach is entirely covered by the peritoneum except for the areas where the blood vessels course along the curvatures, and a small triangular space behind the cardiac orifice. Here the stomach is left bare by the gastrophrenic peritoneal reflection. At the lesser curvature the two layers of peritoneum extend to the liver as the gastrohepatic portion of the lesser omentum. From the greater curvature the greater omentum spreads widely to the diaphragm as the gastrophrenic ligament, to the spleen as the gastrosplenic ligament, and to the transverse colon as the gastrocolic ligament.

Structure

The stomach wall is composed of four distinct histologic layers: the mucosa, submucosa, muscularis, and serosa. The mucosa is thrown into a series of coarse gastric folds known as rugae. These are oriented chiefly longitudinally along the lesser curvature. The submucosal layer is a loose, areolar, vascular layer. The muscular layer of the stomach is composed of an outer longitudinal and inner circular muscular layer, typical of the gastrointestinal tract, but also contains an internal oblique layer. The circular muscle is the dominant muscle layer of the stomach. The outer longitudinal layer is not as uniform as the circular layer, being concentrated particularly along the curvatures. The serosal layer is the peritoneum.

The gastric epithelium consists of a single layer of columnar cells. The stomach has specialized glands in the different regions of the stomach that vary in structure and function.

The cardiac glands are found in the region of the esophageal opening. Each gland is composed of a few branching tubules containing cells that secrete a form of mucus.

Fundic or gastric glands in the fundus and body of the stomach have long secreting tubules with short ducts opening into shallow gastric pits. Three types of cells line these tubules. The mucous neck cells in the upper part of the gland secrete mucus. The chief or zymogenic cells secrete pepsin, a proteolytic enzyme of the gastric juice. At intervals throughout the length of the tubule are large eosinophilic cells between the chief cells known as parietal cells, which are responsible for secretion of the hydrochloric acid in the gastric juice.

The pyloric glands are short, branched tubules opening into long duct-like gastric pits. The exact contribution of the pyloric glands to the gastric secretion is not known, although they resemble mucous neck cells. Gastrin, a hormone that increases acid production from the parietal cells and gastric motility, is secreted by the G cells in the pylorus of the stomach.

Blood Supply

The blood supply to the stomach is extensive and is based on vessels from the celiac trunk. The four major vessels that supply the stomach are the right and left gastric and the right and left gastroepiploic arteries.

Celiac Trunk

The aorta passes through the aortic hiatus of the diaphragm into the abdominal cavity in front of the lower border of the twelfth thoracic vertebra. The celiac trunk and the superior mesenteric and inferior mesenteric arteries are the three principal ventral unpaired branches of the aorta and supply the majority of the gastrointestinal system.

The celiac trunk arises from the front of the abdominal aorta, just below the aortic hiatus and at the level of the upper portion of the first lumbar vertebra. Only 1-2 cm long, the celiac trunk passes forward above the upper margin of the pancreas and then divides behind the posterior body wall peritoneum into the left gastric, common hepatic, and splenic arteries. In the region of the celiac trunk lie the celiac lymph nodes and the celiac plexus of nerves and their ganglia.

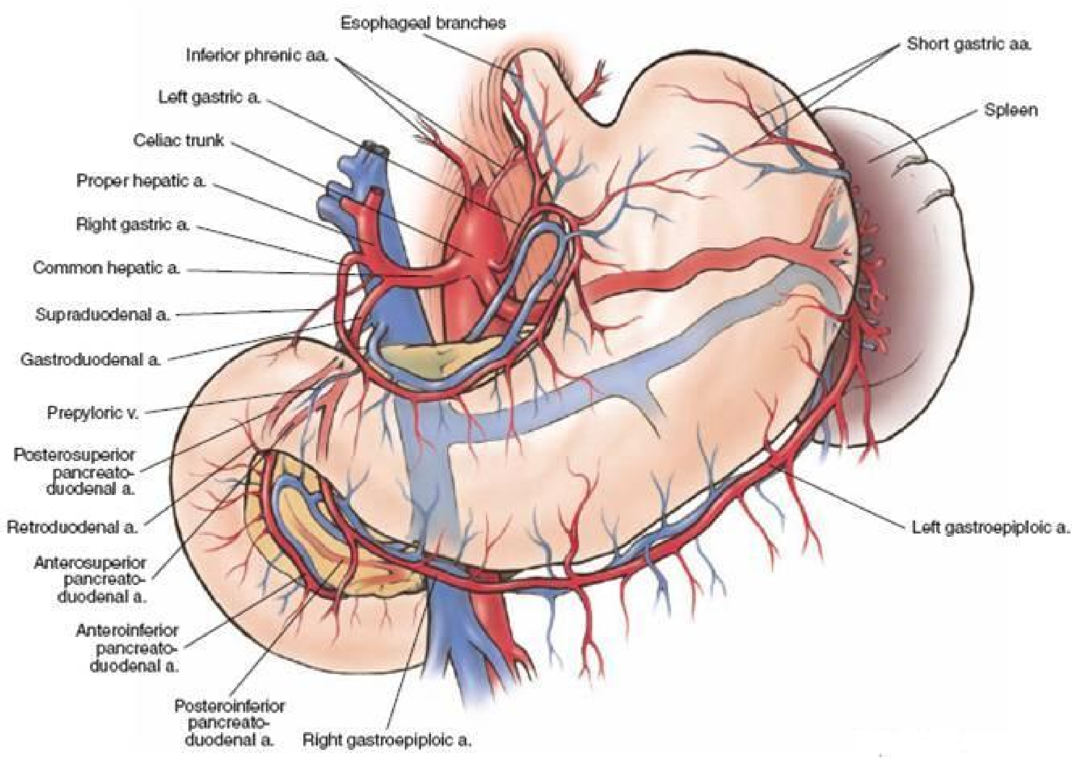


Figure 3

Left Gastric Artery

The left gastric artery, the smallest branch of the celiac trunk, courses upward and to the left toward the cardiac end of the stomach. The vessel lies behind the body wall peritoneum in the floor of the lesser sac, where it frequently raises a fold of peritoneum, the left gastropancreatic fold. It reaches the stomach in the bare area behind the cardia, giving off esophageal branches that ascend along the esophagus to provide a portion of its arterial supply. The left gastric artery then turns onto the lesser curvature of the stomach between the layers of the hepatogastric ligament and follows this curvature as far as the pylorus, providing branches to both surfaces of the stomach, and anastomoses terminally with the right gastric artery.

Right Gastric and Right Gastroepiploic Arteries

The common hepatic artery arises from the celiac trunk, runs forward and to the right along the upper border of the pancreas, passes into the lesser omentum giving off the gastroduodenal artery, and continues to the liver as the proper hepatic artery. The gastroduodenal artery is a short, thick branch that takes its origin from the common hepatic artery at the upper border of the first part of the duodenum. It descends behind this portion of the duodenum and divides at its inferior border into the right gastroepiploic and anterosuperior pancreaticoduodenal arteries.

The right gastroepiploic artery passes from right to left along the greater curvature of the stomach between the layers of the gastrocolic ligament. It anastomoses with the left gastroepiploic artery to form a vascular arch along the greater curvature, from which pass gastric branches to both surfaces of the stomach and omental branches to the greater omentum.

The proper hepatic artery, which is the continuation of the common hepatic artery distal to the gastroduodenal artery, usually gives off the right gastric artery, and terminates by dividing into the right and left hepatic arteries. The small right gastric artery descends through the lesser omentum to the pyloric end of the lesser curvature of the stomach. It supplies branches to both surfaces of the pyloric portion of the stomach and anastomoses with the left gastric artery. The right gastric artery is most commonly a branch of the proper hepatic artery, but may arise from the left hepatic, gastroduodenal, or common hepatic arteries.

Left Gastroepiploic Artery

The splenic artery runs a highly tortuous course along the superior border of the pancreas, behind the peritoneum of the floor of the lesser sac. The left gastroepiploic artery arises from the splenic artery or an inferior terminal branch, passes toward the greater curvature of the stomach through the gastrosplenic ligament, and forms a vascular arcade with the right gastroepiploic artery. Its gastric and epiploic branches are distributed to both surfaces of the stomach and to the greater omentum.

The short gastric arteries are four or five small vessels that arise directly from the splenic artery and pass through the gastrosplenic ligament to reach the fundus of the stomach.

Veins.

The veins of the stomach run parallel with the arteries and drain into the portal venous system.

The left gastric vein arises from tributaries on both surfaces of the stomach. It passes from right to left along the lesser curvature to the cardia, where it receives esophageal veins. The left gastric vein then turns to the right and descends in company with the left gastric artery, behind the posterior body wall peritoneum. Passing beyond the celiac arterial trunk, the left gastric vein ends in the portal vein. This circular course, first along the lesser curvature and then inferiorly on the body wall, is expressed in the old name "coronary vein."

The small right gastric vein is formed from the tributaries of both surfaces of the pyloric region of the stomach. It accompanies the right gastric artery between the layers of the lesser omentum and, passing from left to right, ends directly in the portal vein. A prepyloric vein ascends over the pylorus to the right gastric vein and is an anatomic landmark that enables the surgeon to identify the pylorus.

The right gastroepiploic vein accompanies the right gastroepiploic artery within the layers of the gastrocolic ligament. It receives tributaries from the inferior portions of both the anterior and posterior surfaces of the stomach and from the greater omentum. The vein crosses the uncinate process of the pancreas and ends in the superior mesenteric vein.

The left gastroepiploic vein completes the arch of veins along the greater curvature of the stomach and has the same pattern of drainage as the right gastroepiploic vein. It is directed to the left in the folds of the gastrocolic ligament. Entering the gastrosplenic ligament, the left gastroepiploic vein ends in the beginning of the splenic vein.

The short gastric veins, four or five in number, drain the fundus and the superior part of the greater curvature of the stomach. They pass between the layers of the gastrosplenic ligament toward the hilum of the spleen, where they terminate in the splenic vein.

Lymphatic Drainage

The lymphatic vessels of the stomach have a pattern similar to that of its arteries and veins. There are four major routes of lymphatic drainage from the stomach.

A large group of lymphatic vessels drain the surfaces toward the lesser curvature of the stomach to the left gastric nodes. These form a chain of 10-20 nodes extending from the angular notch of the stomach upward to the cardia. At the cardia a small group of five or six paracardiac nodes surround the esophagogastric junction. The left gastric nodes follow the left gastric blood vessels to the celiac nodes.

Another group of nodes drain the pyloric portion of the lesser curvature to the two or three right gastric nodes. These in turn run along the right gastric artery and drain into the hepatic nodes.

The left half of the stomach drains by lymphatic channels directed toward the greater curvature. Lymphatic vessels from the fundus and the upper portion of the body of the stomach follow the short gastric and left gastroepiploic blood vessels to the pancreatosplenic nodes. Three or four lymph nodes are situated along the postero superior border of the pancreas on the splenic blood vessels. The pancreatosplenic nodes drain the stomach, spleen, and pancreas and then drain into the celiac nodes.

