Techniques in Minimally Invasive Surgery

Marco G. Patti
Amer H. Zureikat
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Laparoscopic Fundoplication

Francisco Schlottmann, Kamil Nurczyk, and Marco G. Patti

1.1 Introduction

Gastroesophageal reflux disease (GERD) is a frequent disorder worldwide, especially in developed countries. In the United States, it is estimated that around 20% of the adult population is affected by GERD, with increasing incidence rates in the last decades mostly due to the epidemic of obesity [1]. The economic impact of this disease is alarming, with direct health care costs of approximately $10 billion per year (being proton pump inhibitors (PPI) the largest contributors to these expenses) [2, 3].

The main purpose of treatment of GERD is to control symptoms, improve patients' quality of life, and prevent GERD-related complications such as bleeding, esophageal stenosis, Barrett's esophagus and/or esophageal adenocarcinoma.The vast majority of patients respond adequately to lifestyle modifications and PPI. A small percentage of patients, however, are candidates for antireflux surgery due to the following reasons: partial control of symptoms (e.g. regurgitation or cough) with medication, presence of large hiatal hernia, poor patients 'compliance with medical therapy, refusal to be on long-term medical treatment, or complications related to medical therapy [4].

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A careful patient selection, a complete preoperative work-up, and a properly executed operation are key for the success of antireflux surgery [5–7].

1.2 Clinical Presentation

Heartburn, regurgitation, and dysphagia are considered typical symptoms of GERD. In addition to the typical symptoms, patients with GERD can present with atypical symptoms such as cough, wheezing, chest pain or hoarseness. These symptoms represent extraesophageal presentations of the disease, including respiratory disorders such as asthma, as well as ear, nose, and throat abnormalities such as laryngitis. As a clinical diagnosis of GERD based on symptoms is often incorrect, a complete diagnostic work-up is necessary in patients undergoing antireflux surgery.

1.3 Preoperative Work-up

Besides a complete history and physical evaluation, several tests should be performed preoperatively:

Upper endoscopy: An upper endoscopy is often the first test used to determine the severity of esophagitis (Table 1.1). The endoscopy is also useful for diagnosing GERD-related complications such as strictures, Barrett´s esophagus or cancer, and may exclude other pathologies such as eosinophilic esophagitis, gastritis or peptic ulcer.

Barium esophagram: This test does not provide objective evidence of GERD but rather provides valuable anatomical information (i.e. presence and size of hiatal hernia, degree of esophageal shortening and presence of a diverticulum or strictures).

Esophageal manometry: Although the esophageal manometry has limited valued for the diagnosis of GERD, it plays an important role during the preoperative evaluation of these patients for three reasons: (a) it is necessary for the correct placement of the pH monitoring probe (5 cm above the upper border of the lower esophageal sphincter); (b) rules out primary esophageal motility disorders (mainly achalasia) that present with similar symptoms to those with GERD; (c) helps tailoring the type of fundoplication (total vs. partial) based on the peristaltic coordination and contractile force of the esophageal body.

Table 1.1 Los Angeles classification of esophagitis

Los Angeles classification of esophagitis	
Grade A	Mucosal breaks ≤ 5 mm long, none of which extends between the tops of the mucosal folds
Grade B	Mucosal breaks > 5 mm long, none of which extends between the tops of two mucosal folds
Grade C	Mucosal breaks that extend between the tops of ≥ 2 mucosal folds, but which involve < 75% of the esophageal circumference
Grade D	Mucosal breaks which involve ≥ 75% of the esophageal circumference

Ambulatory pH monitoring: This study is the gold standard for the diagnosis of GERD because it objectively determines pathologic acid exposure and correlates specific symptoms with episodes of reflux. Acid suppression medications should be discontinued before the test (H2 blocking agents for 3 days and PPIs for 7 days).

1.4 Surgical Technique

1.4.1 Positioning of the Patient and Surgical Team

After induction of general endotracheal anesthesia, an orogastric tube is inserted by the anesthesiologist to keep the stomach decompressed. The patient is positioned supine in low lithotomy position with the lower extremities extended on stirrups, with knees flexed 20°–30°. The surgeon stands between the patient's legs, and the first and second assistants on the left and right side of the operating table, respectively (Fig. 1.1).

Troubleshooting: Pneumatic compression stockings are always used as prophylaxis against deep vein thrombosis because the increased abdominal pressure secondary to the pneumoperitoneum and the steep Trendelenburg position required during the procedure decrease venous return.

1.4.2 Trocar Placement

A total of five 10 mm ports are used for the operation. The 1st port is placed in the midline or slightly to the left of the midline, about 14 cm below the xiphoid process. This port is used for insertion of the scope. The 2nd and 3rd ports are placed under the right and left costal margins so that their axes and the scope form an angle of about 120° (these ports are used for dissecting and suturing instruments). The 4th port is placed in the right midclavicular line at the same level of the 1st (this port is used for the liver retractor). The 5th port is placed in the left midclavicular line at the same level of the 1st (mainly used by the first assistant) (Fig. 1.2).

Troubleshooting: Care must be taken when introducing the first port in the supraumbilical area because this site is just above the aorta and its bifurcation. We recommend using an optical trocar to obtain access. A common mistake is to place the trocars too low, which can make the operation more difficult.

1.4.3 Division of the Gastrohepatic Ligament

Once the left segment of the liver is retracted, the gastrohepatic ligament is divided starting above the caudate lobe of the liver towards the right crus (Fig. 1.3). The right crus is then separated from the lateral aspect of the esophagus with blunt

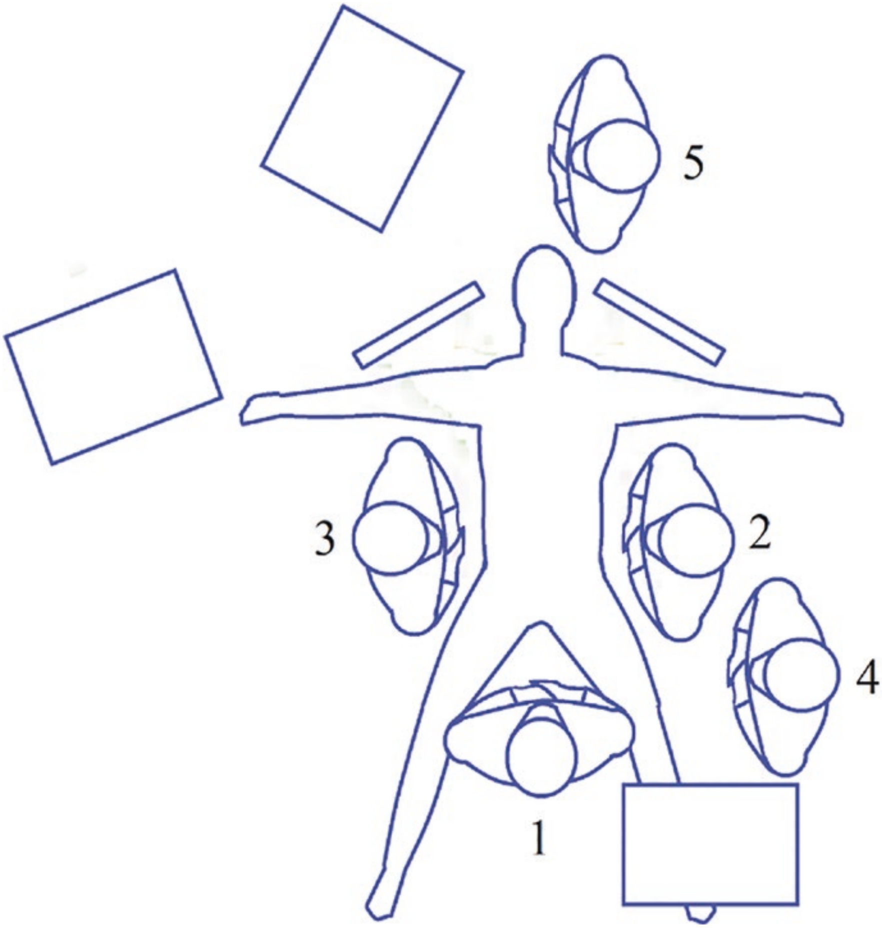


Fig. 1.1 Positioning of the patient and surgical team. (1) surgeon, (2) first assistant, (3) second assistant, (4) scrub nurse, and (5) anesthesiologist

maneuvers and the posterior vagus nerve is identified. The right crus should be dissected all the way down towards the junction with the left crus (Fig. 1.4).

Troubleshooting: An accessory left hepatic artery originating from the left gastric artery may be encountered during this step of the procedure. If this vessel limits the exposure, it can usually be safely divided.

1.4.4 Division of the Phrenoesophageal Membrane

The phrenoesophageal membrane is incised and divided with electrocautery above the esophagus (Fig. 1.5). The anterior vagus is identified and left attached to the esophageal wall. The left pillar of the crus is separated from the esophagus, and dissected bluntly downward toward the junction with the right crus.

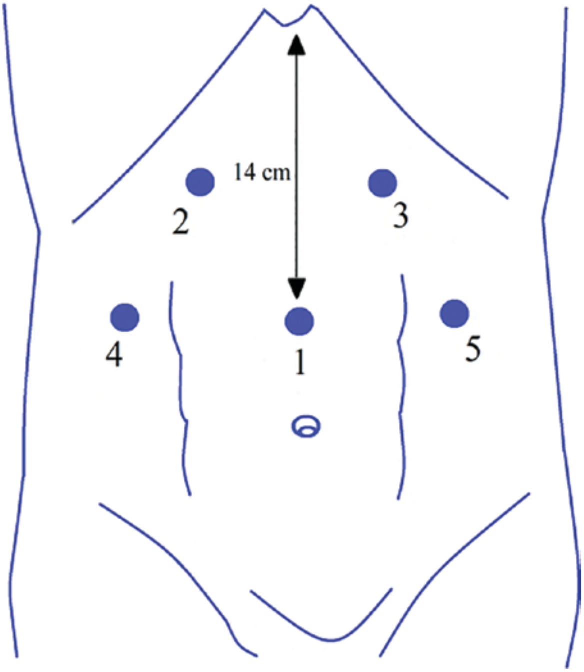


Fig. 1.2 Ports placement for laparoscopic fundoplication

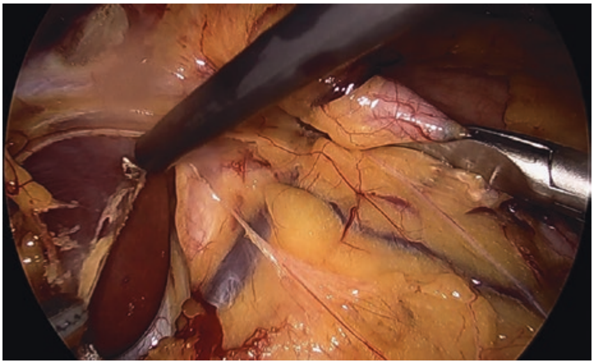


Fig. 1.3 Division of the gastrohepatic ligament

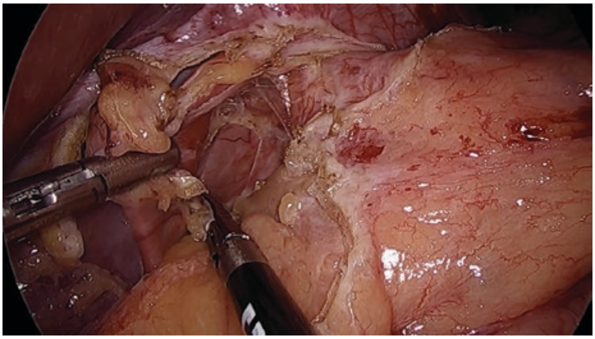


Fig. 1.4 Dissection of the right crus

Troubleshooting: Leaving the anterior vagus nerve attached to the esophagus while lifting the peritoneum and phrenoesophageal membrane away from the esophagus prevents injuring the nerve.

1.4.5 Division of Short Gastric Vessels

Starting from a point midway along the greater curvature of the stomach, the short gastric vessels are taken down with a vessel sealing system towards the fundus and all the way to the left pillar of the crus. This will allow performing a tension-free fundoplication afterwards (Fig. 1.6).

Troubleshooting: Excessive traction of the short gastric branches should be avoided to prevent bleeding from the spleen.

1.4.6 Placement of Penrose Drain and Mediastinal Dissection

A window is opened by blunt dissection under the esophagus, between the gastric fundus, the esophagus, and the left pillar of the crus (Fig. 1.7). The window is then enlarged and a Penrose drain is passed around the esophagus, incorporating both

Fig. 1.5 Division of the phrenoesophageal membrane

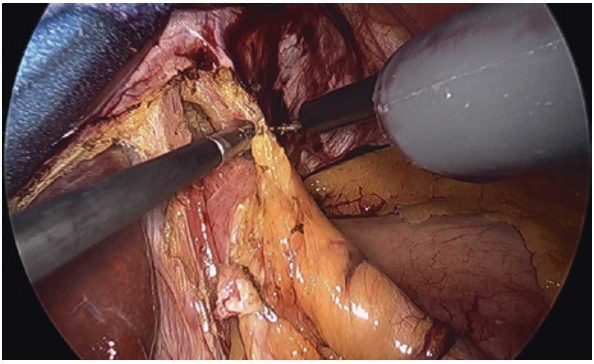
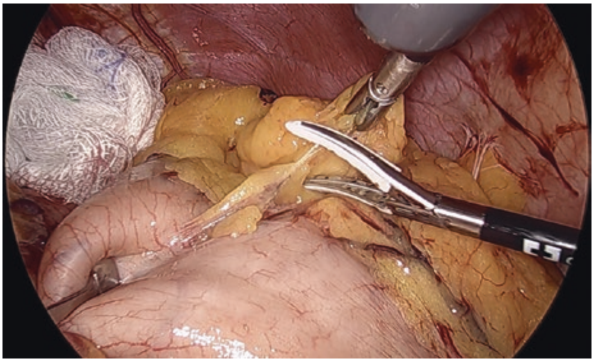


Fig. 1.6 Division of short gastric vessels



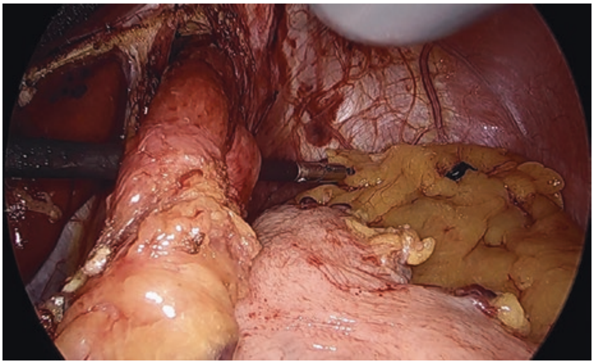


Fig. 1.7 Posterior window behind the esophagus that will be used to place the Penrose drain

anterior and posterior vagus nerves. Retracting the esophagus away from the hiatus with the Penrose drain will help performing mediastinal dissection in order to obtain at least 3 cm of esophagus below the diaphragm.

Troubleshooting: Secure the Penrose drain with a large clip or a loop suture tie. If the pleura is opened during mediastinal dissection, the anesthesiologist should be promptly notified. Reducing pneumoperitoneum pressure, if needed, is usually enough to avoid respiratory events.

1.4.7 Closure of the Esophageal Hiatus

A proper exposure of the hiatus is achieved retracting the esophagus upward and toward the patient's left with the Penrose drain. The closure of the diaphragmatic crura is done with interrupted non-absorbable sutures (e.g. 2-0 silk). The first stitch should be placed just above the junction of the two pillars. Additional stitches are placed 1 cm apart, and a space of about 1 cm is left between the uppermost stitch and the esophagus (Figs. 1.8 and 1.9).

Troubleshooting: When placing the stitches to approximate the crura, care must be taken to avoid injuring the inferior vena cava and the aorta. The closure of the crura should not be too tight, and a close grasper should slide easily between the esophagus and the crura.

1.4.8 Fundoplication

The fundus is passed behind the gastroesophageal junction and a "shoe-shine" maneuver is performed to verify sufficient fundic mobilization and to avoid having part of the gastric fundus above the wrap (Fig. 1.10). There are two main types of fundoplication during an antireflux operation: total 360° fundoplication (Nissen fundoplication) or partial posterior 240° fundoplication (Toupet fundoplication). Previous studies have shown that both types control abnormal reflux similarly [8, 9]. Therefore, we

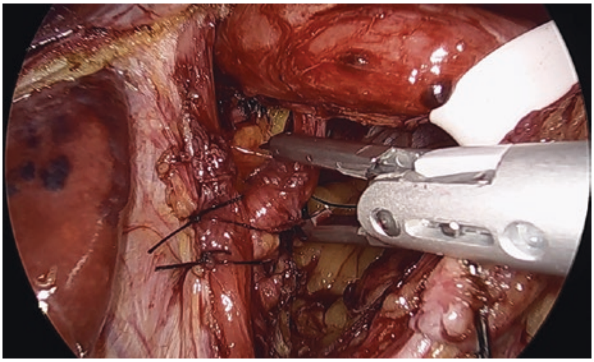


Fig. 1.8 Closure of the hiatus with interrupted non-absorbable sutures

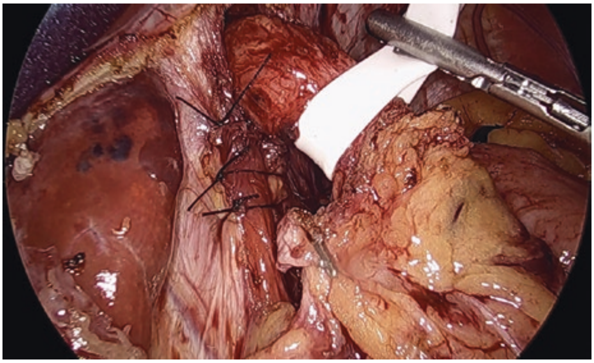


Fig. 1.9 Hiatus adequately closed

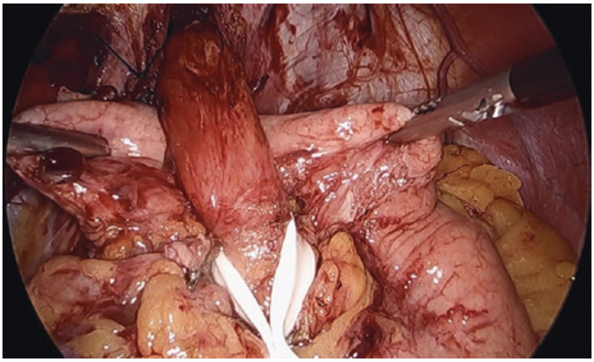


Fig. 1.10 “Shoe-shine” maneuver to verify sufficient fundic mobilization

believe the choice of the type of the wrap should be based on the surgeon’s own training and experience. In patients with severely impaired esophageal motility in the preoperative esophageal manometry, we prefer performing a partial fundoplication.

Total 360° Fundoplication: A bougie is inserted into the esophagus to decrease the risk of postoperative dysphagia. The gastric fundus is pulled under the esophagus, and the left and right sides of the fundus are wrapped with a Babcock above the esophagogastric junction during the placement of the first stitch. We use 3 stitches of non- absorbable material (2-0 silk or polyester) at 1 cm intervals to approximate the right and left side of the fundoplication. The goal is to create a short (about 2 cm in length) and floppy wrap (Figs. 1.11 and 1.12).

Partial Posterior Fundoplication: This wrap is created by placing 6 stitches of non- absorbable material (2-0 silk or polyester). The right and left sides of the fundus are separately sutured to the esophagus, leaving 120° of the anterior esophageal wall uncovered. Three sutures are placed on each side between the muscular layers of the esophageal wall and the gastric fundus (Fig. 1.13).

Troubleshooting: Obtaining a free-tension wrap is critical for the success of the operation.