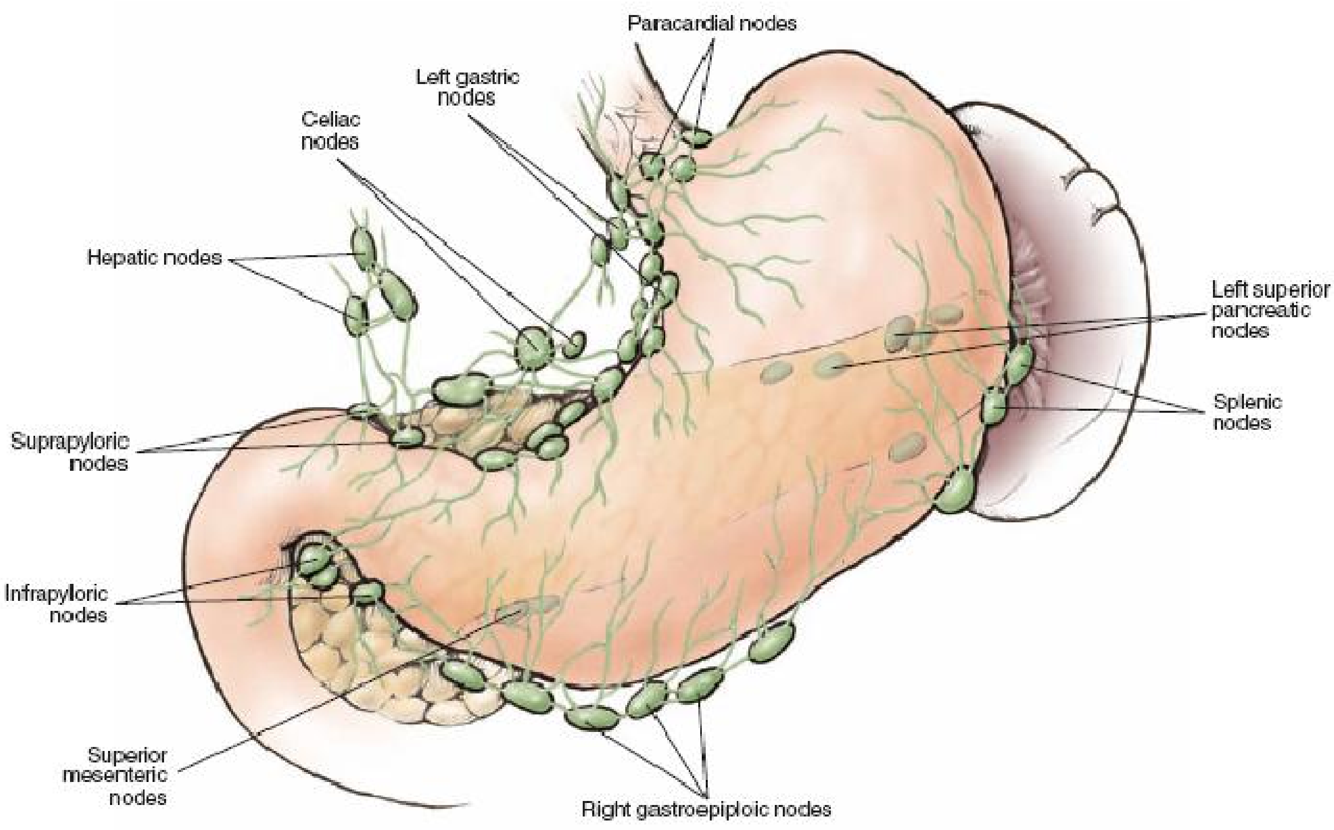


Figure 4

Finally, from the lower portion of the left half of the stomach, lymphatic vessels drain to the 6-12 right gastroepiploic nodes, the efferents of which pass to the right to the pyloric nodes. The pyloric lymph nodes are six to eight nodes located in the angle between the first and second parts of the duodenum in close relation to the terminal division of the gastroduodenal artery. Their efferents pass along this artery to the hepatic nodes and then to the celiac nodes.

Lymph draining from the stomach by means of these various routes passes through the lymph-node groups described and ultimately reaches the celiac nodes. The efferent channels of the celiac nodes help form, with efferents from the superior mesenteric nodes, the intestinal trunk.

Nerve Supply

The nerves of the stomach are both parasympathetic by way of the vagus nerve and sympathetic by means of perivascular plexuses from the celiac plexus.

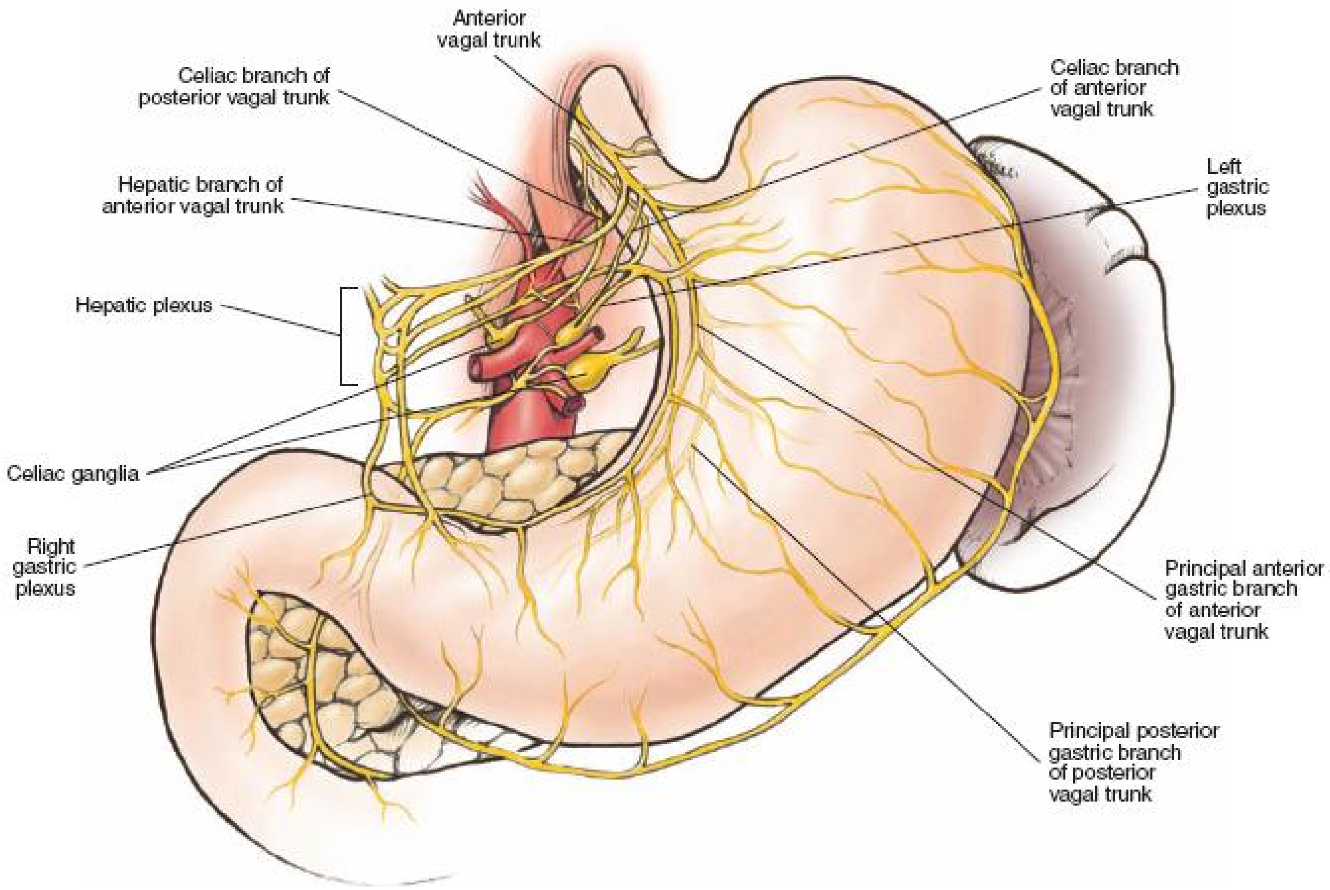


Figure 5

The right and left vagus nerves above the diaphragm coalesce to form the esophageal plexus. Just above the diaphragm the esophageal plexus divides into two nerve trunks that lie anterior and posterior to the esophagus, and then pass through the esophageal hiatus of the diaphragm and down the lesser curve of the stomach.

Both vagus nerves supply gastric branches to the stomach that arise at the cardiac end of the stomach. Each anterior and posterior vagal trunk gives off one long branch, the principal nerves of the lesser curvature, also known as the nerves of Laterjet, which descend on the anterior and posterior surfaces of the stomach and terminate as a "crow's foot" on the pyloric antrum. In addition to the gastric branches, the anterior vagal trunk has a hepatic branch that passes from the stomach to the liver in the upper part of the hepatogastric ligament together with the hepatic branch of the left gastric artery. It also has a small branch that descends through the hepatogastric ligament to the pyloric portion of the stomach, duodenum, and pancreas. The posterior vagal trunk makes a major contribution to the celiac plexus by means of a celiac branch that follows the left gastric artery and vein.

The sympathetic nerve supply of the stomach is by perivascular plexuses (left gastric, hepatic, and splenic) that emanate from the celiac plexus. These are composed primarily of postganglionic sympathetic fibers, the cell bodies of which form the celiac ganglia. The preganglionic fibers reach the celiac ganglia by way of the greater thoracic splanchnic nerve from the fifth to the tenth thoracic cord segments.

The nerves to the stomach appear to have somewhat mixed functions. However, the parasympathetic innervation initiates or enhances muscular movements, and the sympathetic innervation is important in vasomotor control. The parasympathetic fibers exert the greater influence on the secretion of water and hydrochloric acid in the fundus and body; the sympathetic innervation has the major influence in the secretion of enzymes in the stomach.

Surgical Applications

Gastrostomy

There are a number of indications for operative placement of gastrostomy tubes, but they are generally used for gastric decompression or short-term external tube feedings. Long-term enteral feeding through a gastrostomy tube should be avoided because of increased risk for pulmonary aspiration. Patients with carcinomatosis or bowel obstructions requiring extensive lysis of adhesions or patients undergoing long elective abdominal operations may benefit from placement of a gastrostomy tuber ather than prolonged use of a nasogastric tube. The advantages of a gastrostomy tube include the following: (1) it is vastly more comfortable than a nasogastric tube,(2) it allows the patient more mobility, and (3) it does not interfere with respirations or pulmonary toilet. In older patients with underlying pulmonary diseases, a gastrostomy tube may prevent some potentially lethal postoperative complications.

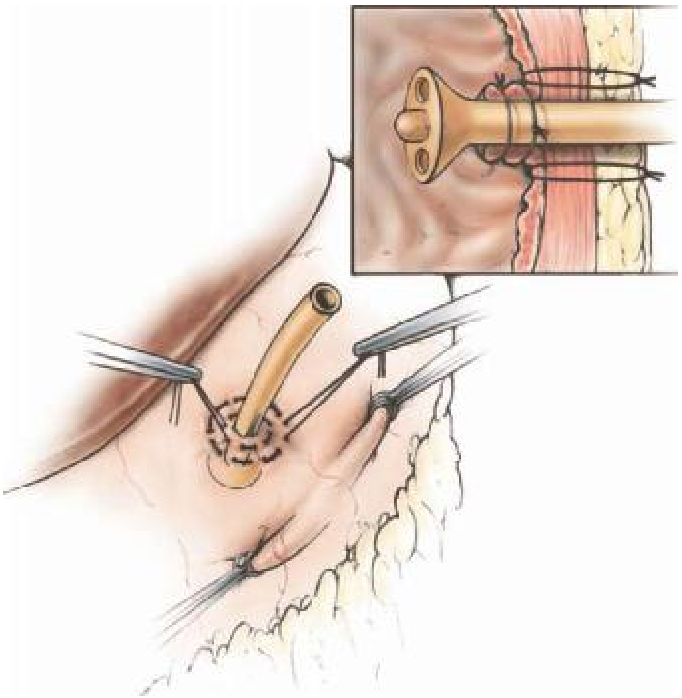


Figure 6

The most widely used temporary gastrostomy is the Stamm gastrostomy. It is performed quickly, easily, and safely and provides excellent venting of the stomach. The stomach is identified and grasped along the greater curvature with two Babcock clamps. A point is chosen on the middle anterior surface of the stomach where it will easily be sewn to the abdominal wall without any tension. A large (20-28 Fr) Malecot or Silastic Foley catheter is brought through a small puncture site in the left upper quadrant, away from the costal margin.

Two concentric 2-0 silk purse-string sutures are placed in the anterior body wall of the stomach. An opening is made in the stomach through the center of the inner purse-string suture using electrocautery. The gastrostomy tube is inserted into the stomach, and the inner purse-string suture is securely tied. While pushing down on the catheter or directly applying downward pressure on the ends of the inner pursestring suture, the outer purse string is tied. The two purse-string sutures form a snug seal and serosal lining for the tube tract. The gastric wall surrounding the tube is sutured to the abdominal wall in all four quadrants to prevent retraction and leakage. The catheter is secured to the skin with a 3-0 nylon suture.

In cases in which the stomach cannot come up to the abdominal wall because of severe adhesions or after a partial gastric resection, a Witzel gastrostomy can be done.

In this method, a single purse-string suture is placed, the tube is positioned through the gastric wall, and a tunnel is fashioned along the anterior gastric wall with 3-0 silk sutures. The gastrostomy tube penetrates the stomach at a distance from the point where it exits the abdominal wall to minimize leakage around the tube.

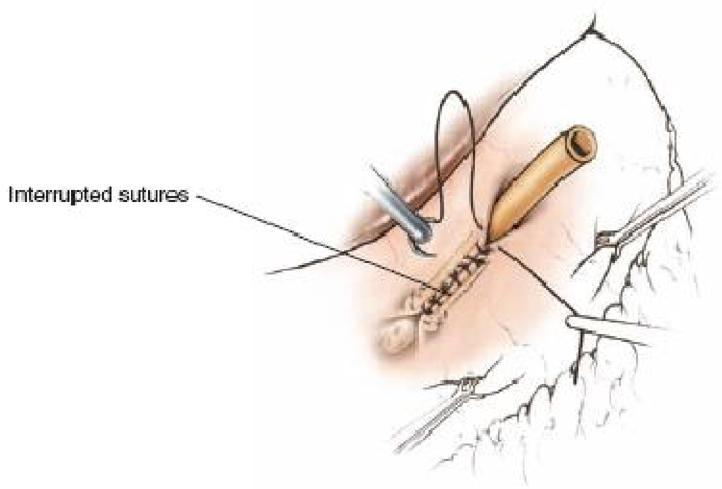


Figure 7

Postoperatively, the gastrostomy tube is placed to drain by gravity and is irrigated on every shift to avoid occlusion by mucus or other debris. The tube should be left in place for a minimum of 2-3 weeks to allow a tract to form between the stomach and the skin, thus preventing intra-abdominal leakage when removed.

Complications from gastrostomy placement are rare but can include leakage and retraction of the stomach from the abdominal wall. Small leaks can be treated conservatively with adequate drainage and nasogastric decompression of the stomach. Major leaks or retraction require repeat operation and repair.

Resection of Smooth Muscle Tumors

Mesenchymal tumors are a rare group of benign or malignant neoplasms that can of affect the gastrointestinal tract, particularly the stomach. They consist of distinct neoplasms: smooth muscle neoplasms, including leiomyoma and leiomyosarcoma; rare peripheral nerve sheath tumors, and GIST. Overall, GIST accounts for at least 80% of gastrointestinal mesenchymal tumors of the stomach and small bowel.

Mazur and Clark first reported the existence of GIST as a separate entity from GI smooth muscle and nerve sheath tumors in 1983. GISTs are thought to originate from the interstitial cell of Cajal (ICC) which are located in and around the myenteric plexus and are thought to function as an intestinal pacemaker cell that regulates intestinal motility. In 1998, the pathological diagnosis of GIST tumors was simplified with the notable discovery of the immunohistological marker KIT (CD117). GIST tumors will have an overexpression of the c-Kit proto-oncogene in 85-90% of tumors. Based on data from the surveillance, epidemiology, and end results (SEER) program of the National Cancer Institute, the incidence of GIST tumors continues to increase every year. It is estimated that currently there are as high as 3,000-5,000 new cases of GIST tumors per year. GISTs can occur anywhere along the GI tract but are most commonly seen in the stomach (65%) or small intestine (25%). The median age of diagnosis is 60 years, and there is a slight male predominance. The clinical diagnosis varies widely, but the majority (70%) present with some vague abdominal symptoms, whereas approximately 20% are asymptomatic.

Table 3 Survival after complete resection (R0/R1) of gastrointestinal stromal tumors

Study	Year	R0/01 No of patients	Survival resections (%)	afterR0/R1 resection (%)
DeMatteo	2000	200	40	54 (5-year)
Crosby	2001	50	70	42 (5-year)
Pierie	2001	69	59	42 (5-year)
Langer	2003	39	90	87 (2-year)
Wu	2003	57	28	40 (2-year)
Carboni	2003	15	100	87 (2-year)
Besana-Ciani	2003	19	79	63 (5-year)

Source: Reproduced with permission from Raut CP, Morgan JA, Ashley SW. Current issues in gastrointestinal stromal tumors: incidence, molecular biology, and contemporary treatment of localized and advanced disease. Current Opinion in Gastroenterology, 23(2): p. 151, 2007. Lippincott Williams and Wilkins. RO = complete macroscopic resection with negative microscopic margins. R1 = complete macroscopic resection with positive microscopic margins.

Asymptomatic GIST tumors are usually found incidentally on radiological exams or at the time of surgery and are usually of smaller size. Larger tumors can cause vague abdominal discomfort, pain, bloating, early satiety, or increased abdominal girth. More significantly, GIST tumors can erode into the lumen of the GI tract and cause significant hemorrhage.

Upper GI endoscopy and endoscopic ultrasound are helpful in the diagnosis of a gastric GIST tumor. Most often a submucosal mass will be seen on endoscopy occasionally with an associated ulcer. CT scan is useful in determining the size, location, and surgical strategy for the treatment of these GIST tumors. PET scans have an important role in evaluating for metastatic disease and determining the success of treatment with Imatinib, a targeted agent against the c-Kit oncogene.

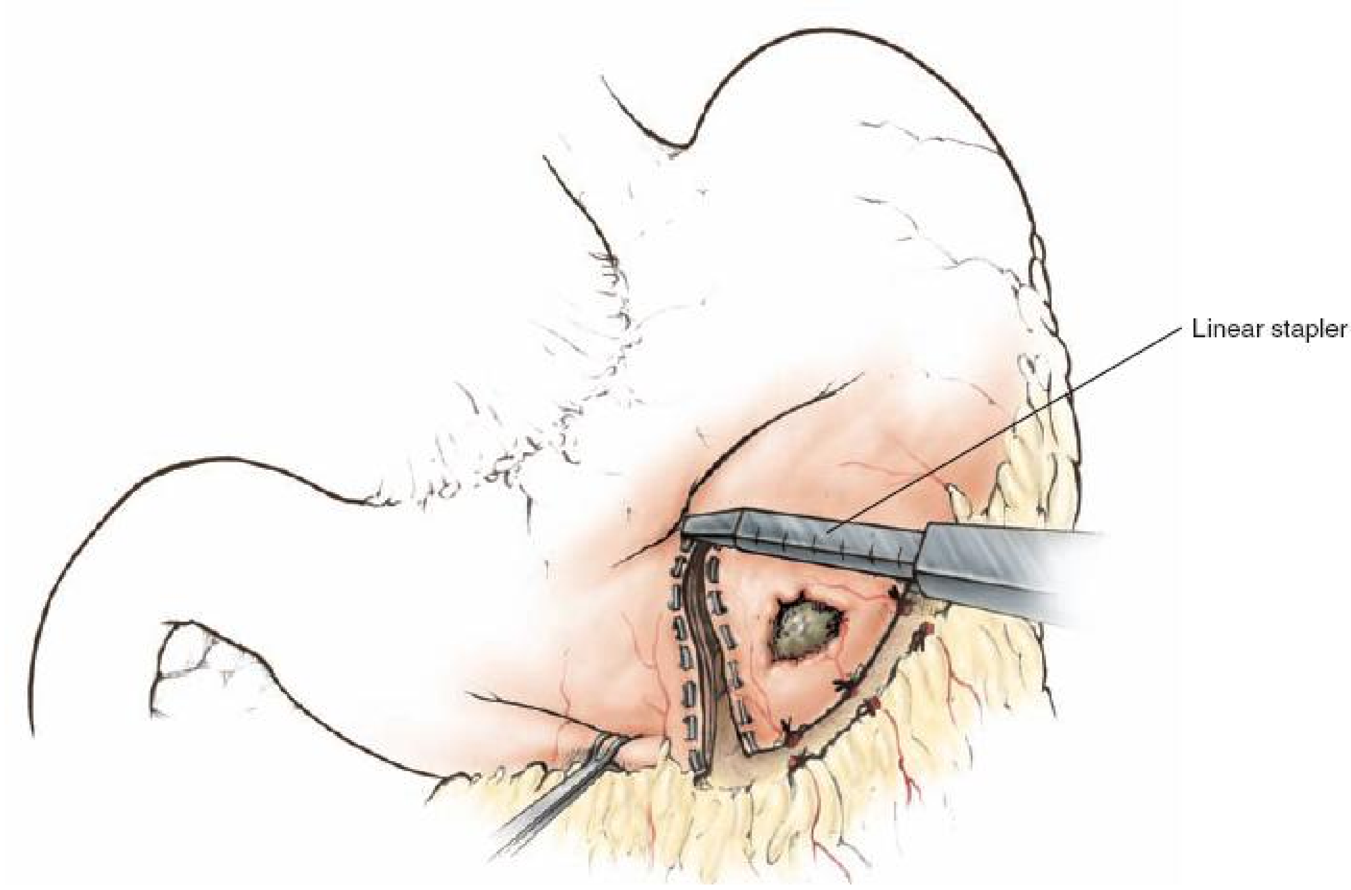


Figure 8

For patients with primary, localized GIST tumors, surgery represents the only potential chance for cure. The resection of small gastric GIST tumors can usually be accomplished with a wedge resection of the stomach. As opposed to adenocarcinoma, GIST tumors are well-encapsulated and only need a resection margin of 1 cm. Similarly, GIST tumors also do not usually metastasize to lymph nodes, such that a lymphadenectomy is not routinely indicated. For tumors along the greater curvature, the omentum is removed from the stomach near the tumor.

Resection can be done using a linear stapler or sharp resection with a hand-sewn two-layer closure. Lesions along the lesser curvature are resected in a similar manner. However, if the lesser curve resection is done with probable disruption of the vagal nerves supplying the pylorus, a pyloromyotomy should be performed to guard against gastric outlet obstruction.

A Heineke-Mikulicz pyloroplasty is perhaps the most commonly performed pyloroplasty and is begun by placing two silk stay sutures at the cephalad and caudal portions of the pylorus. With gentle traction upward on the stay sutures, the pylorus is opened longitudinally and closed transversely with a running absorbable suture and reenforced with interrupted 3-0 silk Lembert sutures. In cases of prepyloric lesions, subtotal gastrectomy should be performed. When GISTs are densely adherent to adjacent organs, en bloc resections should be performed. For larger GIST tumors, full bowel prep should be done in case the mesentery of the left colon is involved and a colon resection is indicated. Laparoscopic resection of small GIST tumors can be done by an experienced laparoscopist, but should only be undertaken when it will not increase the chance of tumor rupture. Complete gross resection of a primary GIST tumor can be accomplished in approximately 85% of all patients. Unfortunately, about 50% patients will develop tumor recurrence after complete resection of their localized GIST tumors. Outcomes of surgical resection are listed in Table 3; 5-year survivals are about 50%.

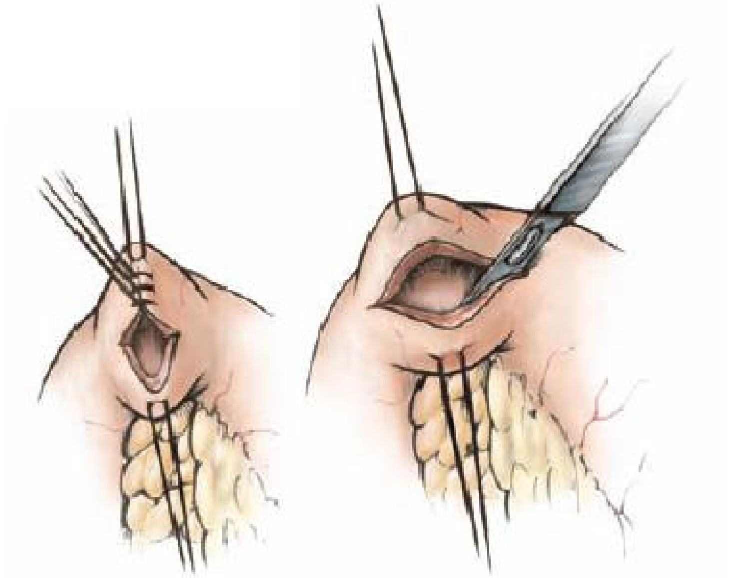


Figure 9

Table 4Risk assessment for primary gastrointestinal stromal tumors.

Risk	Tumor size (cm)	Mitotic rate[a]
Very low	<2	<5
Low	2-5	<5
Intermediate	<5	6-10
	5-10	<5
High	>5	>5
	>10	Any mitotic rate
	Any size	>10

Source: Reproduced with permission from Raut CP, Morgan JA, Ashley SW. Current issues in gastrointestinal stromal tumors: incidence, molecular biology, and contemporary treatment of localized and advanced disease. Current Opinion in Gastroenterology,23(2): p. 151, 2007. Lippincott Williams and Wilkins. [a]Per 50 high-power fields

Several prognostic factors have been determined to predict recurrence of GIST tumors. Tumor size and mitotic index are the two most important prognostic variables that estimate the risk of malignant potential. Based on these two factors, the probability of malignant potential and risk for recurrence are listed in Table 3. Gastric GISTs tend to have a more favorable clinical course compared to those in the small intestine. The ACOSOG has conducted two prospective trials for completely resected primary localized GIST tumors showing a benefit of adjuvant targeted therapy with Imatinib. The Z9000 trial which looked at the recurrence and survival of 106 patients who underwent complete resection of a high-risk GIST (>10 cm), intraperitoneal rupture or bleeding, or multifocal tumors has shown a benefit with the treatment of 1 year of Imatinib compared to historical controls. Z9001 trial was a randomized double-blinded trial in which patients who had undergone complete surgical resection of a GIST tumor >3 cm were given Imatinib or a placebo for 1 year. Those receiving Imatinib had a significant overall survival advantage.