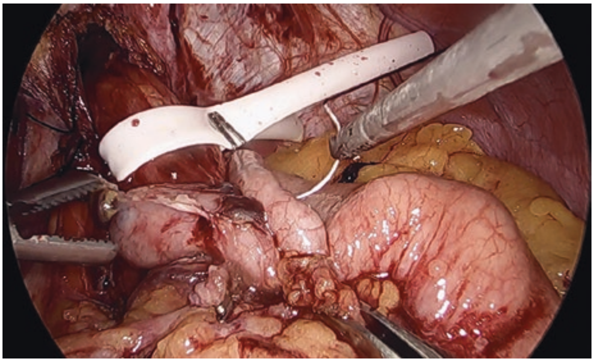


Fig. 1.11 First stitch of the total 360° fundoplication

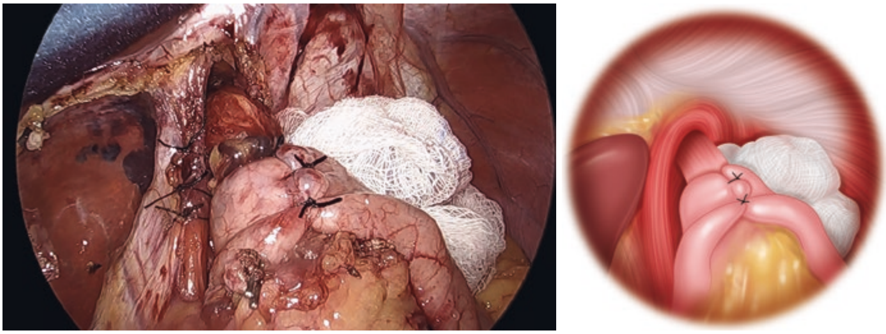


Fig. 1.12 Completed total 360° fundoplication

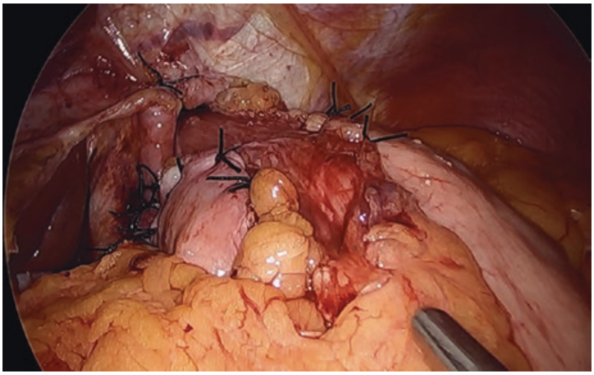


Fig. 1.13 Completed partial posterior fundoplication

1.4.9 Final Inspection

The Penrose drain is cut and passed out of the abdomen. In case a bougie was used for a total fundoplication, it is smoothly removed from the esophagus by the anesthesiologist. After adequate hemostasis is achieved, the liver retractor, instruments and trocars are removed from the abdomen under direct vision. All the port sites should be closed.

1.5 Postoperative Care

Patients are fed the morning of the first postoperative day with clear liquids and then soft diet. Most patients are discharged within 48 hours with instructions to avoid meat, bread, and carbonated beverages for the following two weeks. Regular activities are usually resumed within two weeks. Acid-reducing medications should be discontinued after 6 weeks at the latest.

Conflict of Interest The authors have no conflict of interest

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Chapter 2
Laparoscopic Heller Myotomy and Dor Fundoplication

Kamil Nurczyk, Francisco Schlottmann, and Marco G. Patti

2.1 Introduction

Esophageal achalasia affects between 1 and 3 in 100,000 people, with no noticeable difference regarding gender or race. The risk of developing achalasia increases with the age of patients. Interestingly, it appears that the increasing incidence of the disease is probably due to improvements in diagnostic methods.

Under physiological conditions the lower esophageal sphincter (LES) relaxes in response to swallowing. This mechanism is dependent on esophageal and LES neurogenic control through the myenteric plexus, involving excitatory acetylcholine neurons and inhibitory nitric oxide and VIP neurons. Idiopathic achalasia is caused by the degeneration of the myenteric plexus. As a result, esophageal peristalsis is absent, the LES does not relax properly in response to swallowing and it is often hypertensive.

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2.2 Clinical Presentation

Absent peristalsis and decreased relaxation of the LES hinder the passage of a food bolus. Dysphagia occurs in almost every patient. Consequently, difficulties in swallowing often lead to weight loss. Regurgitation of retained food is also common and may result in aspiration with complications such as pneumonia, wheezing, cough and hoarseness. About half of patients with achalasia experience heartburn which is caused by stasis and fermentation of undigested food in the esophagus. Chest discomfort or pain caused by esophageal distention my also occur. The severity of achalasia symptoms is assessed by the Eckardt score [1].

2.3 Preoperative Evaluation

A comprehensive evaluation should be carried out in every patient and should include a symptomatic evaluation, esophagogastroduodenoscopy (EGD), barium swallow, and esophageal manometry.

The Eckardt score is the grading system most frequently used for the evaluation of symptoms and efficacy of treatment [1]. It attributes points (0–3 points) to 4 symptoms of the disease (dysphagia, regurgitation, chest pain, and weight loss), ranging from 0 to 12.

After the symptomatic evaluation, the work-up usually begins with an EGD to exclude other causes of dysphagia such as a peptic stricture or a tumor. Typical findings are esophageal dilation and presence of retained food. Sometimes candidiasis of the esophageal mucosa is present. It is worth mentioning that gastroesophageal junction cancer infiltrating the LES may mimic achalasia. This misleading condition, called pseudo-achalasia, should be ruled out, especially in elderly patients with short duration of symptoms and marked weight loss [2].

The barium swallow often shows the characteristic 'bird beak' sign (narrowing at the level of the gastroesophageal junction), delayed passage of the contrast into the stomach, an air-fluid level, and tertiary contractions of the esophagus.

The gold standard for the diagnosis of achalasia is the high-resolution esophageal manometry (HRM). It enables the measurement of the pressure, length and relaxation of the lower and upper esophageal sphincters, and assessment of esophageal peristalsis. To confirm the diagnosis of achalasia, it is necessary to document lack of esophageal peristalsis and partial or absent LES relaxation. The Chicago classification introduced by Pandolfino and his colleagues, distinguishes three types of achalasia [3]. Type I involves aperistalsis and absence of esophageal pressurization; type II is associated with aperistalsis and pan-esophageal pressurization in at least 20% of swallows; and in type III there are premature spastic contractions (distal latency < 4.5 seconds) in at least 20% of swallows. The Chicago classification can also help predicting treatment outcome, as many studies have shown higher success rates in patients with type II achalasia [4, 5]. An ambulatory pH monitoring study is rarely performed, mostly in patients in whom heartburn is present.

2.4 Technique

2.4.1 Position of the Patient

After induction of general endotracheal anesthesia, the patient is positioned supine on the operating table and the lower extremities are extended on stirrups with the knees flexed to 20°. Pneumatic compression stockings are applied to the lower extremities and subcutaneous heparin is administered. The surgeon stands between the patient's legs, with the first and second assistant standing on the right and left side of the table (Fig. 2.1).

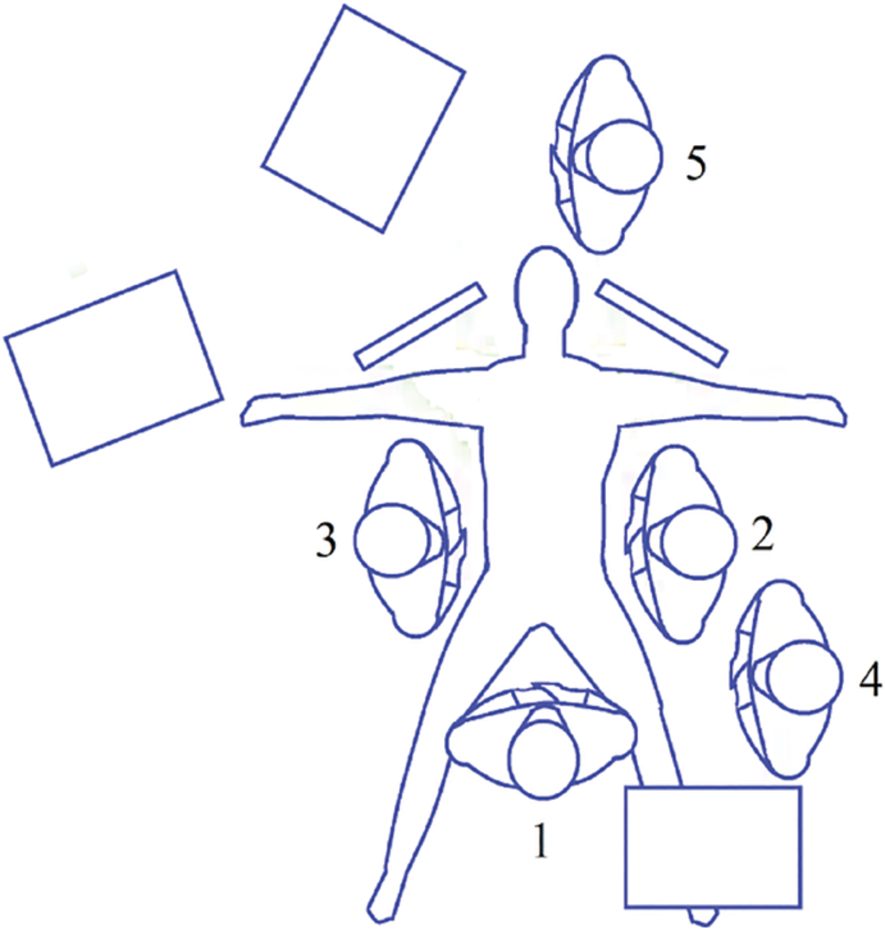


Fig. 2.1 Positions of patient and team: 1—surgeon, 2—first assistant, 3—second assistant, 4—scrub nurse, 5—anesthesiologist

2.4.2 Placement of the Trocars

Five trocars are used for the procedure (Fig. 2.2). The camera port is placed in the midline, 14 cm distal to the xiphoid process. Two additional ports are placed at the same level on the right (for the liver retractor) and left mid-clavicular line (for a bipolar instrument to take down the short gastric vessels and for a Babcock used for traction and exposure). The final two ports are placed below the right and left costal margins, forming a 120° angle, and are used for the dissection, the hook cautery for the myotomy, and suturing for the fundoplication. It is important to make sure that these trocars are not placed too low as this would make the transection of the proximal short gastric vessels and the retraction of the gastroesophageal junction more difficult.

2.4.3 Division of the Gastro-hepatic Ligament and Identification of the Right Crus and Posterior Vagus Nerve

The left segment of the liver is retracted using a laparoscopic retractor to expose the gastroesophageal junction. We begin the dissection of the gastrohepatic ligament above the caudate lobe of the liver and continue proximally until the right crus is

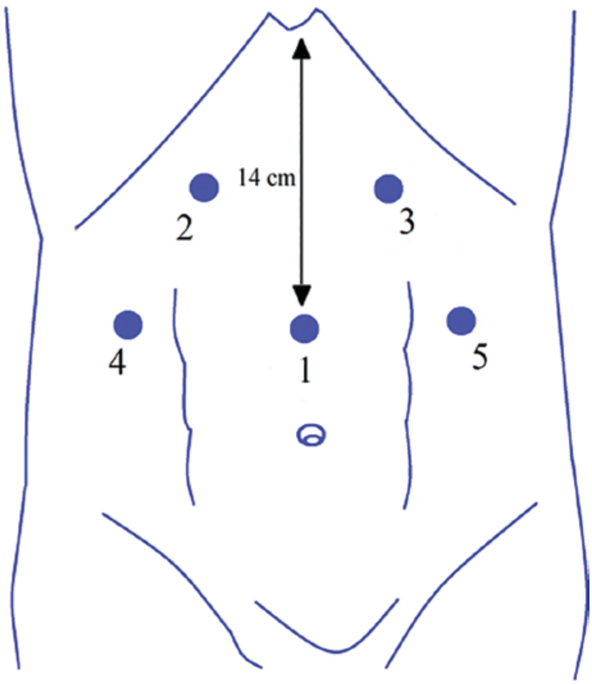


Fig. 2.2 Position of trocars: 1–30° scope camera port, 2—assisting port, 3—dissecting/suturing port, 4—liver retractor port, 5—Babcock clamp port

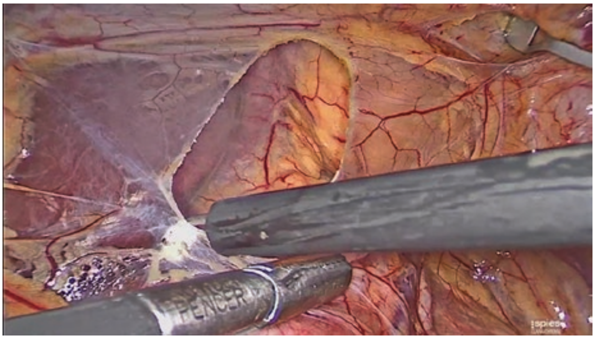


Fig. 2.3 Opening of gastrohepatic ligament

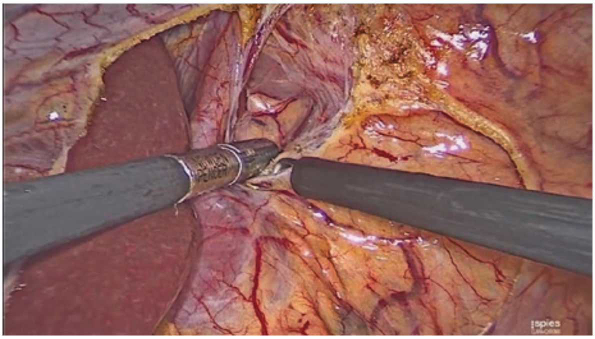


Fig. 2.4 Dissection of right pillar of the crus

identified (Fig. 2.3). The crus is then separated from the esophagus by blunt dissection, and the posterior vagus nerve is identified (Fig. 2.4). We avoid the use of the monopolar cautery during the dissection to prevent injury to the posterior vagus nerve.

2.4.4 Division of Peritoneum and Phreno-esophageal Membrane Above the Esophagus and Identification of the Left Crus of the Diaphragm and Anterior Vagus Nerve

The peritoneum and the phreno-esophageal membrane above the esophagus are divided and the anterior vagus nerve is identified (Fig. 2.5). The left pillar of the crus is separated from the esophagus. Dissection is limited to the anterior and lateral aspects of the esophagus, and no posterior dissection is needed if a Dor fundoplication is planned. Care is given to avoid any injury to the anterior vagus nerve.

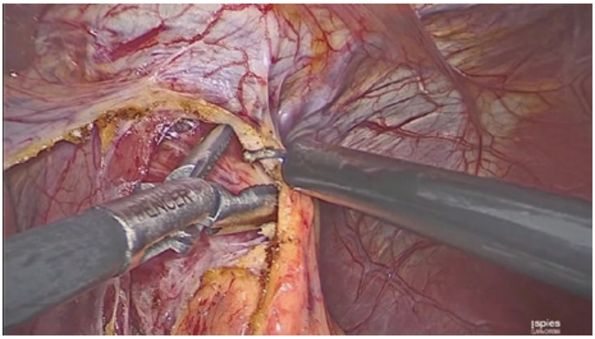


Fig. 2.5 Transection of peritoneum and phreno-esophageal membrane overlying esophagus

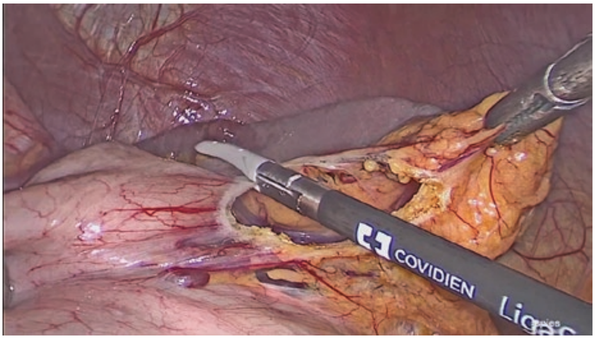


Fig. 2.6 Division of short gastric vessels

2.4.5 Division of the Short Gastric Vessels

The short gastric vessels are divided starting from a point midway along the greater curvature of the stomach all the way to the left pillar of the crus using a bipolar instrument (Fig. 2.6). It is important to avoid too much traction to prevent bleeding from the short gastric vessels or injuring the spleen. In addition, even when using a bipolar instrument, the dissection should be kept about 5 mm away from the gastric wall to avoid electrical damage. The dissection is continued in the posterior mediastinum, lateral and anterior to the esophagus, to expose 6 to 7 cm of the esophagus (Fig. 2.7).

2.4.6 Esophageal Myotomy

The fat pad over the esophageal and gastric wall is removed in order to expose the gastroesophageal junction (Fig. 2.8). A Babcock clamp is then applied below the proximal gastric wall to pull the esophagus downward and to the left in order to expose the right side of the esophagus. We perform the myotomy at the 11 o' clock position using a monopolar electrocautery with a 90° hook as it allows careful

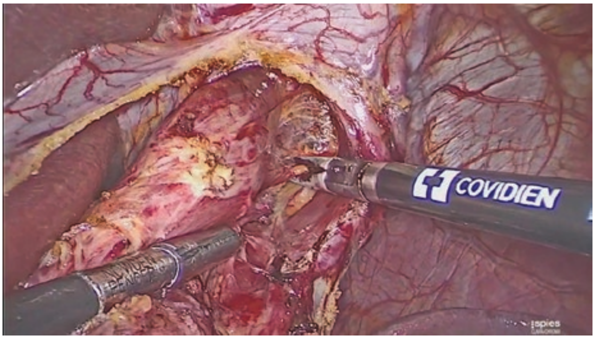


Fig. 2.7 Mediastinal dissection

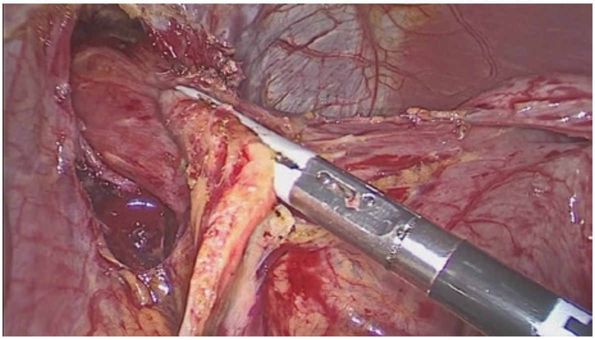


Fig. 2.8 Removal of the fat pad

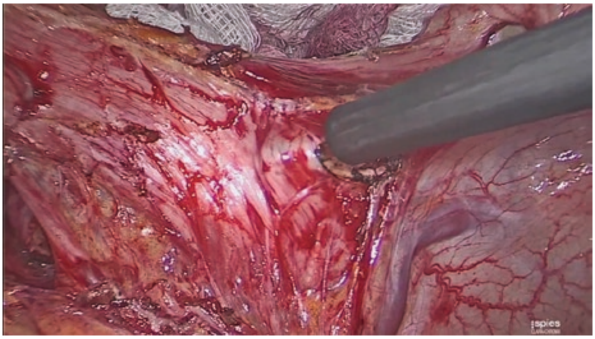
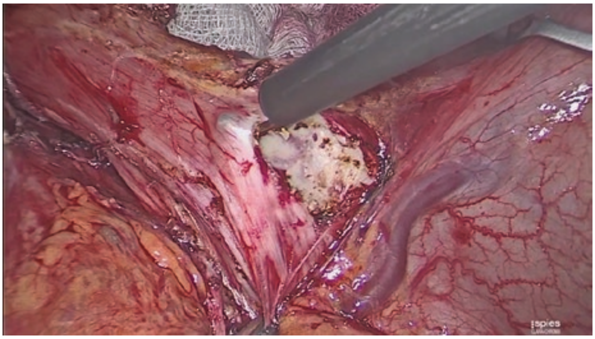


Fig. 2.9 Beginning of myotomy at the gastroesophageal junction

lifting and division of the circular fibers. We usually start the myotomy about 2 cm above the gastroesophageal junction with the goal of reaching the proper submucosal plane (Fig. 2.9). The myotomy is then extended proximally for about 6 cm above the esophago-gastric junction, and distally for about 2.5 cm onto the gastric wall (Figs. 2.10, 2.11, and 2.12). Thus, the total length of the myotomy is typically about 8.5 cm (Fig. 2.13). The edges of the myotomy are then separated so that about 40% of the mucosa is exposed. Sometimes it is quite difficult to identify the proper plane when fibrotic tissue is present due to prior injections of botulinum toxin and/or pneumatic dilatations. If bleeding occurs from the cut muscle fibers, gentle

Fig. 2.10 Proximal extension of the myotomy



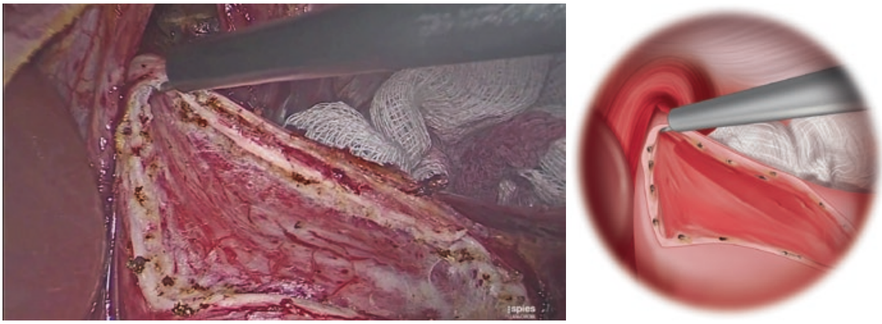
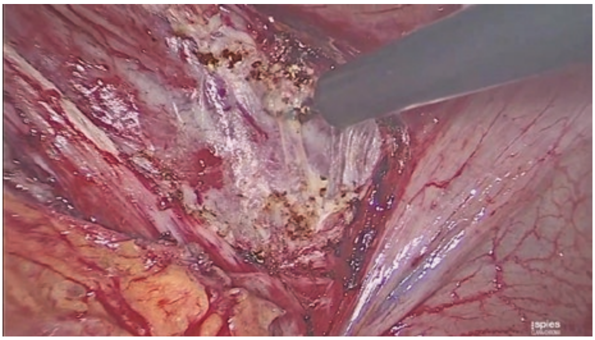


Fig. 2.11 Upper limit of the myotomy

Fig. 2.12 Distal extension of the myotomy onto the gastric wall



compression should be applied avoiding the use of the electrocautery. If a perforation occurs, it is repaired using fine absorbable suture material (4-0 or 5-0).

2.4.7 Dor Fundoplication

The Dor anterior 180° fundoplication has two rows of sutures, one left and one right. The left row comprises three stitches: the uppermost stitch incorporates the fundus of the stomach, the esophageal wall, and the left pillar of the crus; the other two incorporate the stomach and the esophageal wall (Fig. 2.14). The gastric fundus is then folded over the exposed mucosa, so that the greater curvature is next to the right pillar of the crus. The second row of stitches comprises three stitches between the fundus and the right pillar of the crus, and one or two additional stitches between the superior aspect of the fundoplication and the rim of the esophageal hiatus (Fig. 2.15). These last stitches remove any tension from the second row of sutures.

The choice between a Dor fundoplication (180° anterior) and a Toupet fundoplication (220° posterior) is usually based on surgeon's preference. The advantages of

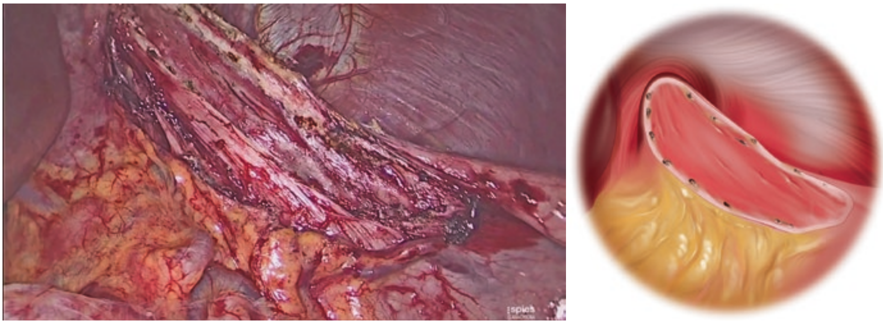
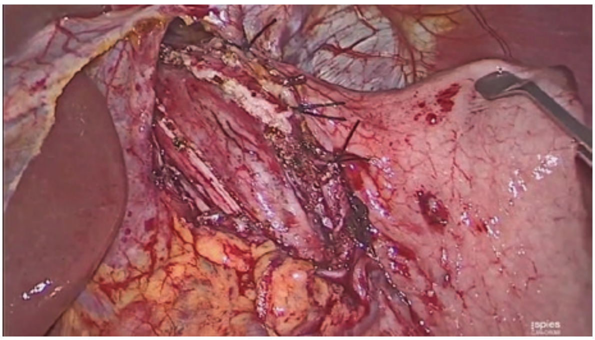


Fig. 2.13 Completed myotomy

Fig. 2.14 Dor fundoplication: left row of sutures



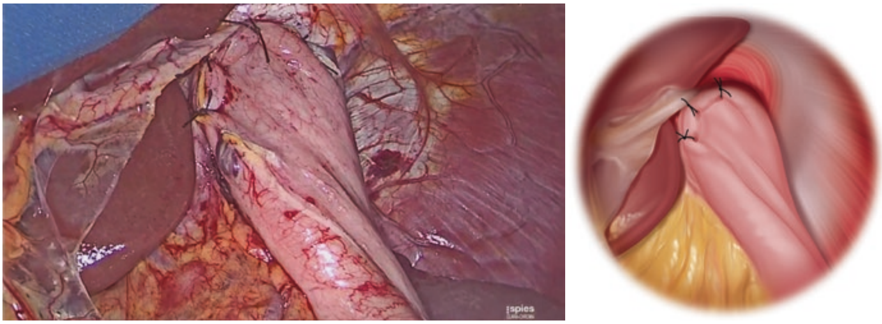


Fig. 2.15 Completed fundoplication with right row and apical sutures

a Dor fundoplication are that it does not require posterior dissection (avoiding a possible injury to the posterior vagus nerve), and that it covers the exposed esophageal mucosa. The advantages of a Toupet fundoplication are that it keeps the edges of the myotomy separated and may provide better reflux control [6].

2.5 Postoperative Course

We do not routinely obtain a contrast study on postoperative day one. This is done only if a mucosal perforation occurs during the myotomy. Otherwise we start with a clear liquid diet for breakfast and advance to a full liquid diet for lunch. Patients are usually discharged on day one. We prescribe oral pain medications for a couple of days, and proton pump inhibitors for 4 weeks. If the patient is asymptomatic, we stop these medications at the second postoperative visit. Endoscopy is recommended every 3 years or in case of persistent or recurrent symptoms.

Overall, we feel that a laparoscopic myotomy with partial fundoplication should be the initial procedure for patients with achalasia, particularly if they are young. While many studies have shown that POEM is at least as effective as a surgical myotomy, it is associated with pathologic reflux in 50% to 60% of patients, therefore repeating the experience of the thoracoscopic myotomy in the 1990s [7, 8].

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Chapter 3
Laparoscopic Paraesophageal Hernia Repair

Francisco Schlottmann, Kamil Nurczyk, and Marco G. Patti

3.1 Introduction

A hiatal hernia is characterized by the protrusion of any abdominal structure into the thoracic cavity through the esophageal hiatus of the diaphragm. Hiatal hernias are subclassified into four types: type I is a "sliding hernia", in which the esophagogastric junction (EGJ) herniates above the diaphragm into the mediastinum. Type II consists in the herniation of a portion of stomach into the mediastinum alongside a normally positioned EGJ. In type III, the EGJ is above the hiatus and a portion of the stomach is folded alongside the esophagus (combination of type I and II).In type IV hernias, an abdominal organ other than the stomach is also herniated through the hiatus [1, 2].

Type I hernias are the most common form of hiatal hernia and account for up to 95% of the total prevalence. Type II, III, and IV hernias are together termed paraesophageal hernias (PEH) and combined account for the remaining 5% of hiatal hernias.

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3.2 Clinical Presentation

Patients with PEH may be asymptomatic or present a wide variety of symptoms such as heartburn, regurgitation, dysphagia, postprandial epigastric or chest pain,vomiting, weight loss, dyspnea, cough or anemia. While most symptomatic PEH should be considered for surgical treatment, routine elective repair of a completely asymptomatic PEH is a matter of debate. While some recommend elective surgical repair to prevent potentially life-threatening complications such as volvulus, strangulation, or perforation [3–5], others recommend observation due to the low risk of developing acute symptoms requiring an emergent operation [6].

We believe that the decision to operate or observe a PEH should take into consideration symptoms, patient's age, comorbidities, and perioperative risks.

3.3 Preoperative Work-up

Besides a complete history and physical evaluation, several tests should be considered preoperatively:

Barium esophagram: Key for the diagnosis of PEH and description of its anatomy. The ability to distinguish between different hernia types helps planning the procedure.

Upper endoscopy: It is important to rule out malignancy and determine the presence of esophagitis, Barrett's esophagus, gastritis, Cameron ulcers, and/or peptic ulcer disease.

Abdominal and chest computed tomography (CT) scan: The CT will provide additional information regarding the anatomy of the hernia and may confirm the herniation of other abdominal organs if a type IV hernia is suspected.

Esophageal manometry: Helps tailoring the operation; in patients with complete aperistalsis or severely impaired peristalsis we perform a partial fundoplication. If the manometry is technically unfeasible (e.g. the patient cannot tolerate the catheter or acute presentation), a partial fundoplication is preferred.

Pulmonary function tests and cardiac risk assessment: Patients with PEH are often elderly and these tests may help in the decision making and during the perioperative management.

Regarding the 24-hour pH monitoring study, we believe it does not add relevant information preoperatively. The operation will undoubtedly alter the anatomy and physiology of the EGJ. Therefore, we believe a fundoplication to prevent reflux should be performed regardless of the presence or not of GERD preoperatively as it also helps securing the EGJ below the diaphragm.

3.4 Surgical Approach

Historically, open repairs through a laparotomy or thoracotomy were used. Unfortunately, these procedures were associated with significant morbidity. In the last decades, minimally invasive procedures emerged as the treatment of choice with recognized benefits in terms of improved postoperative outcomes. Currently, the vast majority of patients with PEH can be managed by a laparoscopic approach [7].

3.5 Surgical Technique

3.5.1 Positioning of the Patient and Surgical Team

After induction of general endotracheal anesthesia, an orogastric tube should be inserted by the anesthesiologist to keep the stomach decompressed. The patient is positioned supine in low lithotomy position with the lower extremities extended on stirrups, with knees flexed 20°–30°. Prophylaxis against deep vein thrombosis is vital (subcutaneous heparin and pneumatic compression stockings). The surgeon stands between the patient's legs, and the first and second assistants on the left and right side of the operating table, respectively (Fig. 3.1).

3.5.2 Trocar Placement

A total of five 10 mm ports are used for the operation. The 1st port is placed in the midline or slightly to the left of the midline, about 14 cm below the xiphoid process. This port is used for insertion of the scope. The 2nd and 3rd ports are placed under the right and left costal margins so that their axes and the scope form an angle of about 120° (these ports are used for dissecting and suturing instruments). The 4th port is placed in the right midclavicular line at the same level of the 1st (this port is used for the liver retractor). The 5th port is placed in the left midclavicular line at the same level of the 1st (mainly used by the first assistant) (Fig. 3.2).

Troubleshooting: An optical trocar to obtain access after achieving pneumoperitoneum is recommended. Be careful of not placing the trocars too low as this could make the operation more difficult (e.g. inability to take down proximal short gastric vessels or perform an adequate mediastinal dissection).

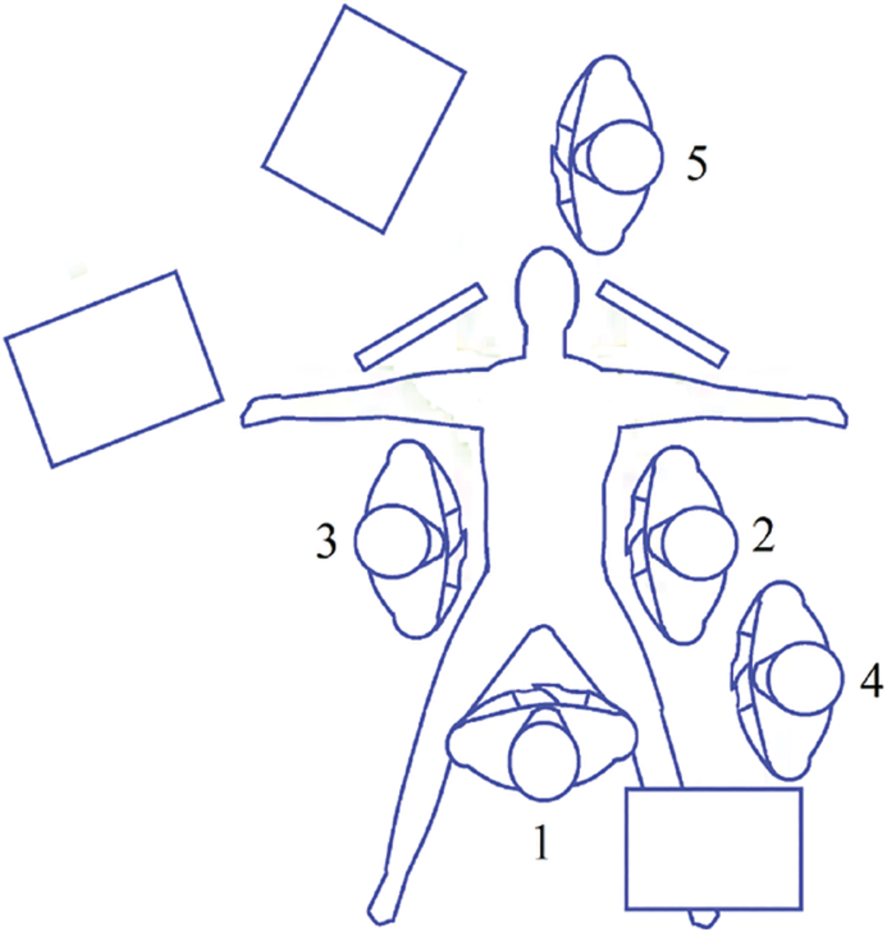

Fig. 3.1 Positioning of the patient and surgical team. (1) surgeon, (2) first assistant, (3) second assistant, (4) scrub nurse, and (5) anesthesiologist

3.5.3 Dissection and Reduction of Stomach and Hernia Sac

A good visualization of the diaphragmatic hiatus should be obtained after placing the liver retractor (Fig. 3.3). Reduction of the stomach into the abdominal cavity is done with gentle maneuvers pulling down the herniated stomach using a Babcock clamp. A “left crus approach” is preferred starting the dissection along the greater curvature with division of the short gastric vessels until the left pillar of the crus is reached (Fig. 3.4). The hernia sac is then incised at the junction with the left crus and an anterior and lateral mobilization of the esophagus is performed. The gastrohepatic ligament is then opened towards the right pillar of the crus and the esophagus is further mobilized and dissected (Fig. 3.5). The hernia sac should be freed

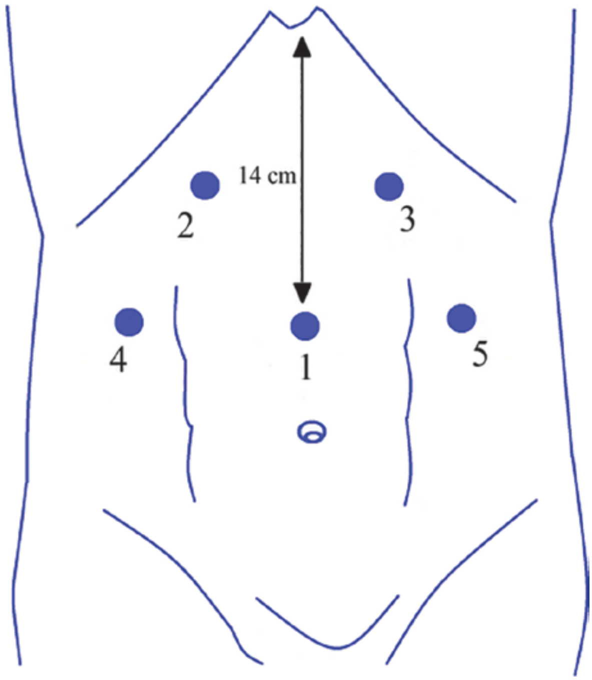

Fig. 3.2 Ports placement for laparoscopic paraesophageal hernia repair

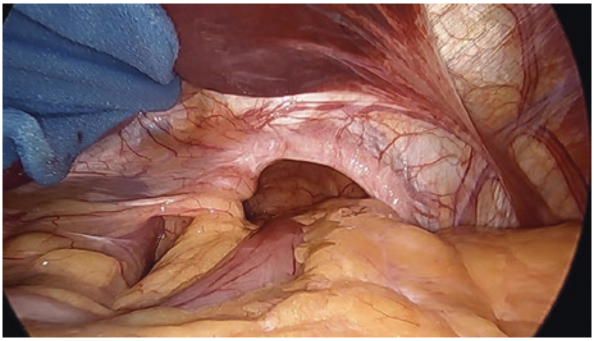

Fig. 3.3 Paraesophageal hernia

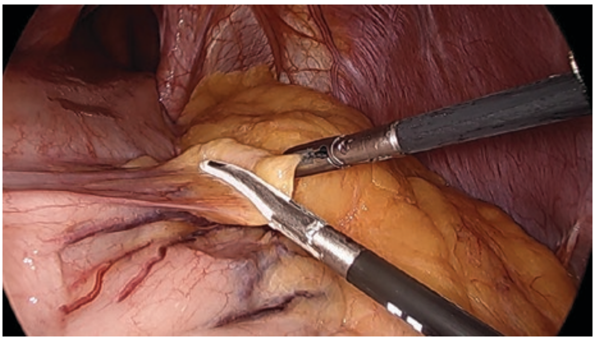

Fig. 3.4 Division of short gastric vessels

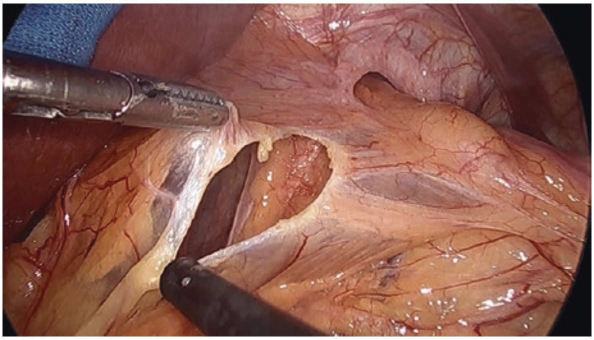

Fig. 3.5 Opening of the gastro-hepatic ligament

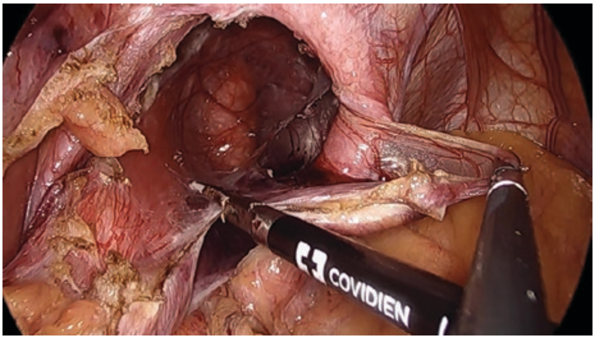

Fig. 3.6 Dissection and resection of the hernia sac

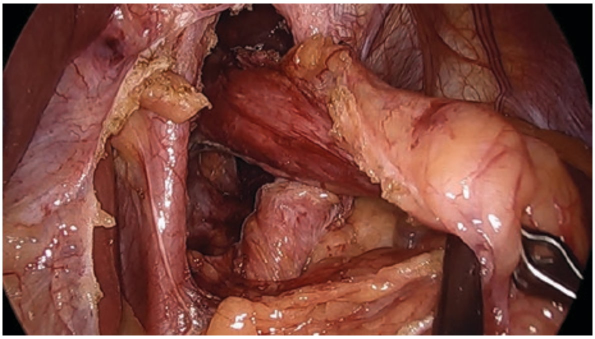

Fig. 3.7 Posterior window behind the esophagus with proper exposure of the hiatus

from mediastinal adhesions by blunt dissection (if the adequate plane is achieved, the hernia sac should be separated relatively easily from the mediastinal pleura laterally, pericardium anteriorly, and aorta posteriorly) The sac is then incised and resected (Fig. 3.6). Finally, a posterior window behind the esophagus is done in order to place a Penrose drain around the esophagus (Fig. 3.7).

Troubleshooting: The "left crus approach" prevents injuring an accessory left hepatic artery if the dissection is started over the gastro-hepatic ligament. This resultant bleeding may be challenging to control if the proximal stump of the artery retracts above the diaphragm into the mediastinum. While dissecting the hernia sac, tears in the pleura, capnothorax and subsequent hypotension or increased airways pressures may occur. The reduction of the insufflation pressure usually corrects these abnormalities.The anesthesiologist should be promptly informed in case further interventions are needed.

3.5.4 Esophageal Mobilization and Lengthening

At least 3 cm of esophagus below the diaphragm should be obtained. Therefore, an extended mediastinal dissection is often needed. In rare cases where a short esophagus is present, esophageal lengthening procedures (e.g. stapled-wedge gastroplasty) may be required.

Troubleshooting: Avoid vigorous caudal traction of the stomach while measuring the length of the esophagus below the diaphragm, as this can falsely lengthen the intra-abdominal segment of the esophagus.

3.5.5 Closure of the Esophageal Hiatus

A proper exposure of the hiatus is achieved retracting the esophagus upward and toward the patient's left with the Penrose drain. The closure of the hiatus starts with the approximation of the right and left pillar of the crus with interrupted non-absorbable sutures (Fig. 3.8). Usually, only posterior sutures behind the esophagus are necessary (Fig. 3.9). Sometimes one or two additional stitches anterior to the esophagus are needed to further narrow the hiatus. A relaxing incision on the right hemidiaphragm just lateral to the right crus may be needed to help approximating the right crus with the left one in cases of significant tension. If a relaxing incision is done, a mesh patch over the resulting diaphragmatic defect is needed.