Palliative Gastrojejunostomy

Gastrojejunostomy is indicated for patients with unresectable gastrointestinal cancers Gastrojejunos-such as pancreatic, duodenal, or distal gastric cancers with evidence of impending or tomysymptomatic mechanical gastric outlet obstruction. For patients with unresectable pancreatic or ampullary malignancies, a gastrojejunostomy is often combined with a biliary bypass. The procedure can be performed through either an upper midline or bilateral subcostal incision. Once exploration confirms unresectablility of the primary tumor and near obstruction of the distal stomach or duodenum, the most dependent area of the greater curvature of the stomach is identified.

The omentum along this area is dissected from the greater curvature, and the lesser sac is entered. The next decision is whether to perform the anastomosis in an antecolic or retrocolic fashion. The retrocolic gastrojejunostomy generally empties better than the antecolic gastrojejunostomy but theoretically could be obstructed by tumors invading the transverse mesocolon. For these potentially obstructing tumors, an anticolic anastomosis is recommended.

To perform the retrocolic anastomosis, the ligament of Treitz is identified, and a proximal loop of jejunum is brought up through an incision in an avascular area of the transverse mesocolon.

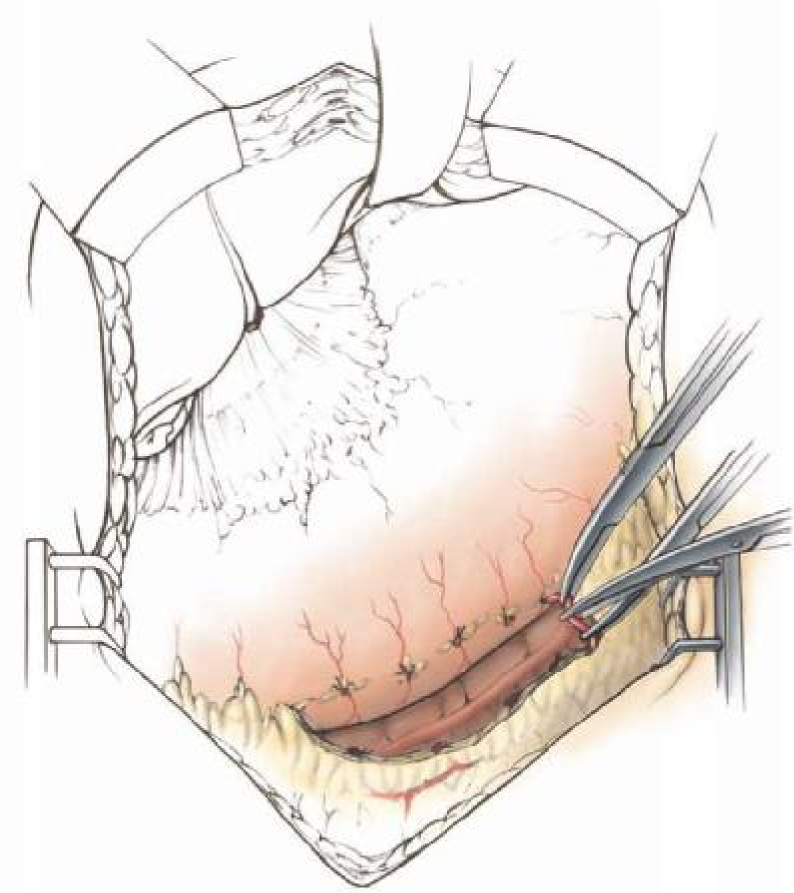


Figure 10

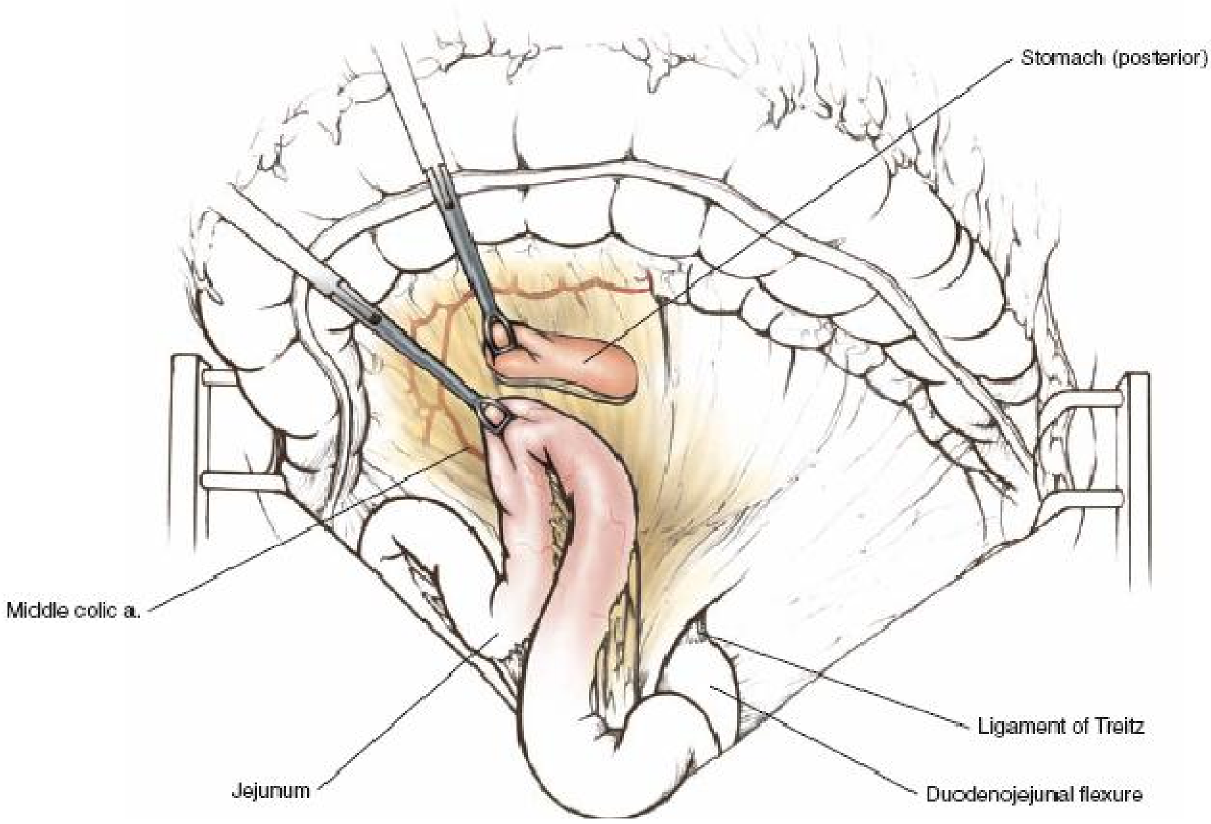
A side-to-side anastomosis is made with an inner layer of 3-0 absorbable sutures and an outer layer of Lembert 3-0 silk interrupted sutures. To minimize the risk for afferent loop syndrome or afferent loop herniation, the afferent loop is brought up to the more proximal stomach, minimizing the length of this segment of jejunum.

The gastrojejunostomy is then sutured to the rent in the transverse mesocolon on the gastric side to prevent obstruction of the anastomosis or bowel herniation.

An antecolic anastomosis is done in a similar fashion. However, the loop of jejunum is brought anterior to the colon, and the same side-to-side two-layer anastomosis is accomplished. A gastrostomy tube and feeding jejunostomy tube are placed distal to the anastomosis to aid in postoperative feeding and gastric decompression.

Subtotal gastrectomy with R2 lymph-node dissection can be performed throughSubtotal either an upper midline or a bilateral subcostal incision. A Goligher retractor isGastrectomy placed for exposure. The abdomen is completely explored to look for occult metastatic disease, and the primary tumor is assessed for resectability. The left lateral segment of the liver is mobilized by incising the left triangular ligament and folding the lobe underneath itself with gentle pressure from a self-retaining retractor.

The stomach is exposed, and the lesser sac is entered by dissecting the greater omentum from the transverse colon. This dissection is facilitated by gentle opposing traction of the omentum and colon and is easier to begin over the left transverse colon.



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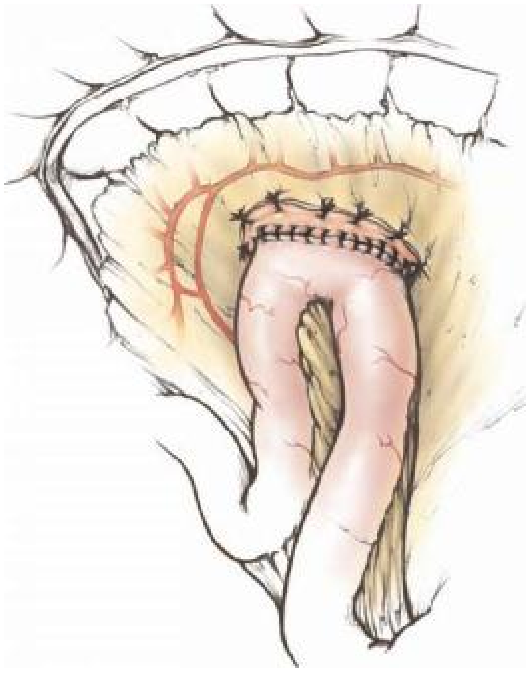

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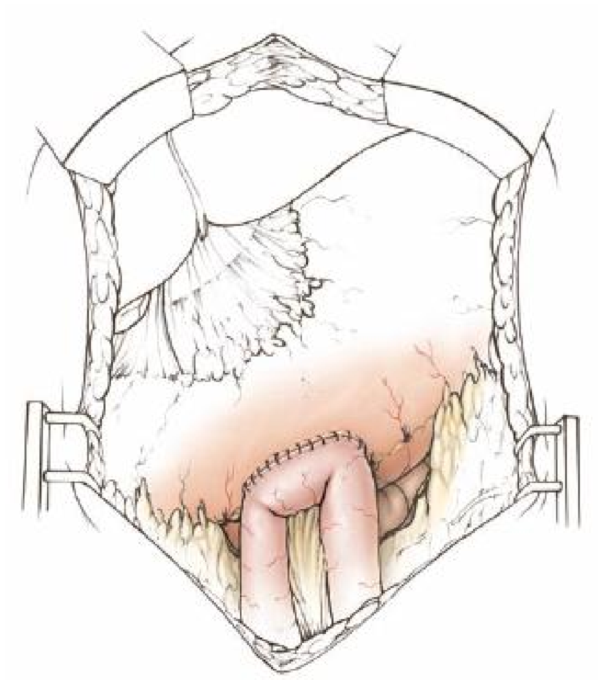