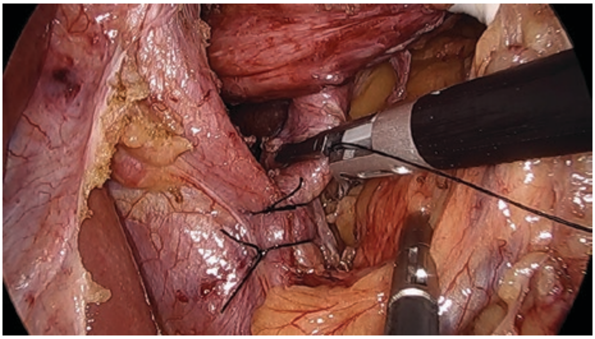

Fig. 3.8 Closure of the hiatus is done with interrupted non-absorbable sutures

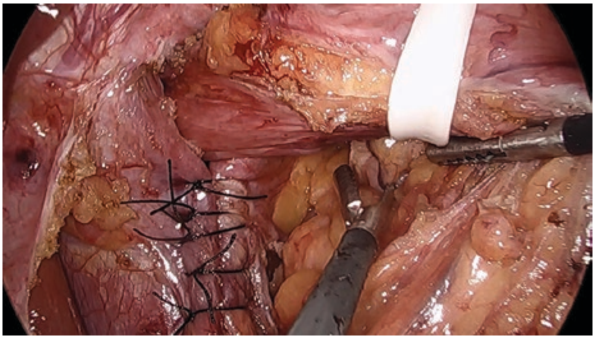

Fig. 3.9 Hiatus adequately closed

The use of mesh to reinforce the hiatal closure is debatably because current evidence shows conflicting results [8–10]. We believe that a mesh should not be routinely used but rather reserved for selected cases in whom a reliable cruroplasty cannot be achieved (e.g. giant PEH, inability to close the hiatus, redo operations).

Troubleshooting: When placing the stitches to approximate the crura, care must be taken to avoid injuring the inferior vena cava and the aorta. The closure of the crura should not be too tight, and a close grasper should slide easily between the esophagus and the crura.

3.5.6 Fundoplication

Arguments against performing a fundoplication during PEH repair are prolonged operative time, a variable prevalence of gastroesophageal reflux in these patients, risk of postoperative dysphagia, and surgical complications associated with a fundoplication. Opposite to these arguments, we strongly believe that a fundoplication should be always performed because of the following reasons: (a) it increases the resting pressure of the lower esophageal sphincter; (b) it corrects gastroesophageal reflux, if present preoperatively; (c) it prevents the development of postoperative reflux secondary to the extensive hiatal dissection; and (d) it works as a gastropexy anchoring the stomach below the diaphragm.

Most patients with PEH are elderly and have some degree of esophageal dysmotility. Therefore, we perform a partial fundoplication in most of the cases. The partial posterior 240° fundoplication (Toupet fundoplication) is created by placing 6 stitches of non- absorbable material. The right and left sides of the fundus are separately sutured to the right and left side of the esophagus, leaving 120° of the anterior esophageal wall uncovered (Figs. 3.10 and 3.11).

Troubleshooting: The stomach should pass behind the esophagus easily. The wrap should incorporate the fundus and not the body of the stomach.

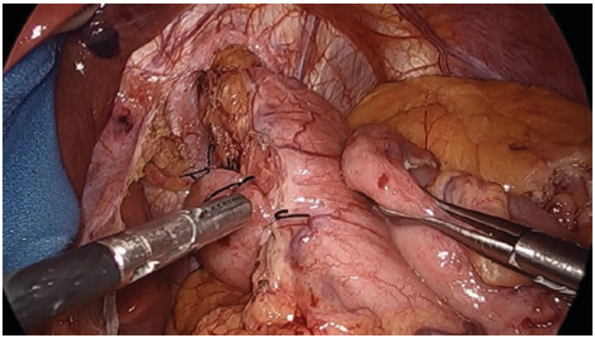

Fig. 3.10 First row of stitches of the partial posterior fundoplication

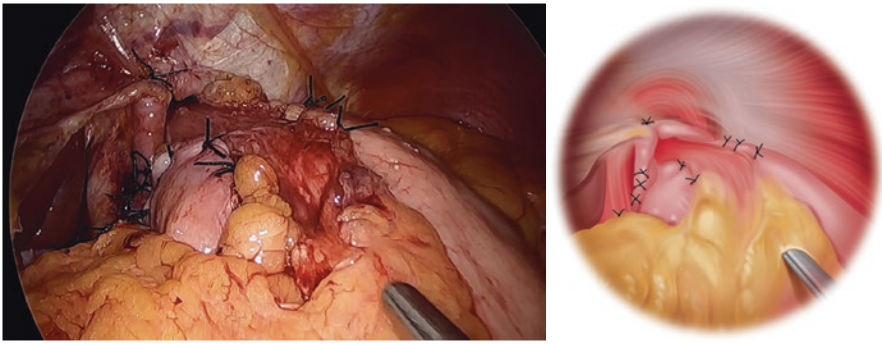

Fig. 3.11 Completed partial posterior fundoplication

3.6 Postoperative Care

Patients are usually extubated immediately after completion of the procedure. Patients are fed the morning after the operation with clear liquids and then a soft diet. They are usually discharged after 24 to 48 hours, with instructions to avoid meat, bread, and carbonated beverages for the following two weeks. The time to full recovery ranges between two and three weeks.

Conflict of Interest The authors have no conflict of interest.

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Chapter 4
Robotic-Assisted Paraesophageal Hernia Repair

Federico Serrot and Carlos Galvani

4.1 Introduction

Paraesophageal hernias (PEHs) are uncommon, comprising 5% of diaphragmatic hiatal hernias [1]. Approximately, 90% of these hernias are Type III hernias and they are typically found in the elderly. PEHs present with a variety of symptoms, including gastroesophageal reflux, chest or epigastric pain, anemia, dyspnea and obstructive gastrointestinal symptoms [2].

The management of PEHs has experienced a great deal of controversy. Formerly, all patients with PEHs, whether symptomatic or asymptomatic, were recommended to undergo surgery. The rationale for this approach was based on an overestimation of the mortality rate for emergent repair of a gastric volvulus or strangulation of another herniated organ [3, 4]. Nonetheless, more recent literature has shown that the mortality rates for emergency PEH repair may not be as high as previously believed. In fact, a study by Stylopoulos et al. demonstrated that the elective repair of completely asymptomatic patients may not be justified considering that the development of emergency symptoms was 1.16% per year [5]. Today is accepted that symptomatic patients with an acceptable operative risk are recommended for repair [6].

Numerous series have demonstrated the safety profile of the laparoscopic surgery [7–10]. However, despite the encouraging low morbidity and mortality rates, most authors have recognized that PEH repair is a technically demanding operation

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with a significant learning curve [11]. Patient factors, the complexity of the disease process, and the high technical demands of the surgery play a significant role in the learning curve and may influence the long term durability of the repair [12]. Likewise, laparoscopic surgery has not experienced major technological developments in this area since its initial application and factors such as unstable camera platform, limited motion/length of straight laparoscopic instruments, two-dimensional imaging, and poor ergonomics are at least in part responsible for the protracted learning curve [13]. From the technical standpoint, there are inherent challenges associated with PEH repair, such as extensive transhiatal mobilization of the esophagus to decrease axial tension and the tension-free re-approximation of the left and right crural pillars.

On the other hand, robotic surgery is in constant evolution and has emerged as an acceptable alternative for the treatment of PEHs, since some of its most notable contributions are reflected in its potential ability to extend the already well-established benefits of minimally invasive surgery. Some of these advantages, symbolized by enhanced ergonomics, visualization and extended intrathoracic reach, have propelled its increased utilization by minimally invasive and general surgeons. Advocates of robotics have suggested that the ease of robotics may decrease the learning curve in these complex cases. However, the validation in clinical practice is insufficient.

The aim of this chapter is to demonstrate our step-by-step technique for robotic-assisted paraesophageal hernia repair (RA-PEHR)

4.2 Clinical Presentation

Currently, all patients with PEHs who are symptomatic, and especially those with obstructive symptoms, should be recommended an elective repair [6]. On the other hand, many believe that asymptomatic PEHs are rare and size and configuration of the hernia are associated with specific symptoms [2]. For instance, if the gastroesophageal junction (GEJ) is obstructed, the patient will complain of dysphagia and regurgitation. However, if the obstruction is at the level of the pylorus, gastric outlet obstruction ensues and symptoms such as nausea, vomiting, and epigastric or chest pain are more likely [14]. Similarly, typical gastroesophageal reflux disease (GERD) symptoms are more common in patients with sliding hiatal hernias but can also be present in PEH. That is not to say that all patients should undergo surgery, but when patients are questioned beyond typical GERD symptoms, additional signs and symptoms such as early satiety postprandial chest pain/fulness, dyspnea, and anemia are found to be associated with PEHs. Most common presenting symptoms: [2]

- Heartburn 65%
- Early satiety 50%
- Chest pain 48%

- Dyspnea 48%
- Dysphagia 48%
- Regurgitation 47%
- Anemia 41%

4.3 Preoperative Evaluation

Most often, hiatal hernias are discovered incidentally either through radiographic studies, or during a screening procedure. An in-depth evaluation in every patient allows us to understand why patients are symptomatic and to plan treatment accordingly. Proper patient selection is critical to achieve excellent outcomes and for that reason a strong correlation of symptoms with preoperative workup increases the likelihood of success.

The preoperative workup includes;

- *Barium esophagogram*: Useful to delineate the anatomy and to determine the size of the hernia, location of the GEJ, and possibly to determine the esophageal length. A sliding hernia is diagnosed by a >2 cm separation between the GEJ and the diaphragmatic hiatus and the rugal folds of the stomach across the esophageal hiatus.

  If the gastric fundus is visualized herniating along the esophagus, the diagnosis of paraesophageal hernia can be made (Fig. 4.1).
- *Esophagogastroduodenoscopy*: The unique benefit of endoscopy is the added ability to examine the mucosa for tissue perfusion, esophagitis, Barrett's esophagus, or other lesions, such as Cameron ulcers. In addition, the endoscopy could be useful to measure the size of the hernia. If a greater than 2 cm distance is noted between the squamocolumnar junction and the impression of the diaphragm a sliding hiatal hernia is present. A paraesophageal hernia can be appreciated on retroflexed view and usually demonstrates the fundus herniating through the diaphragm adjacent to the endoscope (Fig. 4.2).

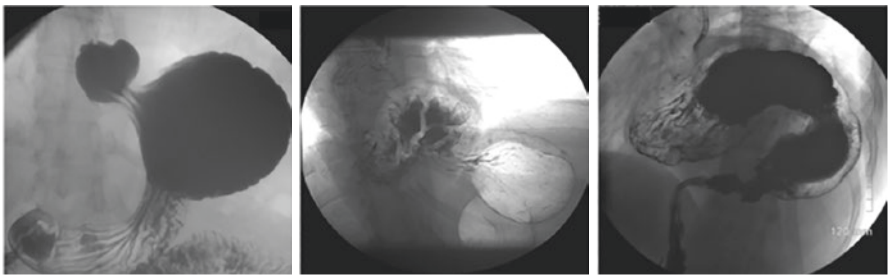

Fig. 4.1 Barium esophagogram. If the gastric fundus is visualized herniating along the esophagus, the diagnosis of paraesophageal hernia can be made

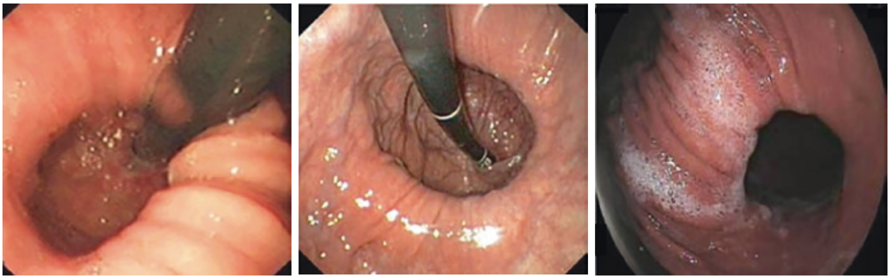

Fig. 4.2 Esophagogastroduodenoscopy. A paraesophageal hernia can be appreciated on retroflexed view and usually demonstrates the fundus herniating through the diaphragm adjacent to the endoscope

Fig. 4.3 Computed tomography (CT) showing herniated stomach as well as other organs that can be herniated within the chest cavity

- *Computed tomography (CT)*: Useful as a primary diagnostic tool in patients that are unable to swallow contrast. CT scan can also visualize other organs herniated within the chest cavity (Fig. 4.3).
- *High-resolution esophageal manometry (HRM)*: Using HRM, a hiatal hernia is noted with separation of the crural diaphragm from the LES. HRM can help determine the size of the hernia and rule out primary esophageal motility disorders in patients that have preoperative dysphagia. It can also help position the pH probe if necessary (Fig. 4.4).
- *Esophageal pH monitoring* has limited relevance in the workup of paraesophageal hernias.

4.4 Technique

4.4.1 Patient Preparation

- Pre-surgical care
  - Preoperative preparation: The preoperative physical status of the patient dictates anesthetic management of patients with paraesophageal hernia. Patients

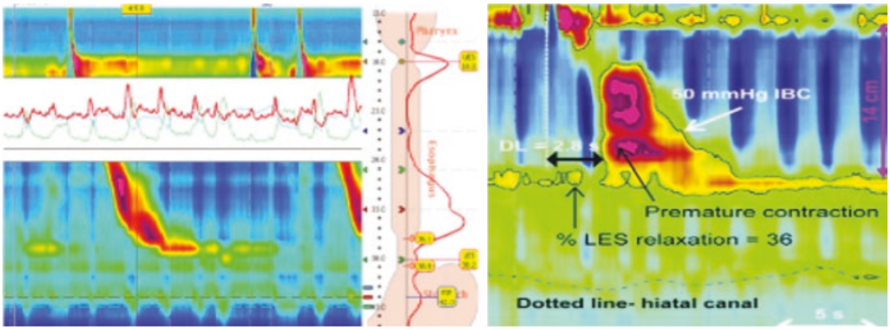

Fig. 4.4 High-resolution esophageal manometry (HRM). A hiatal hernia is noted with separation of the crural diaphragm from the LES

suffering from this disease often can experience chronic aspiration leading to a poor preoperative respiratory status. Consideration of co-morbid conditions is equally important; as the diagnosis is frequently made in older debilitated patients and preoperative evaluation is essential for assessing the operative risk in the individual patient. It is essential for the anesthesia team to have a detailed understanding of the surgical procedure in terms of approach, the extent of the operation, and associated complications. Special emphasis should be placed on the assessment of cardiopulmonary function, because intraabdominal CO_2 insufflation may be poorly tolerated in patients with severe cardiopulmonary compromise. Preoperative cardiac and pulmonary morbidity will determine the extent of preoperative cardiac testing as well as the need for pulmonary function testing (PFT) especially in those patients with restrictive lung disease secondary to recurrent aspiration pneumonia.

– Patients with paraesophageal hernias are at increased risk for aspiration during induction of anesthesia. For that reason, they are advised to ingest only clear liquids 2 or 3 days before surgery, to decrease the risk of aspiration. In older patients with several comorbid conditions, a Foley catheter is placed and usually removed after the case. Premedication with a prophylactic anti-aspiration is highly recommended. The patient is placed in the supine position before the induction of general endotracheal anesthesia. In order to minimize the aspiration risk during the induction of anesthesia, the airway can be secured either after a rapid sequence induction with cricoid pressure; or awake, with the aid of a fiberoptic bronchoscope. With the identification of risk factors, patients undergoing esophageal surgery could be stratified. Standard intraoperative monitoring will suffice for American Society of Anesthesiologists (ASA) physical status class I and II patients. More invasive monitoring may be required in patients with underlying cardiopulmonary pathology [15].
– Adequate attention should be paid to the hemodynamic changes resulting from the combined effects of pneumoperitoneum and placing the patient in a reverse Trendelenburg position. Venous stasis in the lower extremities during

the head-up position may be aggravated in the lithotomy position. Consequently, prophylactic measures to minimize the risk for deep venous thrombosis and pulmonary embolism must be considered such as the use pneumatic compression stocking for mechanical DVT (Deep Venous Thrombosis) prophylaxis, and consideration should be given to chemical prophylaxis as well (e.g. low molecular weight heparin).

– A number of pre and intraoperative anesthesia considerations should be taken into account to enhance postoperative patient recovery such as different ventilation strategies, minimize intraoperative fluids, multimodal analgesia, limit use of long acting opioids as well as routine antiemetic strategies like prophylactic treatment with intravenous antiemetics are always recommended. The implementation of the Enhanced Recovery After Surgery (ERAS) program is a multifaceted approach to the perioperative care of the surgical patient. ERAS for foregut surgery consists of multimodal recommendations that introduce pre-operative, intra-operative and post-operative measures of care for surgical candidates. The aim of this protocol is to optimize physiological stress, reduce postoperative pain while minimizing the use of opioids and enhance early mobilization. Our bariatric surgery ERAS protocol was adapted for foregut surgery [16].

4.4.2 Operating Room Set-up

- A large operating room is preferable when performing robotic surgery. Larger operating rooms allow the robot components, like the 2 surgeon consoles, to be stored in the room and allow the operating room personnel to move more freely around the room. The room should also facilitate docking of the system depending of the type of surgery to be performed. The versatility of the latest generation of robotic systems allows for multi-quadrant access and streamlined setup. Preferably, the room will be a dedicated room with an integration system to allow for flat panel monitors that are mounted from the ceiling, CO_2 gas is piped directly into the room for insufflation, and ceiling mounted equipment booms can house insufflators, electrosurgical units, laparoscopic camera equipment and lights sources. The operating table is placed directly under the room lights. Anesthesia equipment is located at the head of the operating table.
- An overview of the operating room layout is shown in Fig. 4.5.

4.4.3 Patient Positioning

- The patient is brought to the operating room and placed in a supine position with the arms out and properly padded (Fig. 4.6). The patient is then secured to the bed around the legs using a safety strap. Pneumatic compression devices are

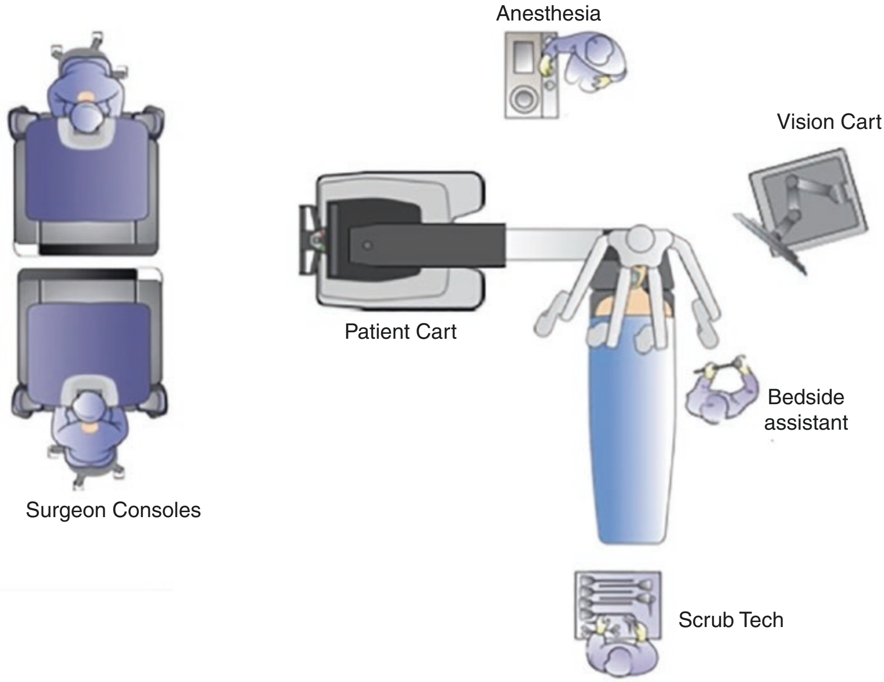

Fig. 4.5 Operating room layout. Dual console xi Davinci system. The da Vinci Xi Surgical system can be docked from the patient's right or left side

Fig. 4.6 The patient is placed in supine position with the arms out and properly padded

placed on the lower legs prior to induction of anesthesia. Following successful endotracheal intubation, an orogastric tube is placed in order to decompress the stomach. Pre-operative antibiotics are given prior to making an incision. An upper body Bair Hugger® (Arizant Inc., Eden Prairie, MN) is then placed above the nipples. Once the patient is positioned, a face protection donut is used to protect the patient's face and endotracheal tube from inadvertent damage or dislodgement during movement of the robotic camera. Once this is established, the abdomen and lower chest are prepped widely, and then sterile drapes are placed.