Figure 13

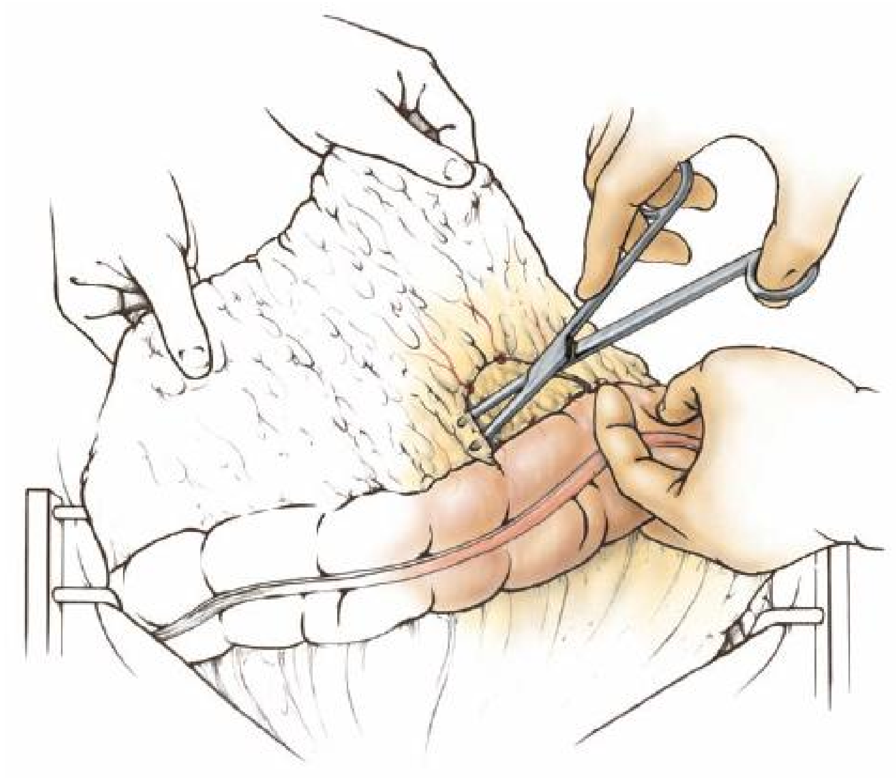


Figure 14

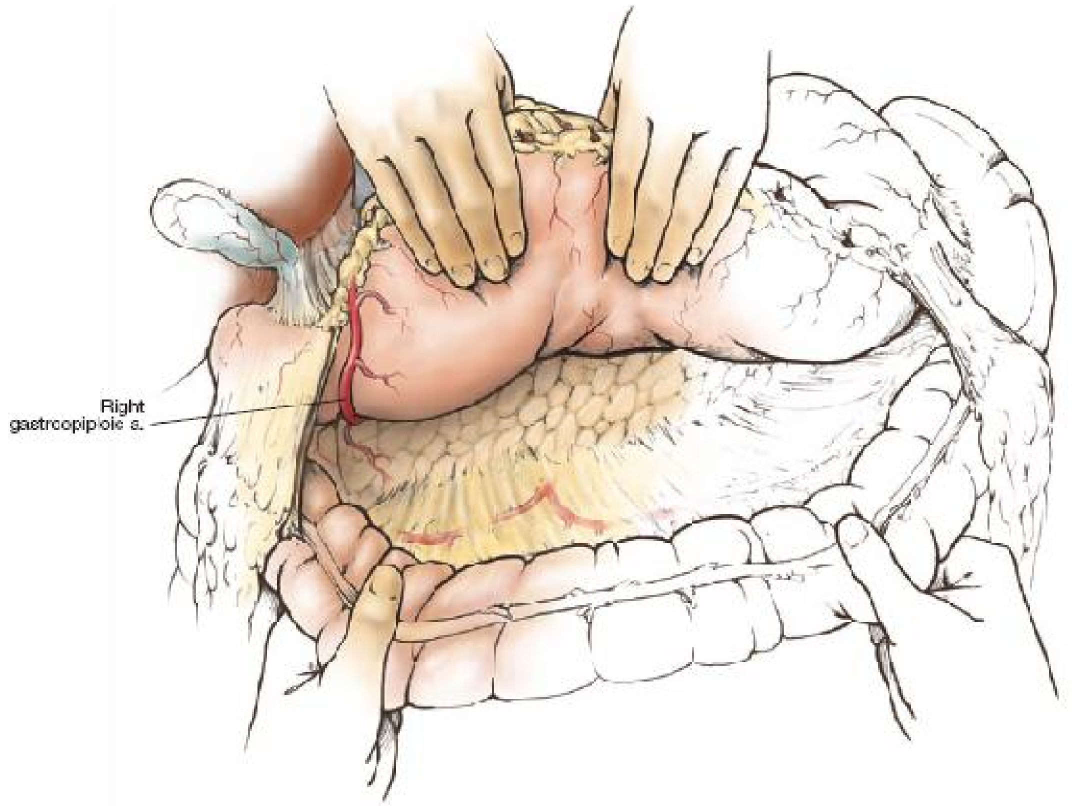


Figure 15

The peritoneum overlying the cephalad portion of the transverse mesocolon is dissected up, with care not to injure the middle colic vessels. In some patients this plane of dissection is not possible because of fusion of the peritoneum. When possible, this plane of dissection is continued past the base of the mesocolon to the inferior edge of the pancreas. The peritoneum and fatty tissue over the pancreas are dissected in a cephalad fashion.

Once the lesser sac is entered, the dissection continues along an avascular plane, moving to the patient's right until the right gastroepiploic vessels are identified and ligated. To mobilize the duodenum and pylorus, a Kocher maneuver is performed by dividing the retroperitoneal attachments to the duodenum. The attachments between the gallbladder and duodenum are released and the hepatoduodenal ligament is transected, exposing the porta hepatis.

The right gastric vessels are identified and ligated. The pylorus and the first portion of the duodenum are mobilized just enough to achieve a tumor-free margin and safe closure of the duodenum.

The duodenum is transected with a stapling device just 2 cm distal to the pylorus. The staple line is oversewn with a row of interrupted 3-0 silk Lembert sutures.

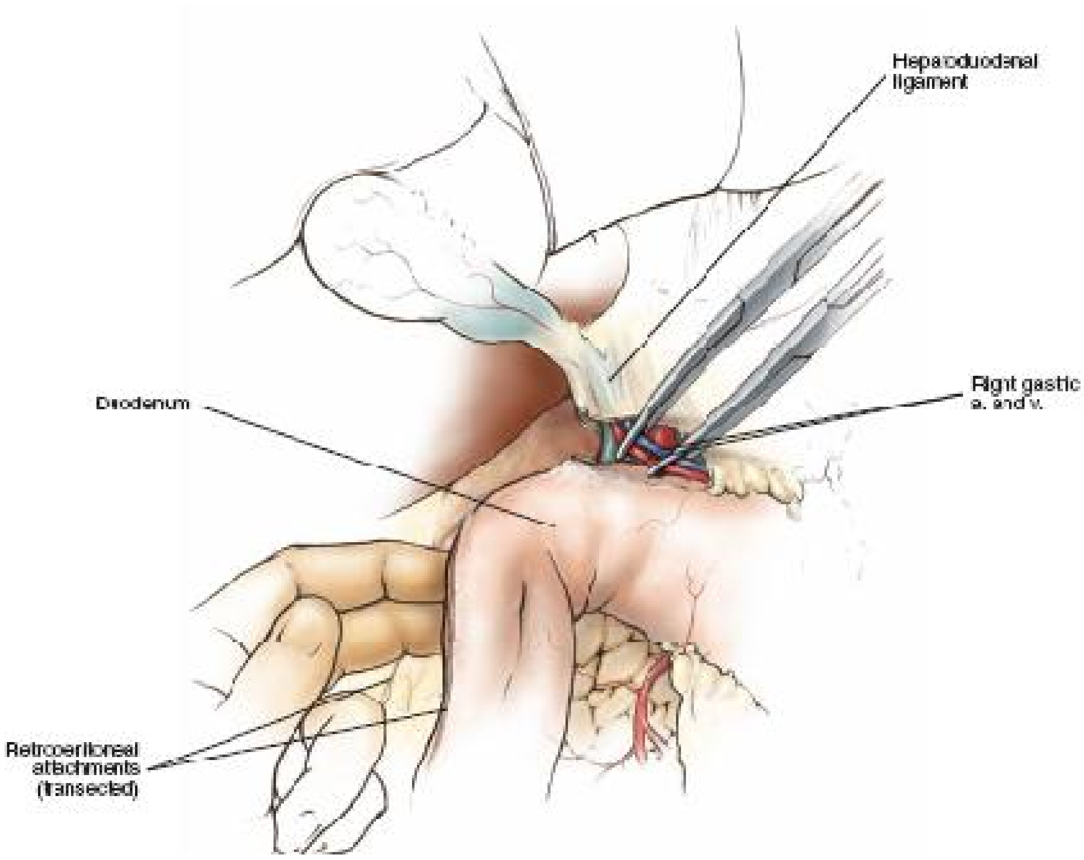


Figure 16

Figure 17

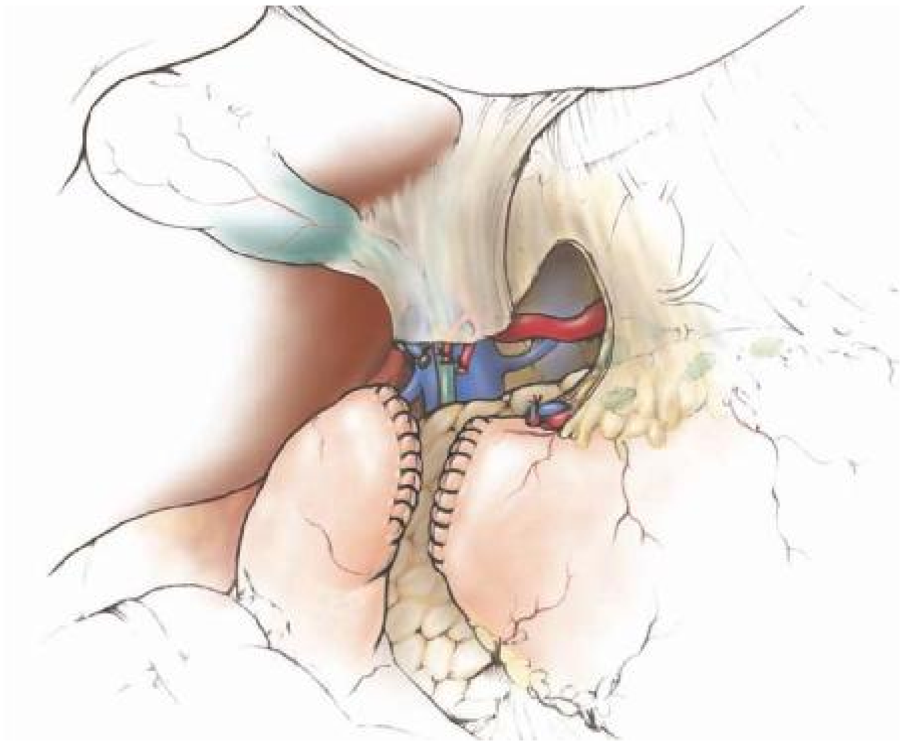


Figure 18

The lesser omentum is taken down from its attachments to the liver along with the lymph-node tissue inferior to the hepatic artery and along its course down to the celiac trunk. It is important to remember that an aberrant or accessory left hepatic artery may originate from the left gastric artery and reside in the lesser omentum. The aberrant artery should be preserved along with the main left gastric artery.

The stomach and omentum are then retracted cephalad, exposing the left gastric artery, which is doubly ligated at its origin and divided. The R2 nodes around the celiac axis are dissected with the specimen along the aorta from the celiac trunk to the superior border of the pancreas to the left along the splenic vessels. The proximal line of gastric transection is chosen about 5 cm from the tumor. The lesser and greater omentum are dissected from the stomach at the proximal transection site.

The proximal stomach is transected with a 90-mm stapling device. Studies have shown no benefit of total gastrectomy compared with subtotal gastrectomy as long as a tumor-free margin is achieved. After histologic confirmation of disease-negative resection margins, reconstruction is begun.

To prevent tension on the anastomosis, I prefer to use a retrocolic or anticolic Roux-en-Y gastrojejunostomy. A loop of proximal jejunum is identified and transected with a stapling device at about 20 cm from the ligament of Treitz. The jejunal limb is mobilized so that the distal limb reaches the proximal stomach. A 50-cm distal limb is measured and marked with a stitch.