Step 1: Port placement

- The port placement described it is specific for the DaVinci Xi System. Entry into the abdominal cavity is obtained through a gasless optical technique in the periumbilical area using an 8 mm robotic trocar. A 5 mm 0/30 degrees laparoscope is used for access and port placement. The first port is placed in the left mid-abdomen two fingerbreadths lateral to the umbilicus and one palm-width inferior to the left costal margin. This port is used for the robotic camera (Arm #2). Insufflation is started to 15 mmHg. Three 8-mm trocars are then placed: one on the left subcostal midclavicular line (Arm #3), one on the right subcostal midclavicular line (Arm #1), and one in the left anterior axillary line (Arm #4). A 5-mm subxiphoid incision is used for the placement of the Nathanson liver retractor. Finally, an assistant port (8 mm) is inserted in between arms #2 and #3 (Fig. 4.7). At this point, the robotic surgical cart is approximated into position and the arms are attached to the four specific trocars. The da Vinci Xi Surgical system can be docked from the patient's right or left side (Fig. 4.5).
- Troubleshooting
  - Since is not necessary to have access to the lower abdomen during the case, it is essential to place the trocars higher in upper abdomen to prevent limited

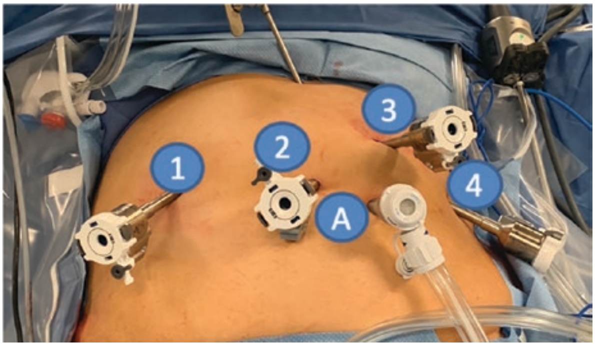

Fig. 4.7 The first port is placed in the left mid-abdomen two fingerbreadths lateral to the umbilicus and one palm-width inferior to the left costal margin. This port is used for the robotic camera (Arm #2). Three 8-mm trocars are then placed: one on the left subcostal midclavicular line (Arm #3), one on the right subcostal midclavicular line (Arm #1), and one in the left anterior axillary line (Arm #4). A 5-mm subxiphoid incision is used for the placement of the Nathanson liver retractor. Finally, an assistant port (8 mm) is inserted in between arms #2 and #3

reach in the posterior mediastinum. The trocar in Arm#1 is frequently placed at the level of the camera or lower to avoid injury to the liver or the right crus during the mediastinal dissection. All the robotic trocars can be placed on the same line across the upper abdomen.

- The function of the assistant port is for the bedside-assistant to be able to suction, retract, and insert/remove suture throughout the duration of the case. The assistant will also help with changing the robotic instruments as needed. As a result, it is important the assistant has some basic laparoscopic skills and understanding of the robotic system.
- In order to avoid collision between the liver retractor and Arm# 2 the system's targeting function is optional.
- The instrumentation used for the case is listed in Table 4.1; Four 8-mm robotic specific trocars, Fenestrated bipolar grasper is placed in the surgeon's left hand (Arm #1), Prograsp forceps on Arm #4, and in the articulated robotic vessel sealer extend is introduced surgeon's right hand (Arm #1). The utilization Arm#4 allows the operating surgeon self-assisting during the case.

Step 2: Reduction of the hernia and dissection of the hernia sac

- The left crura approach is routinely used (Fig. 4.8). As a first step of the operation, the herniated stomach is gently reduced, and early division of the short gastric vessels at the level of the lower third of the spleen using the robotic vessel

Table 4.1 Standard instrument tray for r-Paraesophageal hernia repair

5 mm 30 degrees laparoscope
The Iron Intern® (Automatic Retractor Holder)/ NathansonLiver Retractor
8 mm 30 degrees down/up robotic scope
2 Graspers
Fenestrated bipolar (Arm # 2)
Cadiere/Prograsp (Arm # 1)
Trocars
Three 8 mm robotic trocars
One 8–12 mm disposable trocar
Energy source
Vessel Sealer Extend (Arm # 3)
Needle driver
Suture cut needle driver
Laparoscopic suction-irrigation
Laparoscopic grasper × 1
Laparoscopic needle driver × 1
Penrose drain
2-0 V-Loc™ Non-absorbable (12 in)
2-0 Silk sutures
Phasix™ ST Mesh Rectangle 3″ × 4″ (7 cm × 10 cm)
56 French Maloney (tapered tip) bougie

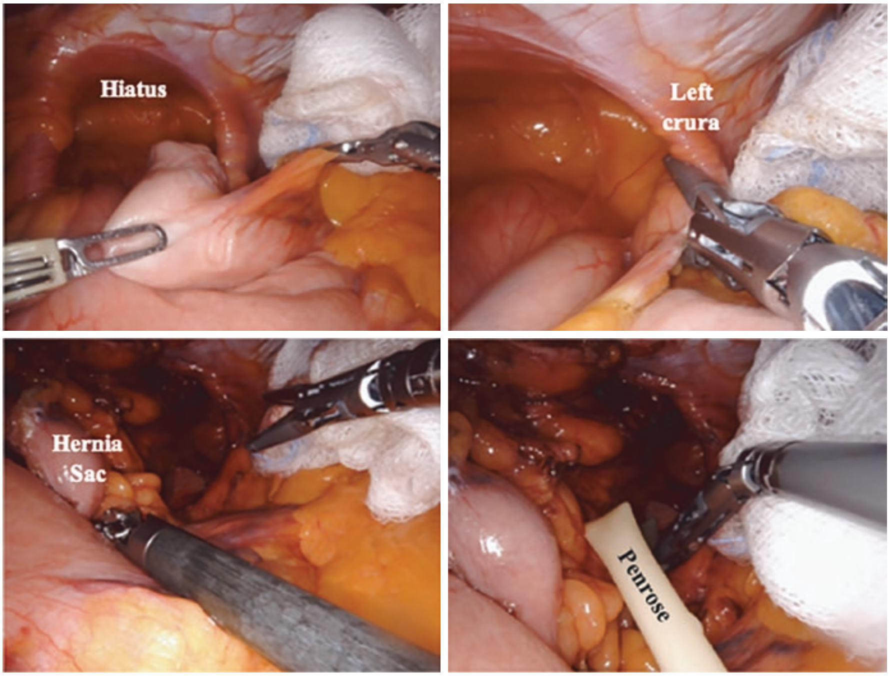

Fig. 4.8 The left crura approach is routinely used. The dissection is continued until complete exposure ofthe left crus is achieved andfull mobilization of the fundus of the stomach. A quarter inch Penrose drain is placed inside the mediastinum behind the esophagus and stomach

sealer is performed. Incision of the hernia sac is started at its junction with the left crura, typically from posterior to anterior, and continued in a circular manner around the rim of the hiatus. The dissection is continued with a combination of blunt dissection and the vessel sealer until complete exposure of the left crus is achieved.

Following complete exposure of the left crus, release of the greater curvature of the stomach, and full mobilization of the fundus of the stomach, a quarter inch Penrose drain is placed inside the mediastinum behind the esophagus and stomach.

Attention is then turned to dissection of the right crus. The gastrohepatic ligament is opened and the right crus is dissected carefully off the esophagus protecting the peritoneum overlying the right crus. This dissection is typically carried out from anterior to posterior along the right crus (Fig. 4.9) starting anterior at the top of the right crus and extending posteriorly until fully exposing the right crus. After complete exposure of the right crus, a retroesophageal window is extended exposing the confluence of the crura. At this point the Penrose drain is found in the mediastinum and used to encircle the esophagus and vagus nerves proximal to the hernia sac.

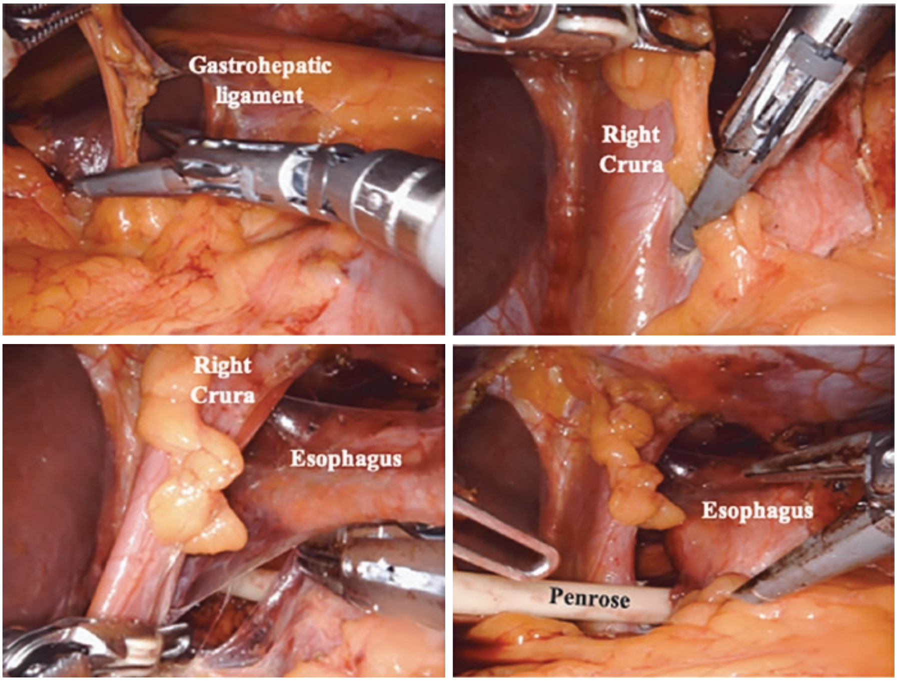

Fig. 4.9 The gastrohepatic ligament is opened and the right crus is dissected carefully off of the esophagus. This dissection is carried out until fully exposing the right crus and creating a posterior window. The Penrose drain is found in the mediastinum and used to encircle the esophagus and vagus nerves proximal to the hernia sac

- Troubleshooting
  - It is our preference to start the case with the division of the short-gastric vessels and from there advance proximally to get to the point where the hernia sac and the base of the left crus meet. In patients that have significant cephalad migration of the stomach, the left gastric vessels tend to migrate alongside the stomach into the chest adjacent to the right crus. Gentle medial retraction of the fundus of the stomach and lateral retraction of the short-gastric vessels with Arm#4 facilitates the exposure of this area.
  - It is particularly important to protect the right and left crus during the dissection as well as the parietal peritoneum on the edge of the crus for better-quality closure.
  - The purpose of the Penrose in the mediastinum during the dissection is for orientation. It is essential to place the Penrose drain superior to the left gastric vessels to prevent injury to the vessels. The Penrose drain is used to encircle the esophagus for further manipulation as the dissection continues into the posterior mediastinum. Arm#4 allows the surgeon to control the retraction of the esophagus during the mediastinal dissection.
  - One should avoid excessive traction either on the hernia sac or on the stomach to prevent injuries to the esophagus, stomach or the vagus nerves.

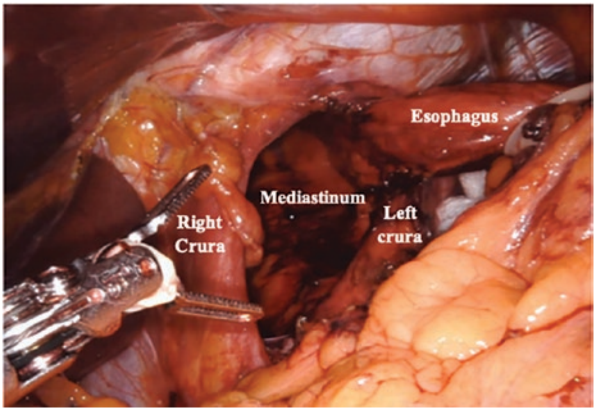

Fig. 4.10 Transhiatal dissection. The progression of the dissection starts on the right side of the esophagus, posterior, left side of the esophagus and anterior and continued in a cephalad direction

Step 3: Esophageal Mobilization

- Transhiatal dissection of the esophagus is started and continued in a cephalad direction. The articulated vessel sealer device and the fenestrated bipolar grasper are used for the circumferential dissection of the esophagus. Mobilization of the esophagus can typically be accomplished using blunt dissection of relatively thin alveolar tissue, by exercising traction and countertraction maneuvers always dissecting away from the esophagus (Fig. 4.10). The progression of the dissection is as follows; the right side of the esophagus, posterior, left side of the esophagus and anterior. The utilization of Arm# 4 for esophageal retraction is key during this step of procedure. Care is taken to avoid injury to the vagus nerves, the mediastinal pleura, the aorta and the pericardium as the dissection is extended in a cephalad direction into the mediastinum. The esophageal mobilization is completed only after 2–3 cm of intraabdominal esophagus are observed to be well into the abdomen without tension. This is measured by opening the jaws of the robotic grasper. If this is not accomplished the dissection is continued.
- Troubleshooting
  - The “scope flip” feature of the Xi system allows to perform a better esophageal mobilization due to the direct visualization of the mediastinal structures.
  - Usually additional esophageal length could be obtained by dissecting off the hernia sac from the anterior esophagus, along with epigastric lipoma.
  - Pleural injury or tear is not an uncommon complication due to the close relationship between the hernia sac/esophagus and the mediastinal pleura. Although intraoperative pneumothorax may develop after the opening of the mediastinal pleura, its consequences for the patient are negligible since CO_2 is quickly reabsorbed and the lung is rarely involved. It is extremely important for the operating surgeon to communicate with the anesthesiologist if pleural injury ensues. Adequate monitoring of end-tidal carbon dioxide levels ($EtCO_2$) and airway pressures will facilitate early diagnosis. Positive end-expiratory pressure (PEEP) application is an effective way of managing pneumothorax secondary to the passage of gas into the pleural space. In our experience,

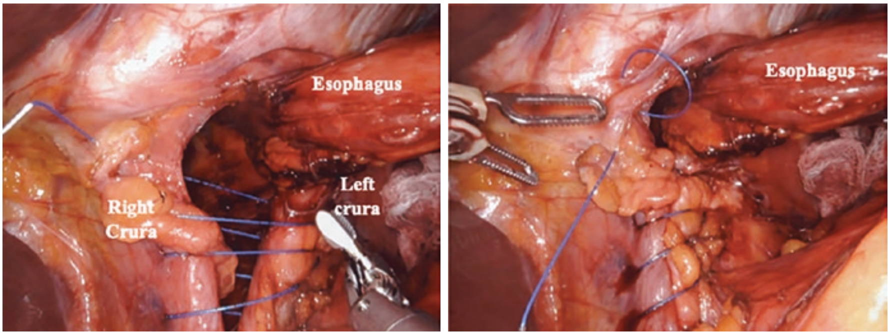

Fig. 4.11 Closure of the diaphragmatic defect is performed using running non-absorbable barbed suture, using a "shoelacing technique"

intraoperative closure of the pleural defect with locking clips as well as decreasing the intraabdominal pressure have helped stop CO_2 diffusion into the pleural cavity. Because the CO_2 is highly diffusible, sealing the pleural injury has not resulted in tension pneumothorax.

Step 4: Closure of the Crura

- The esophagus is retracted anteriorly and to the left by Arm #4, and the vessel sealer is replaced with a suture cut needle driver. Closure of the diaphragmatic defect is started at the junction of the right and left crus to decrease tension on every stitch and is carried out anteriorly. The closure is performed using running non-absorbable barbed suture. We routinely do multiple running loose bites tightened sequentially ("pulley system") advancing towards the esophagus (Fig. 4.11).

  A 56 Fr bougie is passed down the esophagus to tailor the closure and to avoid postoperative dysphagia. However, the bougie is not left in place during the closure since it will compromise exposure and could also result on injury to the esophagus.
- Note
  - If excessive tension is observed during the crural repair additional tactics should be used to decrease radial forces. Decreasing the pneumoperitoneum pressure to 8–10 mmHg, loosening the liver retraction, and relaxing incisions are all suitable alternatives.
  - If undue tearing of the right crus is observed, a relaxing incision should be considered. In this case, the goal is to first perform a right relaxing incision and if this approach is not sufficient to guarantee a tensionless repair, a left relaxing incision should be performed.

Step 5: Mesh reinforcement

- The crural defect must be closed prior to mesh placement. Bridging of the diaphragmatic defect is not recommended. A ruler is introduced in order to tailor the mesh to the patient. Furthermore, a "U-shaped" or "reverse C" shaped bioabsorbable mesh (*Phasix*™ *ST*) is cut to size to reinforce the closure of the diaphrag-

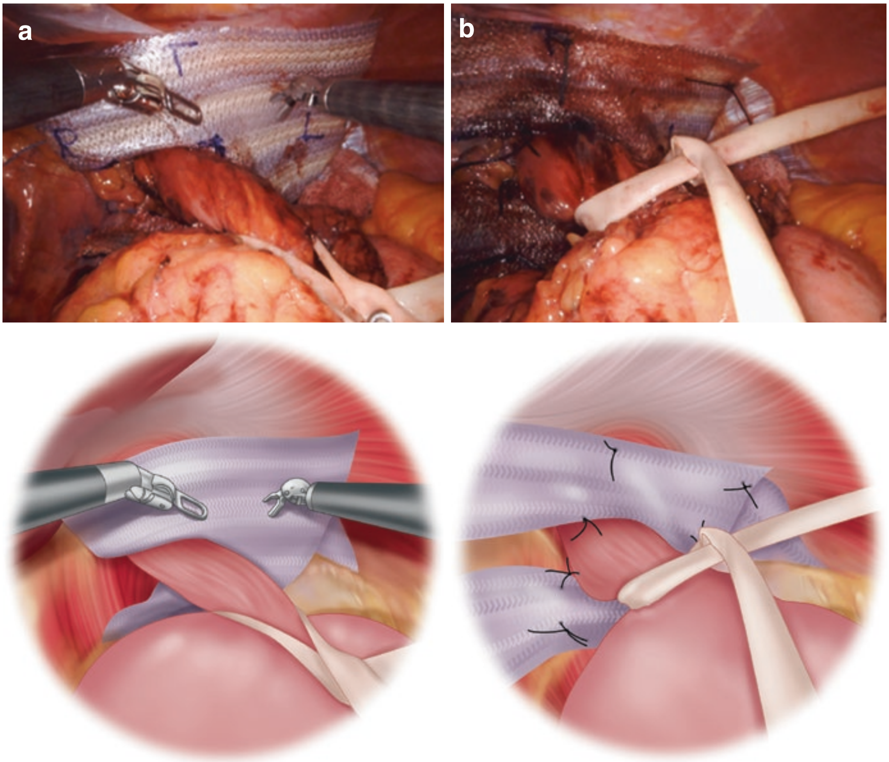

Fig. 4.12 Bioabsorbable mesh is cut to size to reinforce the closure of the diaphragmatic defect; a) "U-shaped"mesh; b) "reverse C" shaped mesh. The mesh is placed onlay and secured in place to with interrupted stitches at 1, 4, 8, and 11 o'clock around the circumference of the hiatus

matic defect (Fig. 4.12).The mesh is placed onlay and secured in place to the edge of the right and left crura and at the bottom of the repair with nonabsorbable interrupted stitches. It is our practice to place the hiatal fixation stitches at 1, 4, 8, and 11 o'clock around the circumference of the hiatus. This configuration is used independent of the shape of the mesh, and we believe not only secures the mesh but also prevents the mesh from coming into contact with the esophagus. Mesh reinforcement is considered useful to prevent early recurrences (6–12 months).

The ideal mesh characteristics are:

– Slow absorbable
– Low profile, easy to use (introduce, position, fixate)
– Decrease risk for erosion
– Does not preclude reoperation

It is our practice to routinely use mesh in the following situations;

- Large hiatal hernias (>5 cm)
- Closure under tension

  - Observed tearing of the R crus

- Redo operations
- Relaxing incisions
- Obese patients with large hiatal hernias

- Note
  - The idea of the “reverse C” shaped mesh is to provide reinforcement to the anterior and left lateral aspect of the hiatus, since these are known site for recurrences.

Step 6: Antireflux Procedure

We routinely perform a fundoplication following a paraesophageal hernia repair. The majority of patients undergo a floppy Nissen fundoplication gauged over a 56 Fr bougie. The bougie is not inserted for the first stitch of the fundoplication. Three 2-0 silk stitches are used to create the wrap, and the most distal stitch is used to attach the wrap to the esophagus. The fundus of the stomach is exposed with 2 graspers, then the posterior fundus is pulled behind the esophagus. A “shoe shine” maneuver is performed to make sure the right and left sides of the fundoplication are symmetric. The right and left graspers then bring the fundus together on the anterior esophagus (Fig. 4.13a). At this time, Arm# 4 holds both sides of the fundus in place while swapping for placement of the first stitch of the fundoplication. Two additional stitches are placed about 1 cm apart. At the completion of the procedure, the bougie is carefully removed

Upper endoscopy is routinely performed at the completion of the case to check the indemnity of the esophagus, stomach, and the adequacy and patency of the fundoplication (Fig. 4.13b)

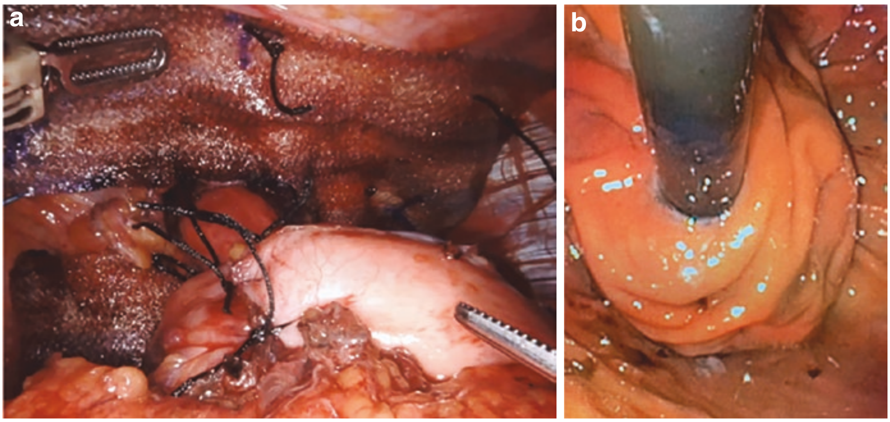

Fig. 4.13 (**a**) Nissen fundoplication: The fundus of the stomach is exposed with 2 graspers, then the posterior fundus is pulled behind the esophagus. The right and left graspers then bring the fundus together on the anterior esophagus. Three 2-0 silk stitches are used to create the wrap, and the most distal stitch is used to attach the wrap to the esophagus. (**b**) Upper endoscopy showing the adequacy and patency of the fundoplication

- Note
  - The fundoplication not only prevents reflux but also anchors the stomach in the abdomen. Our preferred approach is to tailor the fundoplication to preoperative motility, however, in older patients and patients where the manometry was not technically feasible a partial fundoplication is routinely used.
  - Insertion of the bougie by the anesthesia team should be closely monitored by the operating surgeon. Frequent verbal communication is a must. Gently anterior traction of the Penrose drain by the surgeon straightens up the esophagus to facilitate the entrance of the bougie into the esophagus.
  - We routinely use 56 F bougie, however in smaller patients a smaller bougie size is used to prevent mucosal tearing.
  - Construction of the fundoplication should be with the fundus of the stomach and not with the body of the stomach to avoid redundant gastric tissue posterior to the esophagus. An adequate fundoplication decreases the incidence of postoperative dysphagia.

4.5 Post-operative Care

The majority of patients are discharged home POD#1 on an esophageal surgery diet. Most patients start on a liquid diet (often clear or full) immediately after surgery with progression to pureed/soft within a period of 3–4 weeks postoperatively. This diet allows time to heal and reduces the risk of complications in the early postoperative period.

It has been documented that the majority of patients experience transient gastrointestinal symptoms after antireflux surgery [17]. Nonetheless, the symptomatology subsides in the majority of patients within 2–3 months of the initial operation. Some of the most common side effects of the surgery are;

- *Subcutaneous emphysema*

  Due to the extensive mediastinal dissection, subcutaneous emphysema is frequently observed. Subcutaneous crepitus may be palpated in the face, neck, shoulders, and upper chest. Often times this issue is discovered after the completion of the case when the surgical drapes are taken down. This issue is infrequently of clinical significance and resolves without therapy.
- *Postoperative Shoulder pain*

  Another relatively common postoperative complaint from patients is left shoulder pain. This is the result of irritation of the left diaphragm and is self-limited.
- *Post-operative nausea and vomiting*

  Nausea and vomiting after laparoscopic foregut surgery is considered a major setback, since it is not only a reason for patient distress but can also predispose the patient to anatomical failure. A number of pre and intraoperative anesthesia considerations should be taken into account to enhance postoperative patient recovery. Different ventilation strategies, minimizing intraoperative fluids, multimodal analgesia, limiting use of long acting opioids as well as routine antiemetic strategies like prophylactic treatment with intravenous antiemetics are always recommended (Enhanced Recovery After Surgery Protocol). Patients with intractable postoperative vomiting should be carefully assessed before they are discharged in order to assure the integrity of their recent repair

- *Postoperative dysphagia*

  A significant number of patients experience dysphagia mainly for solids after paraesophageal hernia repair. This is primarily due to the modified anatomy and postoperative inflammatory changes. This dysphagia is transient in more than 90% of patients and resolves within the first 6–8 weeks of the surgery. In the early postoperative period patients usually receive dietary counseling and are recommended a special diet with slow progression from liquids to solid food paying special attention to adequate caloric intake. One should be vigilant about patients that experience severe dysphagia for liquids in the early postoperative period. Further workup may be warranted to rule out any anatomic failure. Patients that present with persistent dysphagia beyond 3 months of surgery need further investigation in order to determine the etiology of the dysphagia.

- *Flatulence & Gas Bloating Syndrome*

  The occurrence of gas bloating syndrome is associated with competent wrap, aerophagia and in some patients it is possibly associated with delayed gastric emptying due to unrecognized vagal nerve injury. Nevertheless, in the majority of patients these symptoms are transient, but if persistent they will decrease patient satisfaction and could result in failure of the procedure.

4.6 Follow-up

Patients are seen in follow-up 2 weeks after surgery and every 3 months for the first year. At the 1-year follow-up, patients are asked to undergo a barium swallow to rule out recurrence. After this, patients are seen at regular 6-month intervals or they are followed by a telephone interview performed by a nurse practitioner or a fellow. During each follow-up visit, a detailed symptomatic evaluation is performed on all patients. Beyond this time, barium swallow, upper endoscopy, or esophageal function tests are ordered on an as needed basis.

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Chapter 5
Laparoscopic Gastrectomy: Partial and Total

Carmen L. Mueller and Lorenzo E. Ferri

5.1 Introduction

5.1.1 Clinical Presentation

Symptoms: Early gastric cancer often presents with few if any clinical symptoms or signs and is most commonly identified incidentally during gastroscopy for other symptoms, such as reflux. In contrast, locally-advanced disease is associated with a number of symptoms, many of which are non-specific. These can include: abdominal pain, bloating, reflux, vomiting, weight loss, fatigue and melena.

Physical Examination: Unless the cancer is very advanced or the patient very thin, a palpable abdominal mass is not commonly felt on abdominal palpation. Anemia due to chronic low-volume tumour blood shedding is common in patients with advanced lesions and may manifest as scleral pallor, weakness, tachycardia, postural hypotension and melena on physical examination. Palpation of lymph node basins (supraclavicular, cervical and inguinal) rarely reveals positive findings until the disease is at a very advanced stage. Abdominal distension due to ascites is also a late finding consistent with peritoneal carcinomatosis. Occasionally, abdominal distension and tympany confined to the left upper quadrant can be appreciated in patients with partial or complete gastric outlet obstruction.

Laboratory investigations: Bloodwork may demonstrate iron-deficiency anemia, acute renal failure (particularly in obstructing lesions associated with gastric outlet obstruction and vomiting), hypoalbuminemia, and elevation of tumour markers, particularly CA19-9. Occasionally, massive upper gastrointestinal bleeding can occur due to erosion of the tumour into peri-gastric vessels leading to hematemesis

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and passage of bright red blood per rectum, often in conjunction with abrupt hemodynamic instability and shock.

5.1.2 Pre-Operative Evaluation

Patients with malignancies should have investigations specific to their particular cancer type to determine tumour stage and resectability prior to surgery. Common pre-operative tests for gastric cancer patients include:

1. Upper endoscopy with biopsies to confirm histology and tumour location
2. Computed tomography (CT) scan of the chest, abdomen and pelvis to identify local/regional extent of disease as well as indications of distant organ or peritoneal metastases
3. Whole body positron emission tomography (PET) scan to further clarify tumour stage
4. Endoscopic ultrasound to determine tumour depth, regional lymph node involvement and signs of peritoneal disease
5. Diagnostic laparoscopy to identify peritoneal disease and assess tumour resectability

All patients undergoing planned partial or total laparoscopic gastrectomy should undergo routine pre-operative investigations to determine their fitness for surgery. These frequently include:

6. Medical history including exercise tolerance, cardiorespiratory diseases, surgical history, medications (e.g. anticoagulants), and use of cigarettes, alcohol and illicit substances
7. Physical examination including vital signs, cardiorespiratory auscultation and abdominal palpation and cervical/supraclavicular lymph node examination
8. Baseline blood work (CBC, electrolytes and renal function, coagulation profile, blood grouping and cross match, tumour markers)
9. Electrocardiogram
10. Chest x-ray
11. Selective fitness testing as required (e.g. cardiac stress testing, 6-minute walk test)

5.1.3 Indications for Surgery

Laparoscopic anatomical (partial or total) gastrectomy is most commonly performed for resection of gastric adenocarcinoma (Fig. 5.1). Other gastric diseases that may warrant anatomical resection by the laparoscopic approach also include:

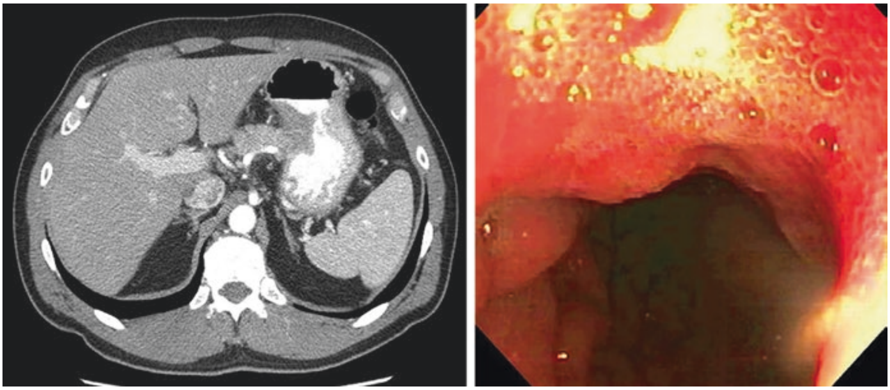

Fig. 5.1 Computed tomography scan (left) and endoscopic image (right) of gastric adenocarcinoma

1. Prophylactic gastrectomy for gene mutation carriers prone to later cancer development (e.g. CDH1 gene mutations)
2. Refractory gastric ulcer disease and benign peptic strictures
3. Refractory bleeding due to gastric antral vascular ectasia (GAVE) or other gastropathies
4. Rare tumours or pre-malignant conditions, either for curative intent or symptom control (e.g. multifocal neuroendocrine tumour, lymphoma, diffuse adenomatous polyposis)
5. Gastro-intestinal Stromal Tumors (GISTs) arising in the stomach, although the vast majority can be managed by non-anatomic wedge gastrectomies [1]

5.2 Technique

5.2.1 Laparoscopic versus Open Approach

The laparoscopic approach can be offered in many cases where gastrectomy is warranted, and utilization of laparoscopy for gastric resection has continued to increase globally since Kitano reported the first laparoscopic-assisted distal gastrectomy in 1994 [2]. Randomized control trials have since demonstrated equivalent short-term operative and oncologic outcomes between laparoscopic and open gastrectomy for cancer when performed by experienced surgeons [3]. However, circumstances in which laparoscopy may be challenging due to difficulties in gastric mobilization/handling with laparoscopic instruments or poor visualization of critical structures continue to exist. The following factors make laparoscopic resection challenging and may warrant consideration of an open approach:

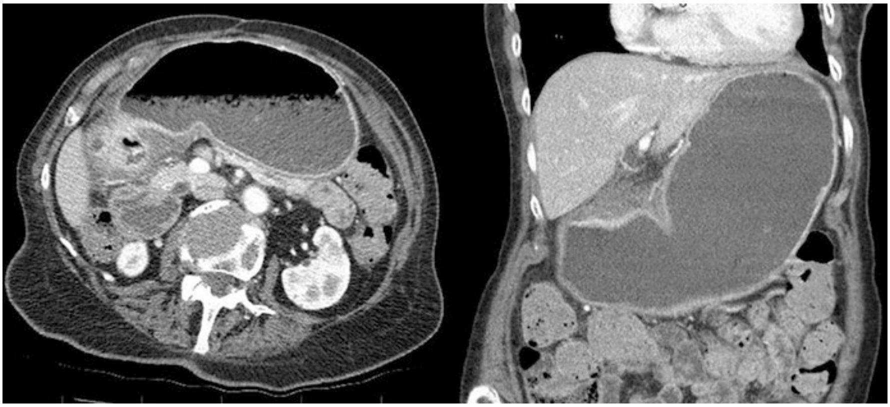

Fig. 5.2 Distal tumour causing gastric outlet obstruction and massive gastric distention

Tumour/Disease Factors:

1. Tumour bulk
2. Presence of gastric outlet obstruction (causing significant gastric distention—Fig. 5.2)
3. Linitis plastica causing diffuse gastric stiffness and rigidity
4. Bulky tumour infiltration of regional lymph nodes
5. Tumour invasion of neighboring organs necessitating multivisceral resection

Patient Factors:

1. Complex prior surgical history
2. Body habitus
3. General condition (e.g. significant hemodynamic instability, poor cardiac output causing intolerance to pneumoperitoneum)

Surgeon Factors:

4. Personal skills and experience in complex laparoscopy and GI tract reconstruction

5.2.2 *Patient Positioning*

The patient is positioned supine with legs split, allowing the operator and assistants to stand on either side of the patient and between the legs, facing the epigastrum (Fig. 5.3). Arms may be extended or tucked in. The patient should be securely fastened to the operating table to ensure no movement or sliding during intraoperative changes in table angle. Laparoscopic gastrectomy requires the patient be tilted into acute reverse Trendelenburg position for prolonged periods and care must be taken to ensure the patient does not slide down the table during the case. Supportive

Fig. 5.3 Patient positioning for laparoscopic gastrectomy. This positioning allows ready access to the epigastrum, left upper quadrant and hiatus necessary to complete gastric mobilization and gastroenteric tract reconstruction

devices such as bean bags and anti-slip cushions placed under the patient, as well as foot braces and safety straps should be used.

5.2.3 Trocar Placement and Operator Positioning

Two main approaches to laparoscopic gastrectomy predominate with slight variations in trocar placement and location of the operators during the case:

1. One surgeon, one assistant/camera operator approach
2. Two surgeons, one camera operator approach

5.2.3.1 One Surgeon, One Assistant Approach

In this configuration, the primary surgeon stands between the patient's legs facing the epigastrum and the assistant stands on the patient's left side. The principal advantage of this approach is the need for fewer skilled personnel in comparison to the two-surgeon configuration. One less trocar is used also. Retraction is provided by only one hand of the assistant (who is operating the camera with the other hand), which can limit exposure and flexibility of access. Dissection of the distal gastric greater curvature and right gastroepiploic vessels is relatively more awkward from this approach for the primary surgeon than in the two- surgeon approach.

5.2.3.2 Two-Surgeon, One Camera Operator Approach

In this configuration, an operator stands on either side of the patient and each have two trocars through which they alternately provide retraction and perform dissection (Fig. 5.4). The camera operator stands between the patient's legs facing the epigastrum. In this configuration, each operator performs part of the dissection (e.g. the right gastroepiploic dissection is more easily performed from the patient's left side, while the proximal greater curvature mobilization and division of short gastric vessels is more easily performed by the operator standing on the patient's right). Retraction and exposure are enhanced in comparison to the one-surgeon approach because each assistant has two instruments with which to assist rather than just one. This configuration may be particularly advantageous in obese patients or those with extensive intra-abdominal adhesions from prior surgery. Training is also facilitated by this approach as the primary surgeon can more easily expose and guide a learner when using two hands rather than just one.

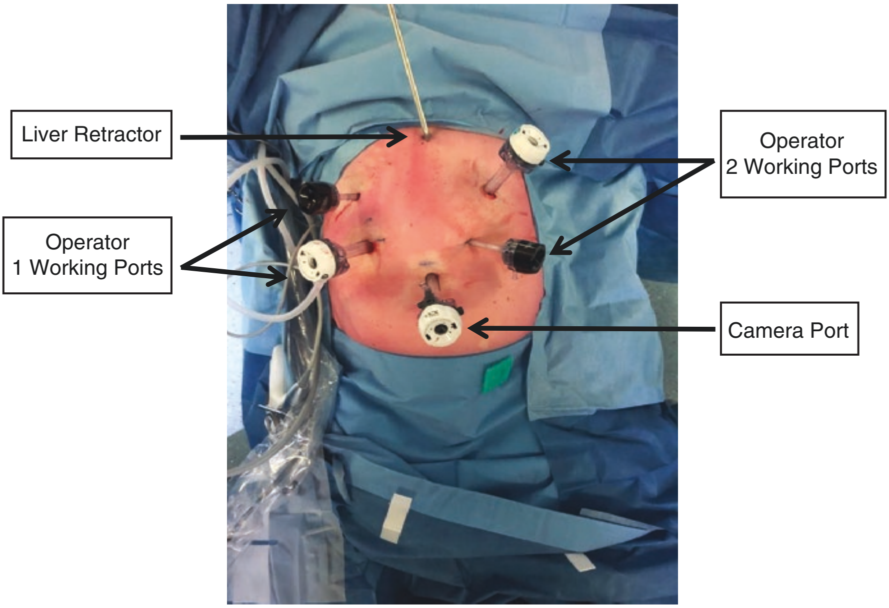

Fig. 5.4 Port set up for two surgeon, one camera operator configuration. The 12 mm trocars are placed for the operators' dominant hands (right-hand dominant configuration shown). The authors prefer using a 10 mm camera to ensure a clear image during aspects of the case requiring high image clarity (e.g. lymph node dissection and reconstruction)

5.2.4 *Lymphadenectomy*

Laparoscopic gastrectomy for cancer involves en bloc resection of the tumour with regional lymphadenectomy. For locally advanced gastric adenocarcinoma, extensive (D2) regional lymphadenectomy is the preferred standard internationally [4–6]. D2 dissection for subtotal gastrectomy involves removal of all perigastric lymph nodes as well as skeletonization of the hepatic and splenic arteries with retrieval of celiac and peri-portal lymph nodes. For total gastrectomy, removal of gastric fundus, short gastric and splenic hilar nodes is added. The Japanese lymph node station numbering system is summarized below [6]. For perigastric nodes, even numbers indicate greater curvature while odd numbers indicate lesser curvature lymph node locations (Table 5.1).

5.2.5 *Gastric Mobilization and D1 Lymphadenectomy*

The case is begun by dividing the pars flacida towards the right pillar of the diaphragm (Fig. 5.5).

At this point, with the lesser sac exposed, the D2 lymphadenectomy can be performed directly. Alternatively, this step can be left until the stomach is fully mobilized and duodenum divided. In bulky tumours or obese patients, waiting until the

Table 5.1 Lymph node station numbers and corresponding locations for D1 (perigastric) and D2 (retroperitoneal) dissections for gastric adenocarcinoma [7]

Station #	Anatomical location	Extent of lymphadenectomy
1	Cardia	D1
2	Fundus	D1
3	Incisura	D1
4d	Distal greater curvature	D1
4sb	Greater curvature, mid-body	D1
4sa	Short gastric vessels	D1
5	Right gastric artery	D1
6	Right gastroepiploic artery	D1
7	Left gastric artery	D1
8a	Hepatic artery (anterior)	D2
8p	Hepatic artery (posterior)	D2
9	Celiac artery	D2
10	Splenic hilum	D2
11p	Splenic artery (proximal)	D2
11d	Splenic artery (distal)	D2
12a	Peri-portal (left side of portal vein)	D2

Note that station 1 and 3 nodes (incisura and cardia) are included in the standard lymphadenectomy for all gastric cancer resections, including distal tumours

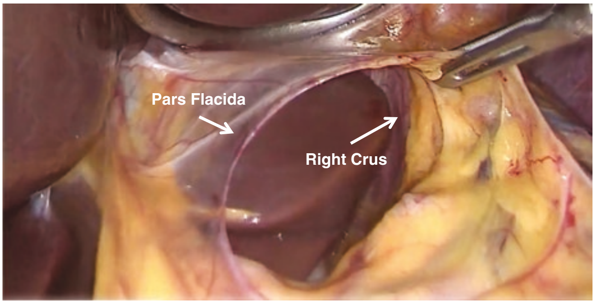

Fig. 5.5 Division of pars flacida towards right diaphragmatic crus

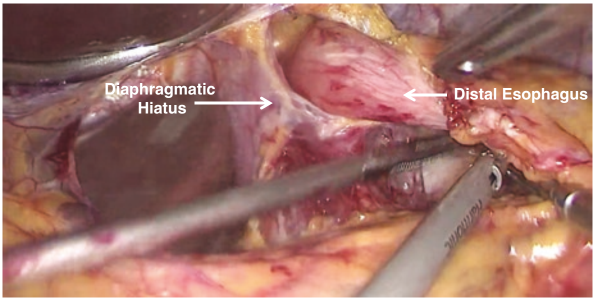

Fig. 5.6 Mobilization of the distal esophagus at the hiatus

duodenum is divided allows the operator to flip the stomach cephalad, providing better exposure to the celiac vessels for D2 dissection (described in detail below).

For a total gastrectomy, the esophagus is mobilized at the hiatus and the vagus nerves divided (Fig. 5.6).

For a subtotal gastrectomy, only the right crural attachments are opened inferiorly towards the median arcuate ligament. Later, during the D2 dissection, this will serve as a target for the end of the celiac lymph node dissection.