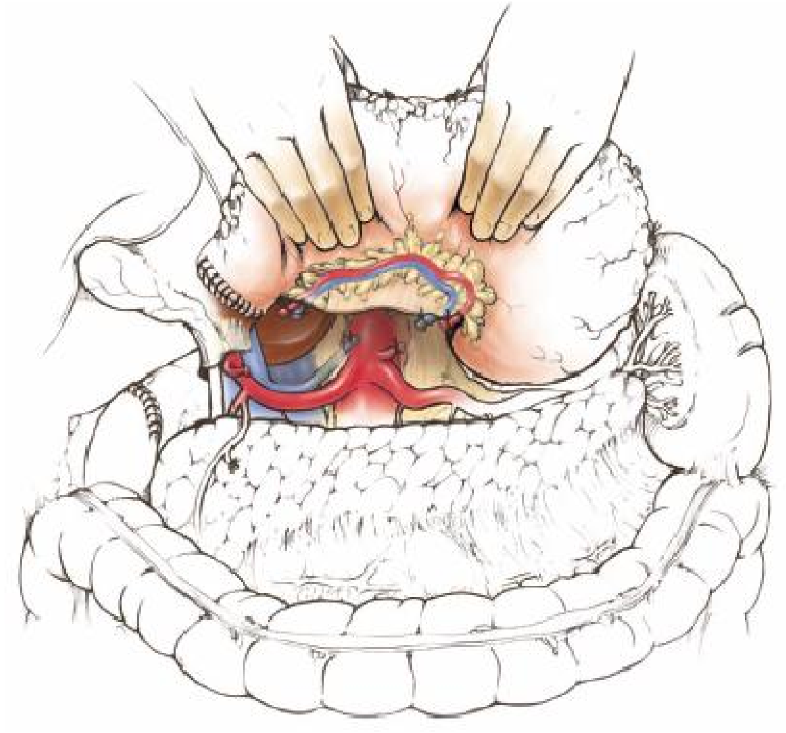


Figure 19

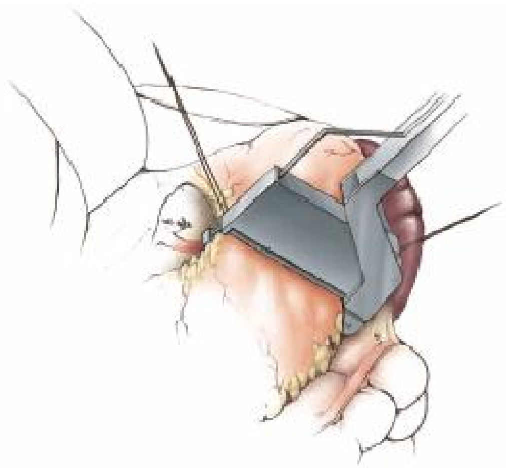


Figure 20

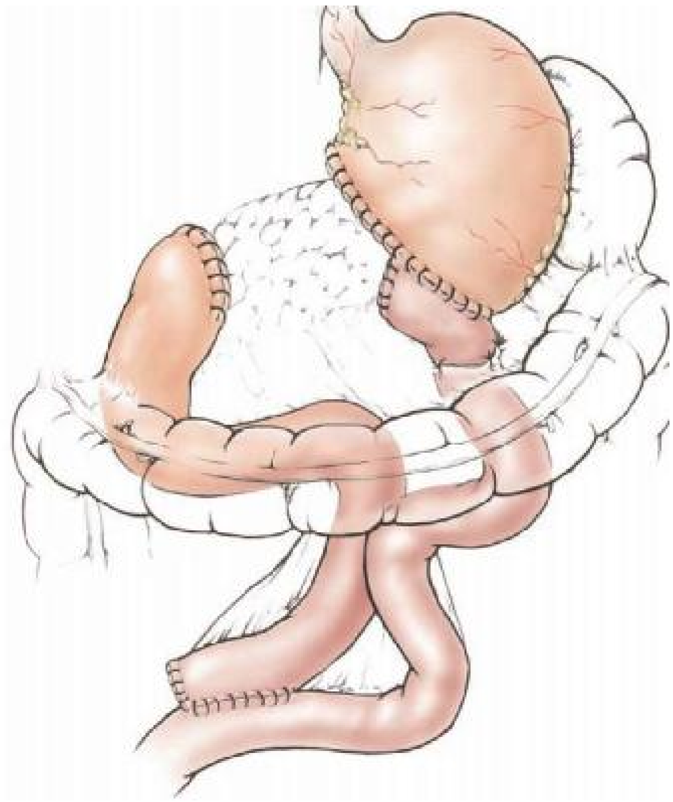


Figure 21

A side-to-side jejunojejunostomy is performed with either a two-layer hand-sewn or stapled method. The distal limb is either brought up through the mesocolon or in front of the colon, and an end-to-side gastrojejunostomy anastomosis is made using a two-layer technique of 3-0 running absorbable sutures for the inner layer and interrupted 3-0 silk Lembert sutures on the outside. An alternate technique is to use either an anticolic or retrocolic Billroth II loop gastrojejunostomy. However, with a large subtotal resection, many times there is not enough length on the loop for a tension-free anastomosis.

For a loop gastrojejunostomy, either a Polya or Hofmeister technique can be performed on the basis of personal preference. Whether the jejunal loop is placed isoperistaltic or antiperistaltic is not important functionally, but, more important, the jejunal loop should be oriented for the anastomosis in a way that minimizes tension, angulation, or undesirable twisting of the small bowel. Difficult duodenal closures should be drained with a closed suction drain. A feeding jejunostomy is placed for early postoperative feeding.

Potential complications after subtotal gastrectomy include intra-abdominal bleeding, delayed gastric emptying, pancreatitis, duodenal stump leakage, and anastomotic leakage. After the perioperative period, some of the so-called postgastrectomy syndromes can be devastating to the patient. These syndromes include afferent loop syndrome, bile gastritis, and dumping syndrome.

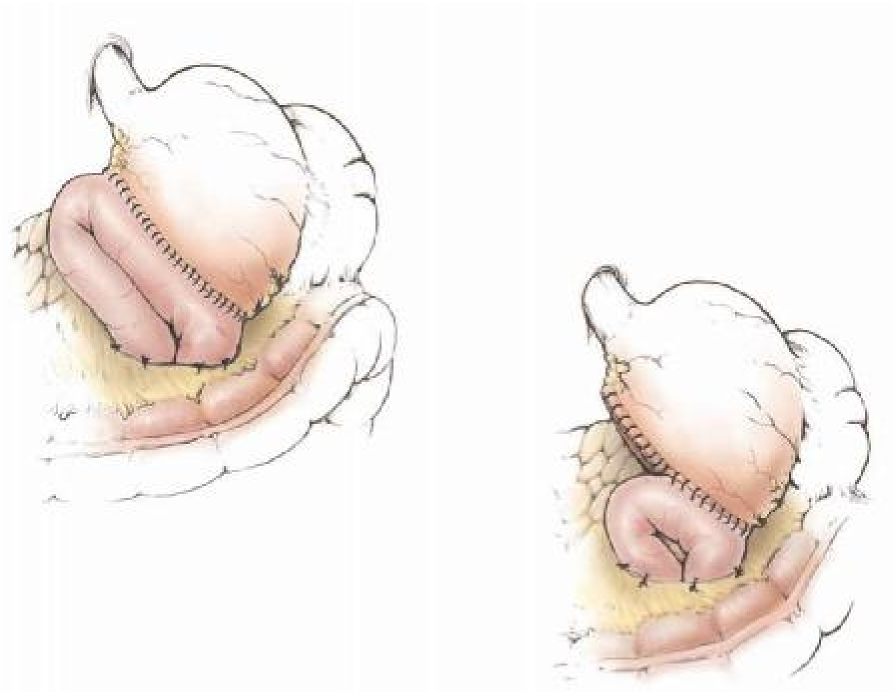


Figure 22

Radical Lymphadenectomy

The role of radical lymphadenectomy in gastric cancer has been very controversial over the past few decades but is based on the principle that a radical resection, including extensive removal of lymph-node tissue, could result in improved outcomes. In Japan, where gastric cancer is far more common than in Western countries, the standardized radical lymph-node dissection has been developed and used with a therapeutic benefit and improved long-term survival rates compared to Western centers. The Japanese classification for gastric carcinoma (JCGC) shown in Table 5 has categorized the regional lymph nodes into various anatomical regions for lymph node stations, identified by numbers. These lymph-node stations are classified into three groups that correspond to the location of the primary tumor and reflect the likelihood of harboring lymph-node metastases. Most perigastric lymph nodes (# 1-6) are defined as Group 1 and lymph nodes at the base of the left gastric artery (# 7) along the common hepatic (# 8), splenic (# 11), and proper hepatic (# 12) arteries and along the celiac axis (# 9) are defined as Group II. The periaortic lymph nodes (# 16) are defined as Group III. The extent of elective lymph-node dissection has been classified as D categories in the JCGC. D1 corresponds to dissection of Group 1 lymph nodes and D2 denotes dissection of Group 2, in addition to the Group 1 lymph nodes. D3 represents D2 lymph nodes plus resection of the periaortic lymph nodes (Group 3). In 1981, Kodama et al. showed that patients undergoing a D2 lymphadenectomy compared to those with a D1 lymphadenectomy had a significant improved overall survival.

Table 5 Anatomic grouping of lymph nodes according to site of primary tumor

Group	Location of primary tumor			
	Entire stomach	Lower third	Middle third	Upper third
Group 1 (N1 or perigastric nodes)	1-6	3-6	1, 3-6	1-4
Group 2 (N2)	7-11	1, 7-9	2, 7-11	5-11
Group 3 (N3)	12-14	2, 10-14	12-14	12-14

[1] right cardial, 2 left cardial, 3 along the lesser curvature, 4 along the greater curvature, 5 suprapyloric, 6 infrapyloric, 7 along the left gastric artery, 8 along the common hepatic artery, 9 around the celiac artery, 10 at the splenic hilus, 11 along the splenic artery, 12 in the hepatoduodenal ligament, 13 at the posterior aspect of the pancreas, 14 at the root of the mesentery

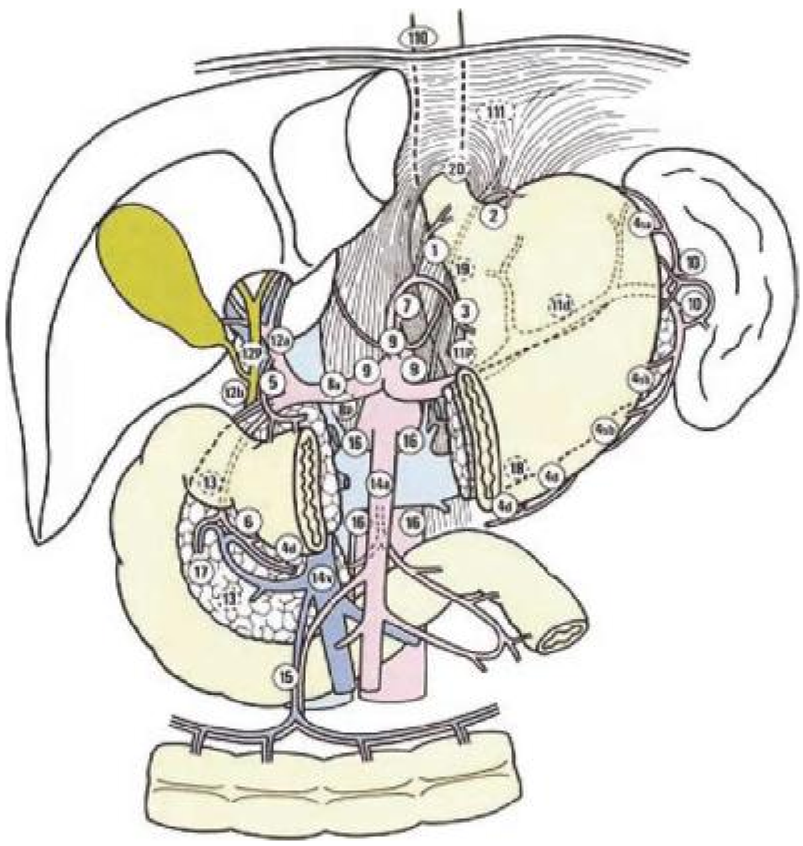


Figure 23

Source: Reproduced with permission from the Japanese Gastric Cancer Association. Japanese classification of gastric cancer, 2nd English edition. Gastric Cancer, 1:16, 1998, Springer.

In order to resolve the controversy about the benefit of D2 lymphadenectomy, several large, randomized studies were conducted in Western centers. In 1989, the Medical Research Council (MRC) in the United Kingdom conducted a trial that accrued 737 patients with histologically proven gastric adenocarcinoma. They randomized 400 resectable patients to equal groups of gastrectomy with either D1 or D2 lymphadenectomy. Patients undergoing a D2 resection had significantly higher post-operative mortality and complication rates compared to those who underwent a D1 resection. However, the excess morbidity, mortality, and prolonged hospital stay was associated with the routine use of pancreaticosplenectomies done in D2 dissections in this study. Both the overall survival and recurrence-free survival were similar between the two groups. The authors concluded that the standard D2 lymphadenectomy offered no survival advantage over D1 resection. A second large multicenter prospective randomized trial was conducted in the Netherlands and again compared the outcome of D1 and D2 lymph-node dissections for gastric cancer. Seven hundred and eleven patients were randomized to either a D1 or a D2 lymphadenectomy after a curative gastrectomy. The D2 resections were done by one of eight specially trained, regional surgeons who had been instructed by an expert Japanese gastric surgeon. Despite efforts to maintain quality control, there was significant noncompliance of lymph-node basins resected. More specifically, noncompliance occurred in 51% of D2 dissections in which no lymph nodes were obtained from at least two of the lymphnode stations to have been dissected. Similar problems with noncompliance in the D1 dissections also occurred. Patients undergoing D2 dissections also had higher postoperative mortality and significant more postoperative complications. Similar to the MRC trial, D2 dissections in this study also required a pancreaticosplenectomy for proximal tumors and morbidity and mortality were increased in this group. The lack of benefit of D2 lymphadenectomy in these randomized trials has been challenged by many authors. First, the inadequate pretrial training in these studies was associated with a much higher mortality rate than reported in contemporary nonrandomized studies conducted in high-volume centers. Second, obligatory resection of the spleen and distal pancreas during total gastrectomy was specified in both trials and in most cases is not necessary. Third, efforts to validate the different extent of lymph-node dissection between D1 and D2 operations, in fact, indicated a considerable degree of overlap between the treatment groups. The effects of such contamination and noncompliance errors reduce the estimated difference in survival between the groups. In the United States in general, low postoperative morbidity and mortality have been universally observed in centers with high volume and surgeons trained and experienced in D2 dissections. Several nonrandomized trials done in specialized high-volume centers have shown similar morbidity and mortality between D1 and D2 lymphadenectomy. The same nonrandomized specialized series have suggested and associated improved survival in subgroups of patients undergoing D2 lymphadenectomy compared with limited D1 resections. In a prospective nonrandomized multicenter study, Seiwert et al. found equivalent morbidity (30%) and mortality (5%) rates for standard and radical lymph-node dissections performed on 1,654 patients with operable gastric cancer. D2 lymphadenectomy was an independent, prognostic factor associated with improved survival on multivariate analysis in Stage II and Stage IIIa patients. In a similar retrospective study of 320 patients, Pacelli et al. compared limited D1 with extended D2/D3 dissections. Postoperative morbidity and mortality were similar between the two groups. The authors reported a significant benefit in patients who had D2/D3 dissections with improved overall 5year survival rates in all patients. The role of D2 dissections in the United States remains controversial, but the mortality and morbidity of patients undergoing a D2 lymphadenectomy in high-volume centers is similar to those undergoing a D1 dissection. Surgeons experienced in D2 lymphadenectomies should be able to provide patients with acceptable morbidity and mortality, better cancer staging, and perhaps better long-term survival. Several recent studies looking at the role of D3 lymphadenectomy compared to D2 lymphadenectomyhave been completed. Universally, these have shown no statistical survival advantage and most surgeons have abandoned D3 periaortic lymph-node dissections.