Next, the gastrocolic omentum is divided along the gastric greater curvature (Fig. 5.7).

This is continued towards the inferior pole of the spleen for a subtotal gastrectomy. For a total gastrectomy, the entire gastric body and fundus are mobilized by dividing the short gastric vessels. For an oncologic procedure, it is important to resect all potential lymphatic tissue with the specimen, and thus the surgeon should divide the short gastric vessels at the splenic hilum, taking the station 4sa lymph nodes with the specimen.

Once the proximal greater curvature is mobilized, the distal dissection is performed. The transverse colon is retracted inferiorly by the assistant and the posterior wall of the stomach elevated to expose the interface between the right gastroepiploic vessels and the transverse mesocolon. The mesocolon is gently separated from the right gastroepiploic pedicle with blunt dissection and divided until the duodenum is exposed in the first stage. The remaining gastrocolic omentum is then divided,

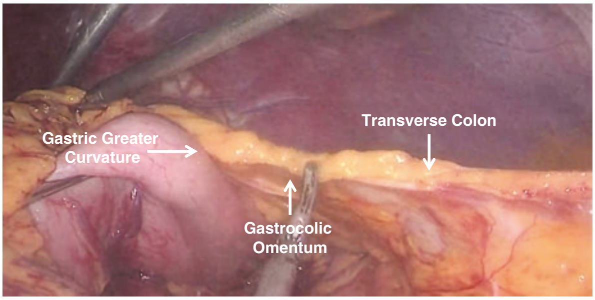

Fig. 5.7 Division of the gastrocolic omentum to mobilize the gastric greater curvature

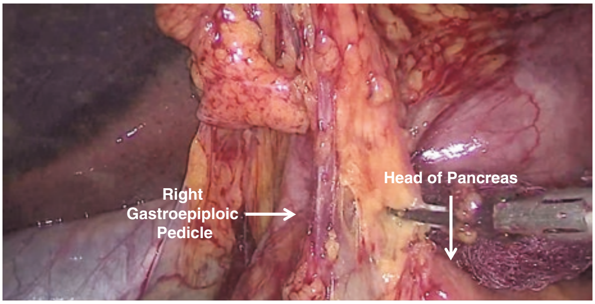

Fig. 5.8 Identification of the right gastroepiploic vessels over the head of the pancreas

completely separating the stomach from the transverse colon. The right gastroepiploic vessels are then skeletonized and ligated as proximally as possible on the head of the pancreas (Fig. 5.8).

During this portion of the dissection, it is crucial to identify the head of the pancreas and ensure the dissection does not progress underneath it, as this can risk injuring major vessels such as the middle colic vein or superior mesenteric vein and artery. In exposing the posterior wall of the duodenum on the head of the pancreas, the gastroduodenal artery is seen and used as a landmark to identify the take-off of the right gastroepiploic artery. The station 6 lymph nodes are swept up with the specimen and taken *en bloc* by dividing the gastroepiploic vessels.

Next, the right gastric artery is isolated at its origin on the proper hepatic artery in the porta hepatis (Fig. 5.9). It is ligated and divided, and the station 5 lymph nodes mobilized out of the porta towards the duodenum.

The duodenum should now be fully cleared off on both sides and ready to be divided. For distal tumours, care should be taken to ensure sufficient mobilization of the duodenum to achieve a negative pathological margin. If necessary, the duodenum can be mobilized off the head of the pancreas for several additional centimeters to achieve greater distance from the tumour. This should be done carefully as perforating vessels between the head of the pancreas and the duodenum often bleed, and it is easy to make a hole in the posterior wall of the duodenum during this mobilization, especially if using an uninsulated thermal energy device.

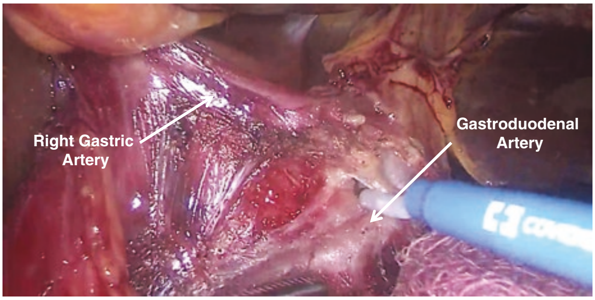

Fig. 5.9 Dissection along the gastroduodenal artery with right gastric artery retracted to provide tension

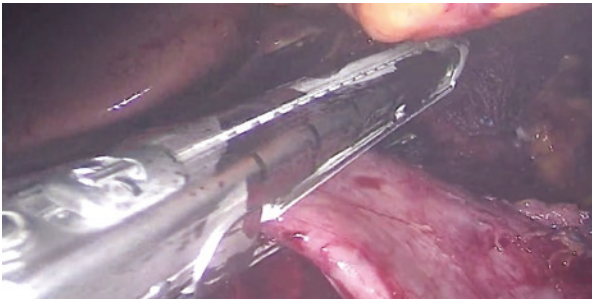

Fig. 5.10 Stapled division of the duodenum

5.2.6 Distal Specimen Division

The duodenum is divided in the first stage using an endoscopic stapler, usually passed from the surgeon's left hand (one surgeon approach) or by the right hand of the surgeon on the patient's right side (two surgeon approach). The duodenum should be stapled straight across with no bunching of tissues to avoid duodenal stump leaks (Fig. 5.10). Oozing from the staple line can be controlled with application of clips.

The stomach is then rotated cephalad and towards the spleen to expose the celiac axis and allow ready access to the retroperitoneum for the D2 lymph node dissection (see below).

5.2.7 D2 Dissection

While perigastric nodes are easily taken with standard gastric mobilization (see Table 5.1 above), D2 dissection requires additional maneuvers to complete. The assistant retracts the left gastric vessels such that they are placed under tension at a 90-degree angle to the celiac axis (Fig. 5.11).

The operator then opens the peritoneum along the superior border of the pancreas and follows this plane proximally and distally (Fig. 5.12).

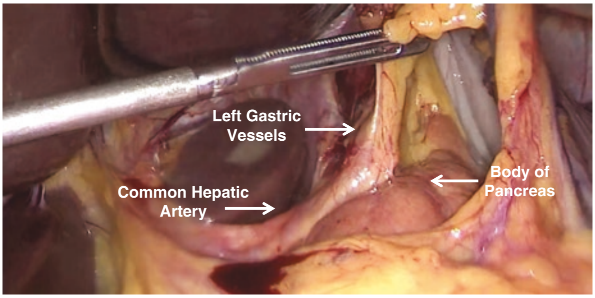

Fig. 5.11 Retraction of left gastric vessels to expose the retroperitoneum for D2 dissection

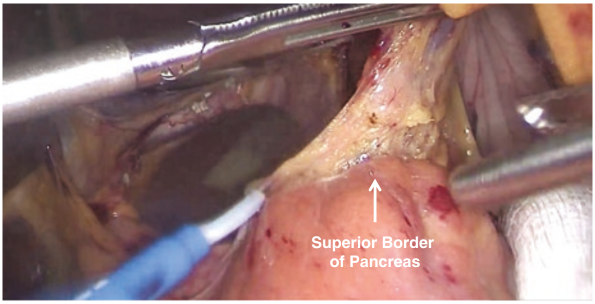

Fig. 5.12 D2 dissection begun along the superior border of pancreas

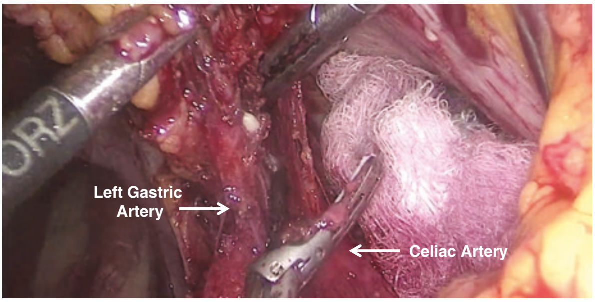

Fig. 5.13 Completion of left side of celiac dissection

While the goal is to skeletonize the splenic artery, variations in its location and path may make this vessel hard to identify and the pancreatic border should instead be used as a landmark to begin the dissection. This is particularly true in obese patients where visceral fat can quickly obscure key landmarks. Once the peritoneum is opened, lymphatic tissue is swept up towards the stomach off the retroperitoneum. This will eventually expose the left adrenal gland. The splenic artery should then be visible and skeletonized with lymphatic tissue mobilized towards the left side of the celiac artery (Fig. 5.13).

On the right of the celiac axis, the 8a lymph node overlying the hepatic artery is mobilized, exposing the vessel beneath (Fig. 5.14).

Dissection is carried towards the porta hepatis and the 12a node overlying the left side of the portal vein is carefully mobilized (Fig. 5.15).

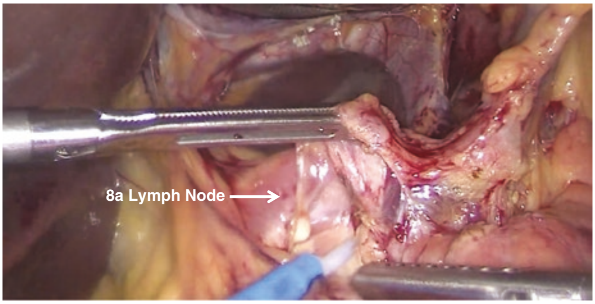

Fig. 5.14 Dissection of 8a lymph node off the common hepatic artery beneath

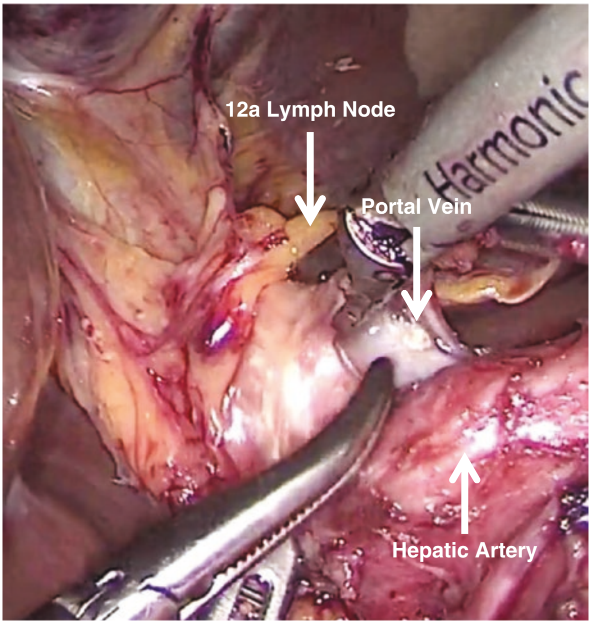

Fig. 5.15 Dissection of the 12a lymph node off the portal vein behind the hepatic artery

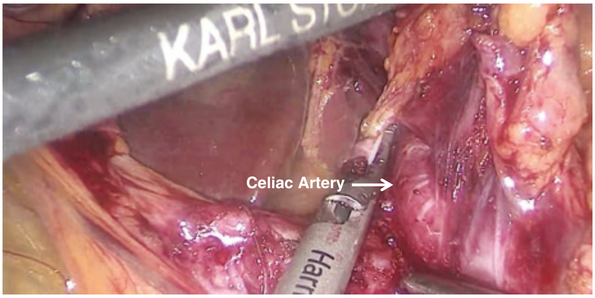

Fig. 5.16 Completion of the right side of the celiac dissection

The 8p lymph node behind the hepatic artery and station 9 nodes along the right side of the celiac artery are then swept off the retroperitoneum towards the base of the left gastric artery such that only the left gastric vessels remain (Fig. 5.16).

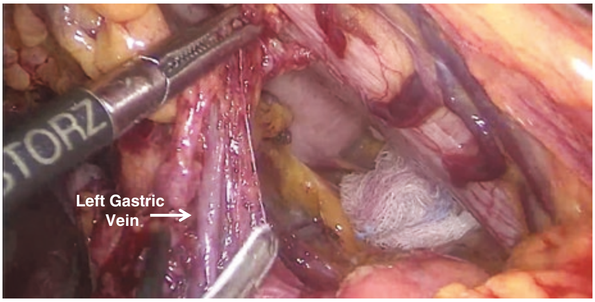

Fig. 5.17 Exposure of left gastric vein

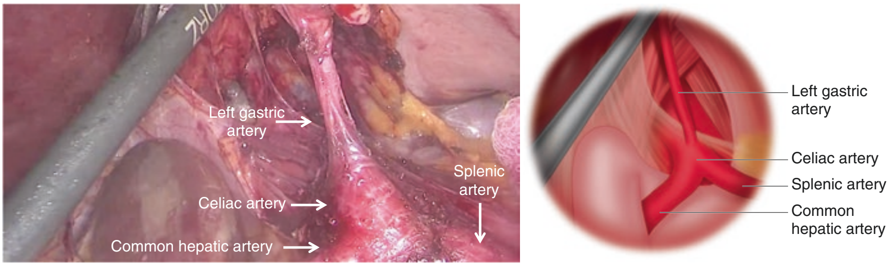

Fig. 5.18 Celiac axis and left gastric artery skeletonized

Typically, the left gastric vein is found between the origins of the hepatic and splenic arteries (Fig. 5.17), however its insertion is highly variable, and care should be taken during the D2 dissection to identify and carefully ligate this vein as it can be easily avulsed.

With all lymphatic tissue mobilized towards the origin of the left gastric artery, this vessel is skeletonized, ligated and divided at its base, completing the D2 dissection (Fig. 5.18).

5.2.8 Proximal Specimen Division

Once the D2 dissection is complete and the left gastric vessels divided, the remaining stomach is ready to be divided proximally. For a subtotal gastrectomy, the cardia and lesser curve lymph nodes (stations 1 and 3) are mobilized inferiorly to the level chosen for division of the stomach to be excised with the rest of the specimen (Fig. 5.19). For total gastrectomy, this step is unnecessary, as the esophagus is divided and the cardia nodes naturally removed with the specimen.

An endoscopic stapler is used to divide the proximal stomach, and this is most easily achieved from the patient's left side. Several stapler firings are usually

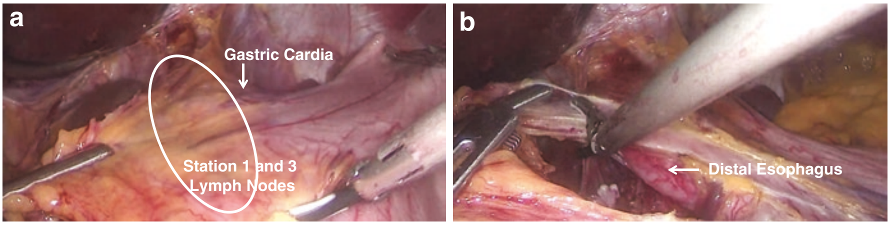

Fig. 5.19 (**a**) Retraction of stomach to allow dissection of station 1 and 3 lymph nodes off the gastric lesser curvature for subtotal gastrectomy. (**b**) Station 1 lymph nodes are mobilized off the gastric cardia towards the distal esophagus to allow for complete lymphadenectomy with gastric pouch preservation in subtotal gastrectomy

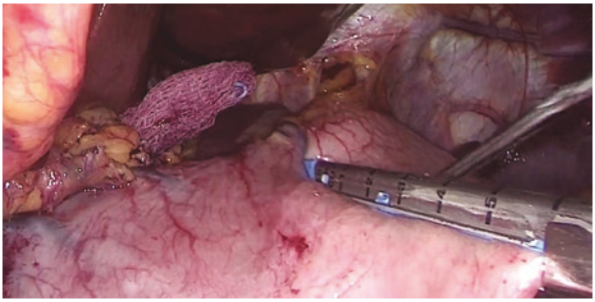

Fig. 5.20 Proximal gastric division with laparoscopic stapler for subtotal gastrectomy. Note that the station 1 lymph nodes have been mobilized off of the high lesser curvature and included with the specimen

required to completely transect the stomach for a subtotal gastrectomy. The authors prefer stapling on an angle from the tip of the spleen towards the high lesser curvature, such that the remaining gastric pouch is shaped like a funnel, which might improve drainage (Fig. 5.20).

For total gastrectomy, it is helpful to place stay sutures on either side of the esophagus before division to enable retraction of the esophagus after the stomach is removed (otherwise it will naturally retract several centimeters into the thorax).

5.2.9 *Specimen Retrieval*

Once the specimen is completely divided, it is placed in the patient's right upper quadrant for later retrieval. If margins are a concern, immediate extraction through a small accessory incision is done to allow pathological frozen section analysis before reconstruction is completed.

Choices abound for where to retrieve the specimen. Some practitioners prefer a small Pfannensteil incision for its cosmesis, low hernia rate and minimal associated pain. However, due to the distance of this incision from the surgical site, this extraction site can only be used for specimen retrieval (no reconstruction can be performed from here). Alternatives include a small upper midline incision or small left subcostal incision. These can then subsequently be used to reconstitute bowel continuity if the reconstruction is to be done extracorporeally (see below).

5.2.10 Reconstruction

Several options exist for reconstruction after partial or total gastrectomy (intra- vs extra-corporeal, Billroth II vs Roux-en-Y). Regardless of the method selected, the first step is proper identification of the Ligament of Treitz and proximal jejunum. This is done by elevating the transverse mesocolon to expose the jejunum as it exits the retroperitoneam (Fig. 5.21).

Approximately 20 cm distal to this, in a portion of the bowel that easily reaches the gastric remnant or distal esophagus, the assistant securely grasps the bowel, so the location is not lost, and the bowel orientation is not rotated.

5.2.10.1 Extracorporeal Reconstruction

This is most easily performed for subtotal gastrectomy in a thin patient. A subcostal incision is made, and the specimen retrieved through a wound protector. The clamped proximal jejunum is exteriorized. The distal stomach can also be exteriorized through this incision and either a roux-en-y or Billroth II reconstruction made as per the operator's preference. These can be either hand-sewn or performed with staplers (Fig. 5.22).

Extracorporeal esophagojejunostomy can also be done in the case of a total gastrectomy, however this can be quite technically challenging, especially in large or obese patients. If this reconstruction approach is selected, the specimen should be extracted through an upper midline accessory incision which then allows visualization of the distal esophagus for reconstruction. Again, the anastomosis can be established either in a hand-sewn manner or using staplers.

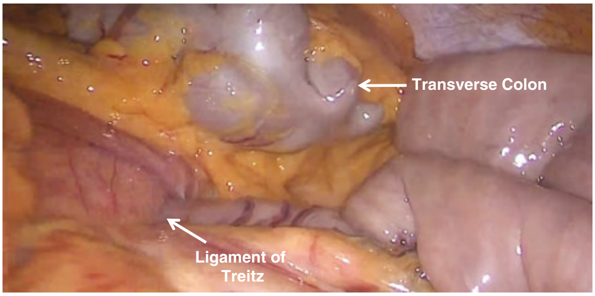

Fig. 5.21 Exposure of the Ligament of Treitz at the root of the transverse colon mesentery

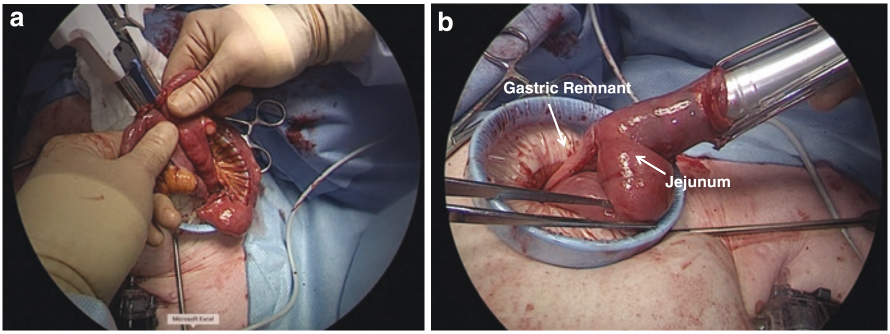

Fig. 5.22 (**a**) Creation of stapled jejunojejunostomy through left upper quadrant accessory incision for roux-en-y reconstruction. (**b**) Creation of circular stapled gastrojejunostomy through left upper quadrant accessory incision for roux-en-y reconstruction in subtotal gastrectomy

Some practitioners prefer performing the jejunojejunostomy through an accessory incision, which is usually quite easy and efficient, and the esophagojejunostomy intracorporeally due to improved visualization (hybrid approach).

5.2.10.2 Intracorporeal Reconstruction

Intracorporeal reestablishment of bowel continuity allows improved visualization in comparison to the extracorporeal method but is more technically challenging. Furthermore, in a thin or small patient, limited space can make this approach more difficult than the extracorporeal options described above. Reconstruction is performed with the surgeon standing either between the legs or on the patient's right-hand side.

5.2.11 Billroth II

For intracorporeal Billroth II, an anticolic, retrogastric orientation is easiest to perform. There is also no risk of bowel herniation or obstruction where the jejunum traverses the colonic mesentery as would be the case for a retrocolic reconstruction. The loop of proximal jejunum is brought up to the posterior wall of the stomach and secured in place using a stay suture. Enterotomies are made in the stomach and jejunum, and one arm of the endoscopic stapler passed in each to create a common channel. The enterotomy defect can then be closed either by hand sewing (less likely to narrow the outflow tract lumen) or stapling (technically easier and faster).