Total gastrectomy

Total gastrectomy can be performed by extending the proximal dissection of the Gastrectomysubtotal gastrectomy described previously.

After the omentum is mobilized off the transverse colon, and dissection of the duodenal region and R2 lymphadenectomy are complete, the dissection is continued along the greater curvature, dividing the gastrosplenic ligament and each of the short gastric vessels. During this dissection, the surgeon needs to avoid excessive traction, which could result in a capsular tear of the spleen. Studies have shown no benefit to removing the spleen during gastrectomy unless there is direct tumor invasion. The dissection along the lesser omentum is extended up to the esophagus.

With the left lateral lobe of the liver retracted medially, the esophagus is identified by palpation of the nasogastric tube, and the peritoneum along its intra-abdominal portion is divided. A Penrose drain is placed around the esophagus to aid in the dissection. The vagus nerves are identified and divided above the esophagogastric junction.

The esophagus is divided, and frozen-section pathologic evaluation is done because of the frequency of unsuspected proximal lymphatic infiltration of tumor.

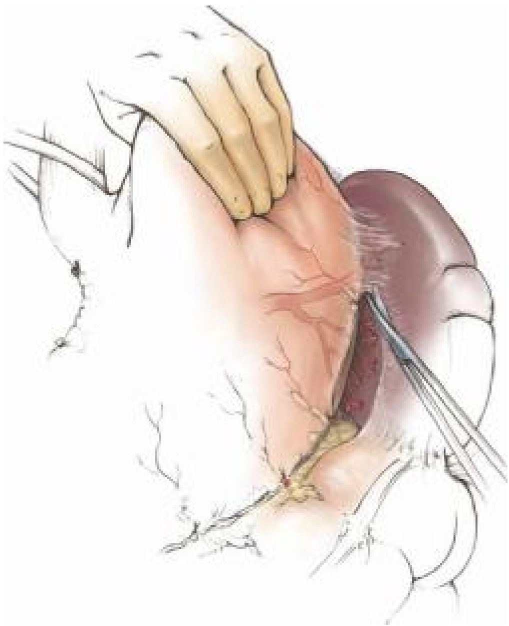


Figure 24

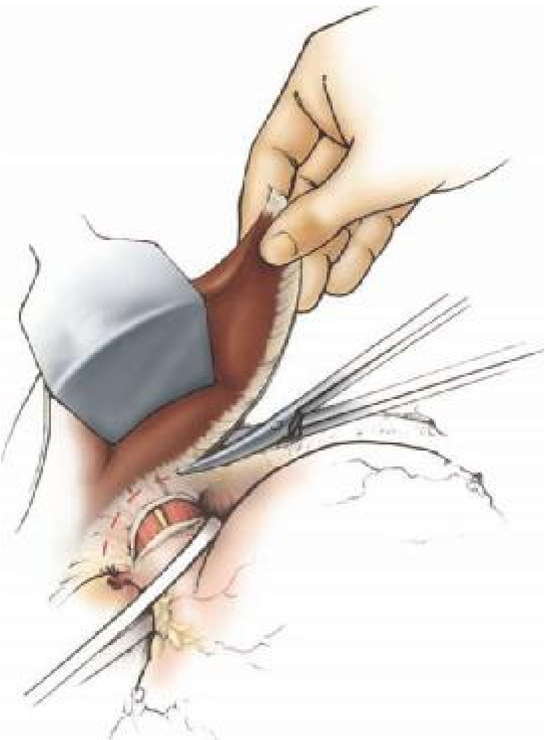


Figure 25

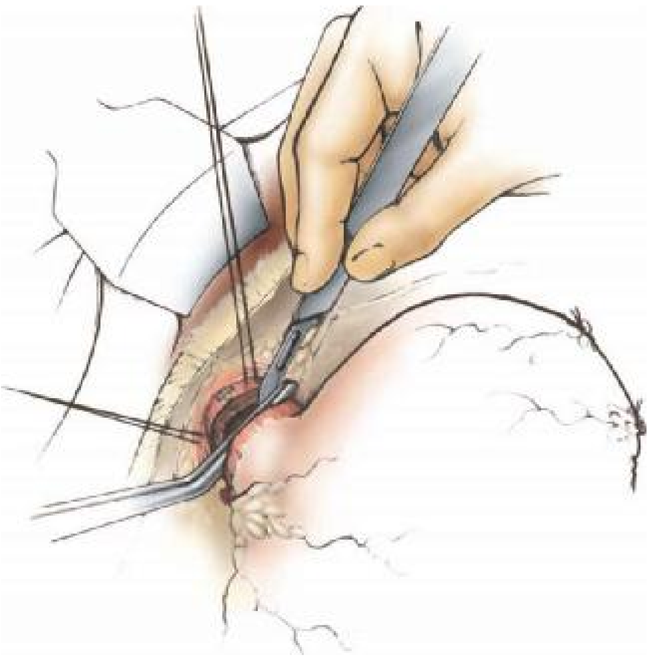
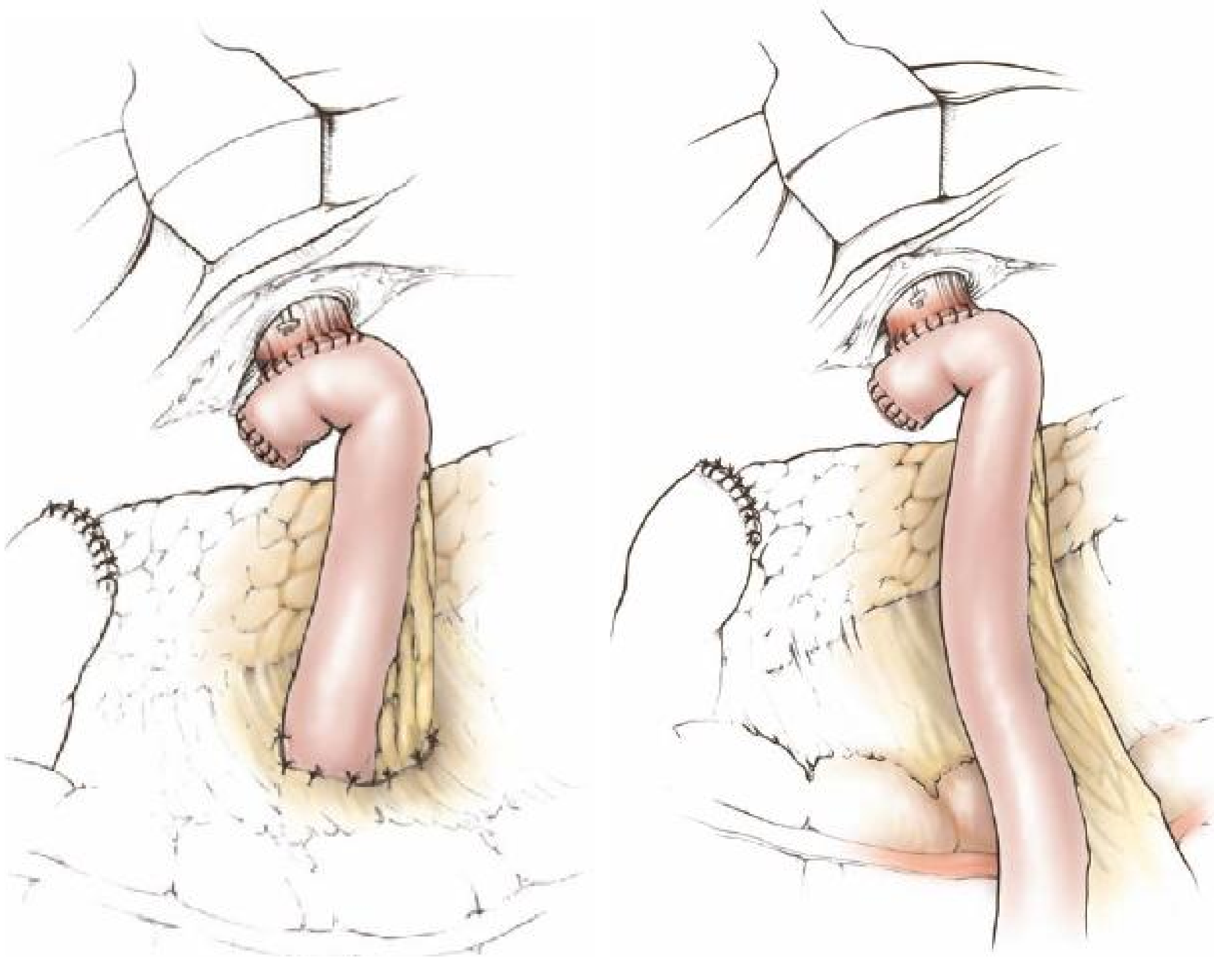


Figure 26



RETROCOLIC ANTECOLIC

Figure 27

After removal of the specimen and disease-free margins are confirmed histologically, a Roux-en-Y end-to-side esophagojejunostomy is performed. Stay sutures are placed on the lateral aspects of the esophagus. The Roux limb is then brought up either retrocolic or antecolic. A point 8-10 cm from the end of the Roux limb is then used for the end-to-side anastomosis, which can be done either with the circular stapling device or a two-layer hand-sewn anastomosis.

For the stapled anastomosis, the staple line at the end of the Roux limb is removed.

The appropriate-sized circular stapler is introduced through the Roux limb.

A 2-0 Prolene purse-string suture is placed in the end of the esophagus, and the anvil of the circular stapler is inserted into the esophagus. The purse-string suture is tightened and the stapler engaged.

After removing the stapler, the end of the jejunal limb is closed with a linear stapler. The nasogastric tube is placed down the efferent limb.

There are many modifications of the reconstruction of a total gastrectomy. Some surgeons have advocated the use of a jejunal pouch (Hunt-Lawrence pouch), which can be created by performing a side-to-side jejunojejunostomy just below the esophagojejunostomy to act as a food reservoir. This pouch can be created using either a handsewn or stapled technique.

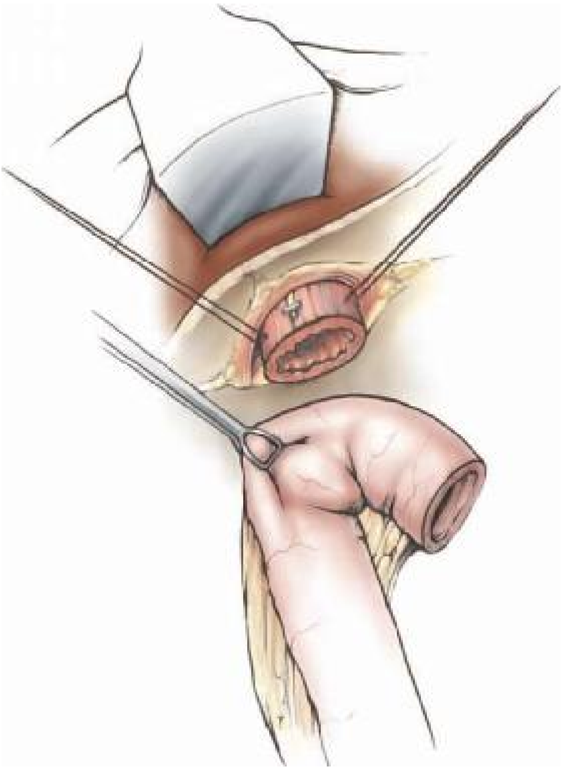


Figure 28

Figure 29

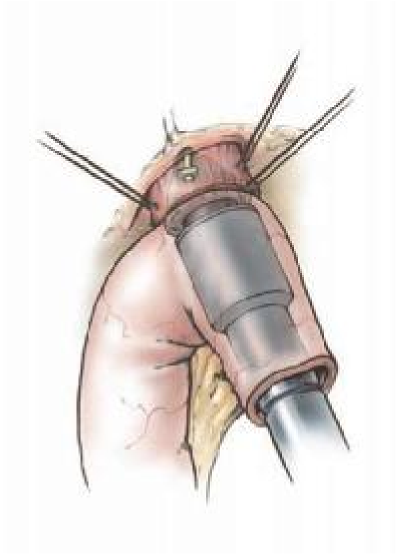


Figure 30

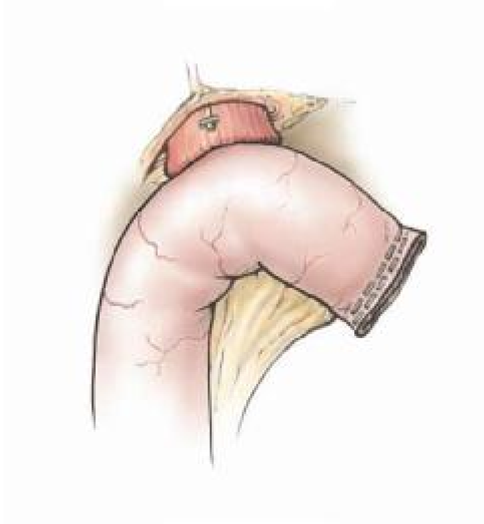


Figure 31

However, there is no objective evidence that these pouches provide nutritional benefits over a standard Roux-en-Y esophagojejunostomy. A feeding jejunostomy is placed for early postoperative feeding. A closed suction drain is placed near the esophagojejunostomy.

Large gastric tumors may locally invade adjacent organs, and the operating surgeon must be prepared to resect these organs en bloc if necessary. Bulky tumors along the posterior wall of the antrum or body may extend into the pancreas or retroperitoneal structures. When this occurs, the distal pancreas and spleen should be removed en bloc with the stomach. The splenic flexure of the colon is mobilized to gain better exposure of the spleen. The retroperitoneal and colonic attachments to the spleen are divided. The spleen and distal pancreas are elevated and brought to the midline.

Extended Gastrectomy

The splenic vein and artery are ligated. The pancreas is divided at the level of the mesenteric vessels. The residual pancreas requires ligation of the pancreatic duct with a 5-0 Prolene suture and closure of the pancreatic stump with 3-0 Prolene mattress sutures. A closed suction drain is placed near the pancreatic closure.

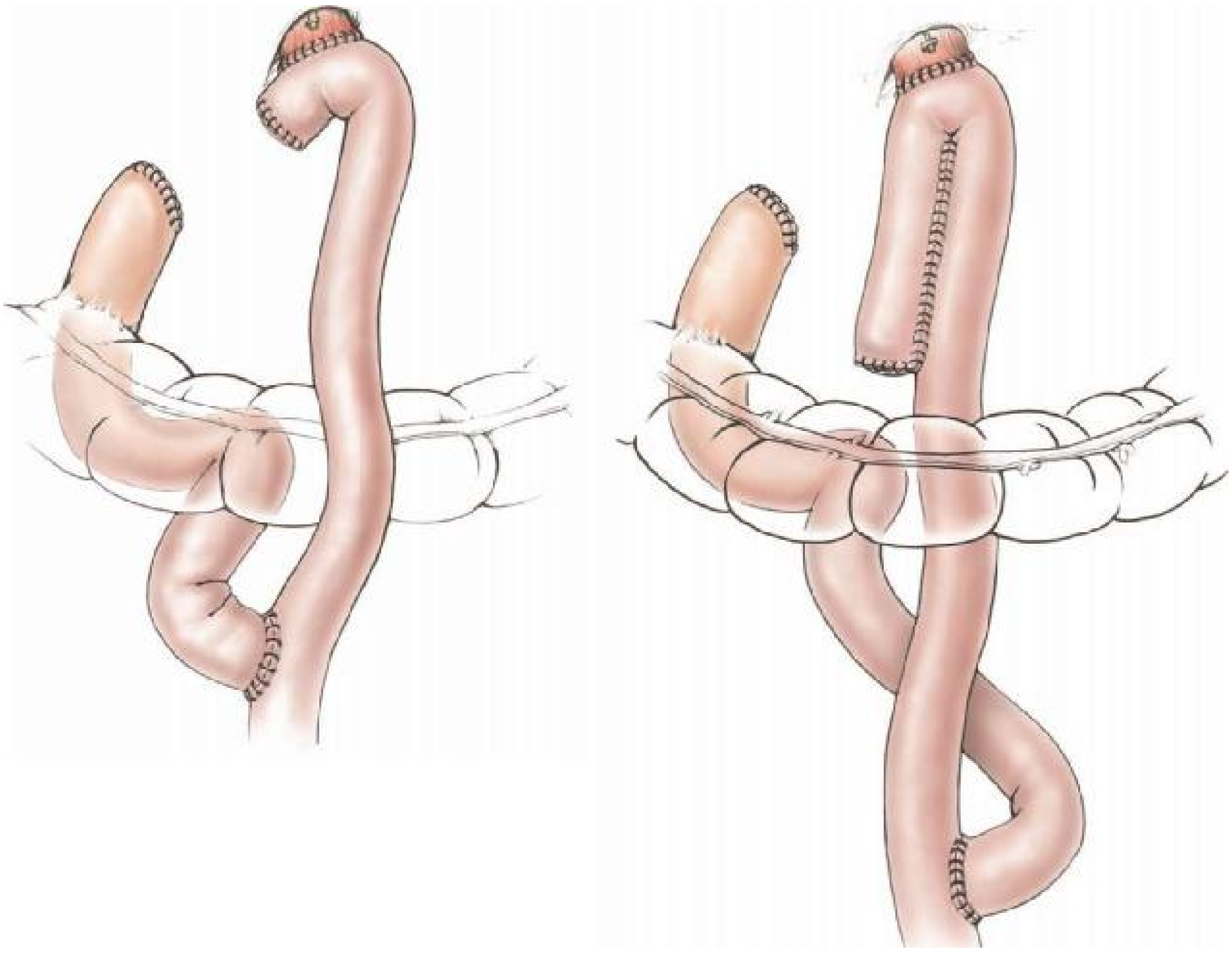


Figure 32

On occasion gastric carcinoma can locally also invade the left lateral lobe of the liver. This represents direct tumor invasion, not metastatic disease. An umbilical tape is placed around the porta hepatis if inflow occlusion is needed.

Overlapping large 0 chromic liver sutures are used for hemostatic control along the liver transection line. The liver tissue is then divided with at least a 1-cm gross margin using the ultrasonic dissector or the electrocautery unit. The remainder of the gastrectomy is done in the standard fashion.

Large tumors along the greater curve of the stomach may invade either the transverse colon mesentery or the transverse colon itself, and may require en bloc resection of the stomach and transverse colon. Given an adequate mechanical and antibiotic bowel preparation, a primary colon resection is performed with reanastomosis of the colon.

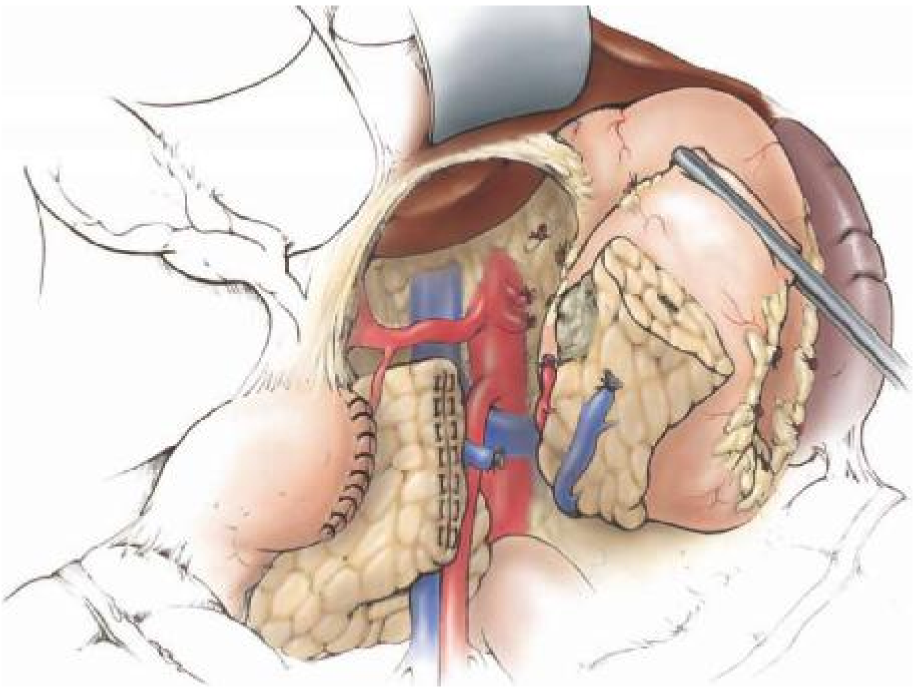


Figure 33

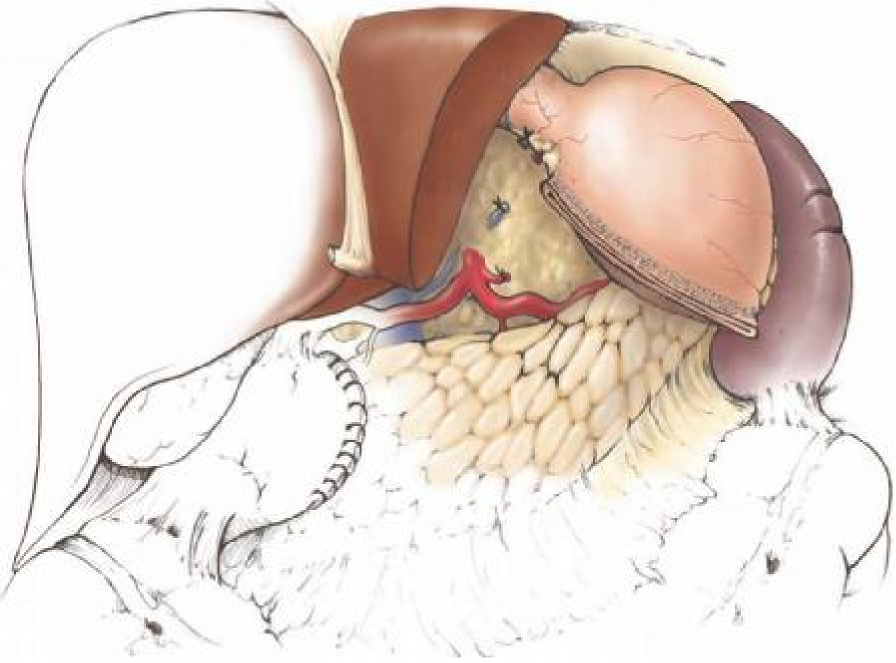


Figure 34

Anatomic Basis of Complications

Major

- Too much traction on the gastrosplenic ligament may result in splenic injury, requiring splenectomy.
- Division of an aberrant left hepatic artery in the lesser omentum from the left gastric artery may cause ischemia or necrosis of the left lobe of the liver.
- Breakdown of the duodenal stump closure will result in intra-abdominal abscess formation and sepsis.

Minor

Pancreatitis can develop from dissection along the gland.

- Delayed gastric emptying will result in intermittent nausea and vomiting.
- Afferent loop syndrome can develop due to mechanical obstruction of an afferent loop of jejunum.

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Gouzi J, Huguier M, Fagniez P, et al Total versus subtotal gastrectomy for adenocarcinoma of the gastric atrium. A French prospective controlled study. Ann Surg. 1989;209:162-6

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This article presents an overall review of the diagnosis, preoperative staging, and surgery of gastric cancer. Only 30% of patients with gastric cancer will have disease that is resectable with a curative intent. Patients with proximal tumors had a poorer survival rate compared with that in other locations.