Obstruction or narrowing of either the efferent or afferent limb must be avoided in a Billroth II reconstruction as either will cause problems with biliary limb drainage and can lead to duodenal stump blow out. Intra-operative upper endoscopy can be used to confirm patency of both limbs.

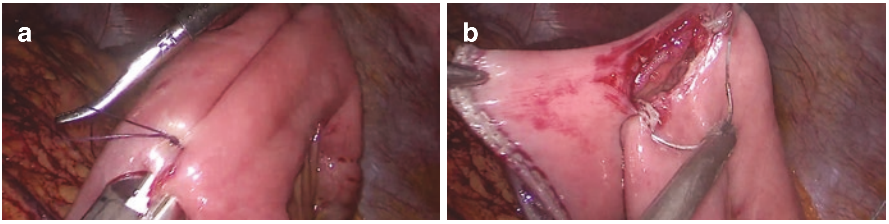

Fig. 5.23 (**a**) Intracorporeal stapled jejunojejunostomy creation for Roux-en-Y reconstruction. (**b**) Set up for hand-sewn intracorporeal enterostomy closure after creation of jejunojejunostomy by linear stapler. The assistant suspends the bowel by stay suture to facilitate exposure (off screen)

5.2.12 Roux-en-Y: Jejunojejunostomy

An intracorporeal jejunojejunostomy is created in a similar manner to that described above. The proximal jejunum is divided approximately 20 cm distal to the ligament of Treitz in a place where the roux limb mesentery allows it to reach easily to the distal gastric pouch or esophagus. The small bowel mesentery can be divided further with either a vascular stapler or vessel sealing energy device to achieve greater length. The assistant holds the end of the biliary limb to avoid later confusion while the surgeon runs the roux limb, counting off sufficient length to avoid bile reflux (minimum 40 cm for subtotal gastrectomy and 60 cm for total gastrectomy). The biliary and roux limbs are then aligned and enterotomies made in each. A stay suture can be used to facilitate proper orientation and is then later used to close the enterostomy. One limb of the endoscopic stapler is passed through each enterotomy and fired to create the common channel. The enterostomy defect is then closed. If this is done hand sewing, it is easier to start at the inferior corner and sew up (away from the surgeon) towards the stay suture which is used to tie the final knot. If stapling, stay sutures might be used to suspend the edges of the enterostomy while passing the stapler. In either case, great care should be taken to avoid narrowing the anastomosis as this will lead to roux limb obstruction (Fig. 5.23).

5.2.13 Roux-en-Y: Proximal Anastomosis

To create either a gastrojejunostomy or esophagojejunostomy intracorporeally, similar steps are taken as above. The anastomosis can be made using any of the following:

1. Fully hand-sewn technique
2. Linear stapler to create the back wall and hand sewing the anterior defect
3. Circular stapling

For hand sewn anastomoses, the roux limb is brought up to the gastric remnant or distal esophagus and secured in place with stay sutures. Enterotomies are made

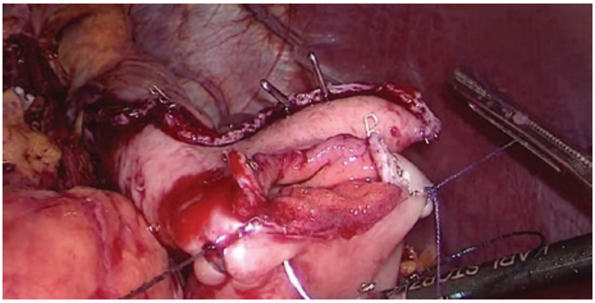

Fig. 5.24 Intracorporeal, transverse hand-sewn closure of enterotomy defect after linear stapled gastrojejunostomy creation

in both limbs. A single layer anastomsosis using two sutures (3-0 vicryl or 3-0 PDS are common choices) is then performed. One suture completes the back wall and the other the front wall and they are tied to each other. The sutures can be run from either the patient's left or right side, depending on the comfort of the operator.

For linear stapling, the limbs are similarly oriented with stay sutures as above and enterotomies made in each. One arm of the endo-stapler is passed into each limb. A 30 mm anastomosis is sufficient—using a longer stapler can lead to tension when closing the enterostomy defect as it will be unnecessarily large. The stapler is used to create the back wall of the anastomosis, leaving the enterotomy defect anterior. This is then closed in a transverse manner by hand sewing. Closing this defect vertically should be avoided as this can lead to narrowing of the anastomosis [8] (Fig. 5.24).

A circular stapled anastomosis is created by either seating a 25 mm anvil in the distal esophagus or gastric remnant by passing it on an oral-gastric tube via the mouth, or by sewing the anvil into the lumen by hand from the abdomen. The staple line on the end of the roux limb is then opened and the circular stapler passed directly through the abdominal wall and positioned in the roux limb. The stilette is deployed, and the anvil and stapler ends are mated, tightened together and the stapler fired. The open end of the roux limb is then closed with a single firing of a straight endostapler.

5.2.14 Closure of Mesenteric Defects

Whichever reconstruction method is chosen, mesenteric defects are traditionally closed to prevent formation of internal hernias. This can be achieved with running or interrupted sutures according to the operator's preference (Fig. 5.25).

5.3 Post-Operative Management

After laparoscopic gastrectomy, most patients can be managed according to the recommendations of the Enhanced Recovery After Surgery (ERAS) society consensus guidelines for anatomical gastrectomy [9]. This approach minimizes the use of tubes and drains, emphasizes multimodal analgesia and early ambulation, and early

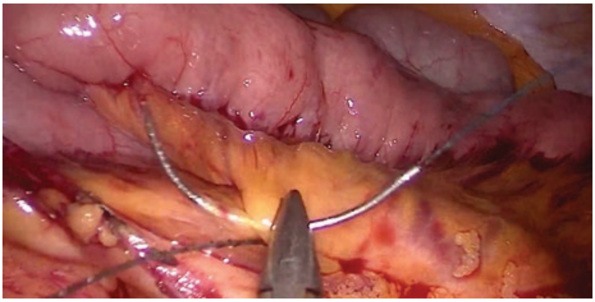

Fig. 5.25 Intracorporeal sutured closure of mesenteric defect after Roux-en-Y reconstruction

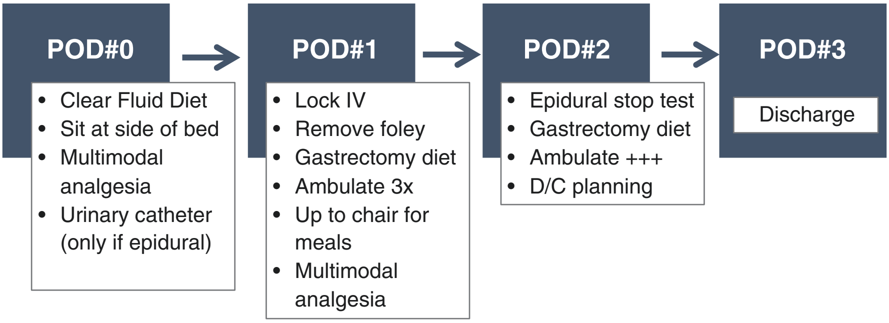

Fig. 5.26 Typical patient trajectory after laparoscopic or open gastrectomy at the Montreal General Hospital, Montreal, Canada. Patients are managed according to Enhanced Recovery After Surgery (ERAS) principals and according to consensus guidelines from the ERAS society [9]

resumption of *ad lib* oral intake. Use of nasogastric suction, abdominal drains and indwelling urinary catheters are of no benefit in most patients and should not be routinely used. Offering patients oral post-gastrectomy diet as early as day 1 has not been shown to result in increased adverse events, and as such percutaneous or naso-jejunal feeding tubes are generally unrequired. Dietician consultation before discharge is recommended to help patients transition to post-gastrectomy anatomy and dietary constraints. Sample dietary recommendations for post-gastrectomy patients can be found at: http://www.muhcpatienteducation.ca/DATA/GUIDE/822_en~v~stomach-cancer-nutrition.pdf. A typical patient trajectory after gastrectomy at the Montreal General Hospital is depicted in Fig. 5.26. It is important to remember that any deviation from normal post-operative course mandates immediate investigation and may require deviation from the standard care trajectory.

5.4 Conclusion

Laparoscopic gastrectomy can be safely performed for many indications. Recent data from randomized control trials reveals experienced operators can achieve similar short term surgical and oncologic results to open surgery for even locally advanced cancers [3]. Nevertheless, laparoscopic gastrectomy is an advanced procedure and thus familiarity with the operative steps, variety of reconstruction techniques and potential pitfalls are necessary to ensure good outcomes.

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Chapter 6
Minimally Invasive Ivor Lewis Esophagectomy

Caitlin Harrington and Daniela Molena

6.1 Introduction

Esophageal cancer is the eighth most common cancer worldwide [1]. There will be an estimated 18,440 new cases diagnosed in the United States alone in 2020, and although 5-year survival rate falls around 19.9% [2] for all stages of disease, prognosis is much more favorable for early stage diagnosis. Operative resection, in combination with neoadjuvant chemotherapy, has been the mainstay for curative treatment of locally advanced disease. The first esophagectomy was performed in 1913, and was found to carry a high morbidity and mortality. Since then, minimally invasive approaches have been developed, including the transthoracic (Ivor Lewis) esophagectomy described in this chapter, three-field (McKeown), and transhiatal esophagectomy. These operations offer equivalent oncological outcomes [3–5] with a major reduction in the morbidity and mortality associated with open approaches [6–8]. Furthermore, studies have demonstrated that morbidity and mortality is most effectively reduced when resection is performed in high volume centers, with case volumes of more than 20 esophagectomies per year [9].

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6.2 Clinical Presentation

The classic presentation of a patient with advanced stage esophageal cancer is dysphagia to solids and eventually liquids, in combination with unintentional weight loss. Patients with early stage cancers may be asymptomatic. Some patients describe retrosternal discomfort while eating that is related to food getting "caught" as they eat, or experience regurgitation of solids and/or liquids.

6.3 Preoperative Workup

Any patients with these symptoms should undergo an endoscopic evaluation. Any abnormalities to the mucosa should be biopsied. An obvious mass is pathognomonic for esophageal cancer, but earlier stages can present with more subtle findings like ulcerations or plaques. A biopsy should be taken for tissue diagnosis. If cancer is confirmed, the patient should be fully staged:

1. An endoscopic ultrasound (EUS) will show the depth of invasion for accurate T staging. Concerning nodal disease that may be noted during EUS should undergo fine needle aspiration (FNA). Endobronchial ultrasound (EBUS) can also be used for biopsy of concerning nodes.
2. A contrast enhanced computed tomography (CT) of the neck, chest, and abdomen, along with a whole body integrated fluorodeoxyglucose positron emission tomography (FDG-PET) should be performed to evaluate for distant metastases, paying attention to common sites including the lungs, liver, adrenal glands, and bone. Lesions that are worrisome for metastatic disease should be biopsied.

If initial staging indicates that a patient should receive neoadjuvant therapy, the patient should be re-staged before undergoing surgery.

6.4 Surgical Technique and Operative Steps

6.4.1 Abdominal Phase

6.4.1.1 Position of the Patient and Trocar Placement

A double lumen endotracheal tube is used for general anesthesia. An esophagogastroduodenoscopy should be performed either on the day of surgery or few days prior to evaluate tumor position and changes related to radiation therapy. An orogastric tube is placed to decompress the stomach. The patient is placed in a supine position with feet secured against a padded foot board. Arms should be positioned out and supported so that they are secure when the patient is placed in reverse

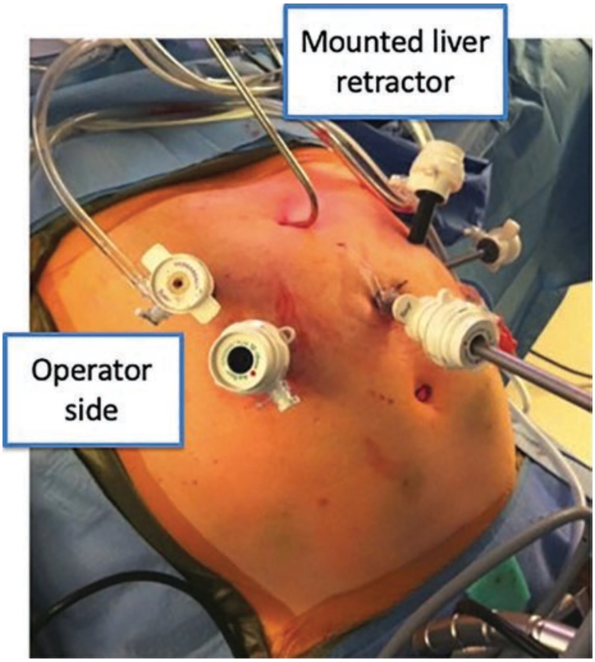


Fig. 6.1 Abdominal phase positioning: *patient is shown in supine position with surgeon on right side of the Table. A 10 mm optical trocar is placed left costal margin at the mid clavicular line, a 5 or 10 mm trocar is placed midline below the falciform ligament, two 5 mm ports are placed in the right and left upper quadrants, and a 10 mm trocar is placed in the right flank*

Trendelenburg. The abdomen and lower chest are widely prepped and draped. The primary surgeon stands on the right side of the operating table, with the camera operator on the same side towards the patient's feet. A camera holder can be very useful in case of limited available personnel. The assistant stands on the patient's left side (Fig. 6.1). The abdomen is entered with a 10 mm optical trocar underneath the left costal margin at the mid-clavicular line and pneumoperitoneum is achieved with CO_2 at 15 mmHg. All other ports are placed under direct visualization: either a 5- or 10-mm trocar in the midline just below the falciform ligament where the camera is introduced, 2 additional 5 mm ports in the right and left upper quadrants and a 10 mm trocar in the right flank. A Nathanson liver retractor is placed just below the xiphoid process.

Troubleshooting: Before prepping and draping, positioning the patient in steep reverse Trendelenburg can help identify potential issues with lines or areas of the body not sufficiently secured. Although abdominal entry with an optical trocar in the left subcostal region is fairly safe in experienced hands, a Hasson trocar might be safer for patients with extensive previous abdominal surgery.

6.4.1.2 Celiac Lymphadenectomy

Upon entry, the peritoneal cavity is examined to rule out metastatic or unresectable disease. Next, the gastrohepatic ligament is entered and divided until dissection reaches the base of the right crus, and then moves inferiorly to expose the celiac trunk. The left gastric artery is identified, along with the splenic and common hepatic arteries, and their associated lymph nodes are carefully dissected to perform a complete lymphadenectomy (Fig. 6.2). The left gastric pedicle is dissected starting along the superior edge of the pancreas and dissection continues along the hepatic artery, to the right crus and behind the left gastric artery (Fig. 6.3). The left gastric vein is usually clipped and divided with shears while the left gastric artery is stapled at its origin. Once the artery is divided, dissection is continued along the splenic artery and the lateral aspect of the left crus until the first short gastric vessels running along the left crus are identified and divided.

Troubleshooting: When a large left accessory hepatic artery or a left replaced hepatic artery is present, the left gastric artery should be preserved, and a complete lymphadenectomy should be performed by skeletonizing the artery from all surrounding fatty tissue. The branches for the stomach can be clipped or divided with energy device. While dividing the peritoneum at the superior edge of the pancreas be aware that the left gastric vein at times drains into the portal vein posteriorly to the hepatic artery rather than anteriorly.

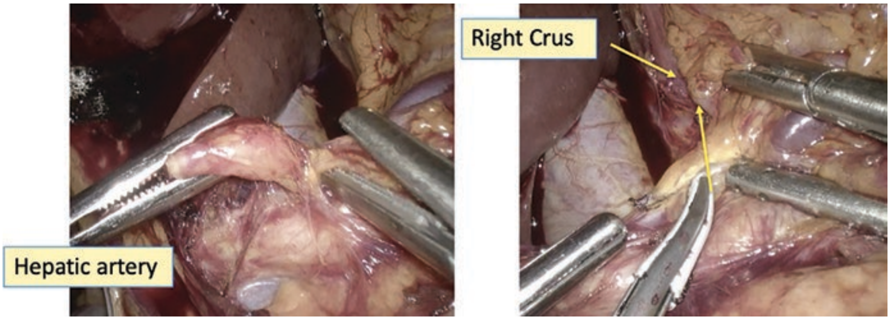
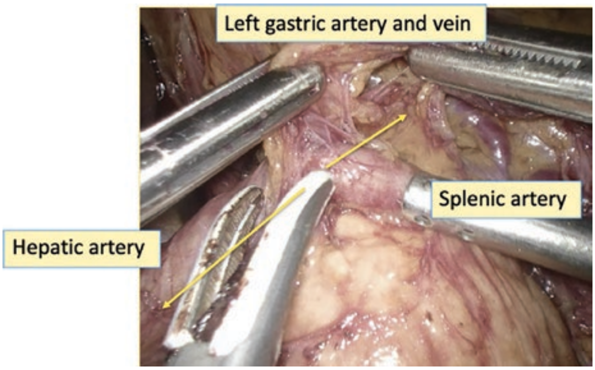


Fig. 6.2 Celiac lymphadenectomy: *A complete lymphadenectomy of the hepatic, splenic and left gastric arteries is shown*

Fig. 6.3 Superior edge of the pancreas: *During celiac lymphadenopathy, the left gastric pedicle is dissected at the superior edge of the pancreas*



6.4.1.3 Mobilization of the Greater Curvature

Dissection around the right crus is continued across the hiatus down the left crus. The stomach is then retracted anteriorly and to the right to expose the gastrocolic ligament, which is divided 3–4 cm away from the right gastroepiploic artery, which will serve as the blood supply of the gastric conduit. It is important that complete mobilization of the right gastroepiploic artery to its base is performed. Dissection continues along the greater curvature of the stomach towards the fundus through the gastrosplenic ligament, preserving the greater curvature fat, until it meets the dissection of the left crus. This is performed carefully so that the short gastric vessels are taken with a long stump on the splenic side and so that the spleen itself is not injured. Posterior attachments to the stomach must also be divided for full mobilization to be complete. At this point, the pylorus should be able to reach the hiatus (Fig. 6.4).

Troubleshooting/Pearls: *A Kocher maneuver is unnecessary for this mobilization and should not be performed, as it can allow for duodenal herniation into the chest. The transverse mesocolon can be adherent to the right gastroepiploic pedicle and will hold the stomach down if not carefully dissected off the pedicle. The entire gastrocolic ligament should be divided towards the duodenum to avoid tension in the anastomosis.*

6.4.1.4 Transhiatal Dissection

The esophagus is circumferentially dissected at the level of the hiatus, allowing for passage of a penrose drain, which will serve as a handle to aid in retraction. The plane of dissection will be carried from pleura to pleura, pericardium to aorta, to the level of the inferior pulmonary vein. Periesophageal lymph nodes are kept with the specimen (Fig. 6.5).

Troubleshooting: If a pneumothorax occurs during this dissection, one must create a wide pleural opening to allow for equilibration of pressure so that a tension physiology in the chest does not develop. The patient may become hypotensive if this

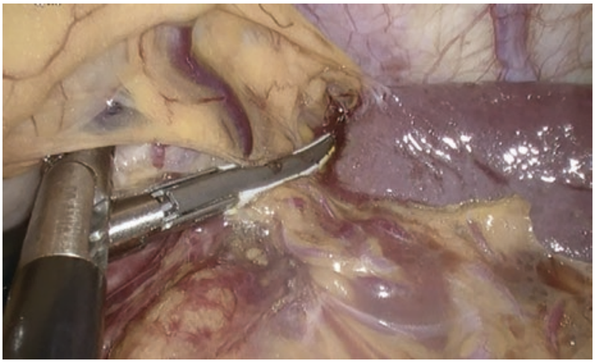


Fig. 6.4 Mobilization of the greater curvature of the stomach: *Dissection is carried towards the fundus through the gastrosplenic ligament until it meets the dissection of the left crus, and posterior attachments to the stomach are divided so that the pylorus can meet the hiatus*

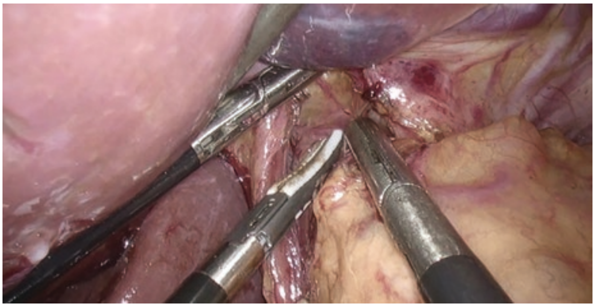


Fig. 6.5 Transhiatal dissection: *The esophagus is circumferentially dissected at the level of the hiatus*

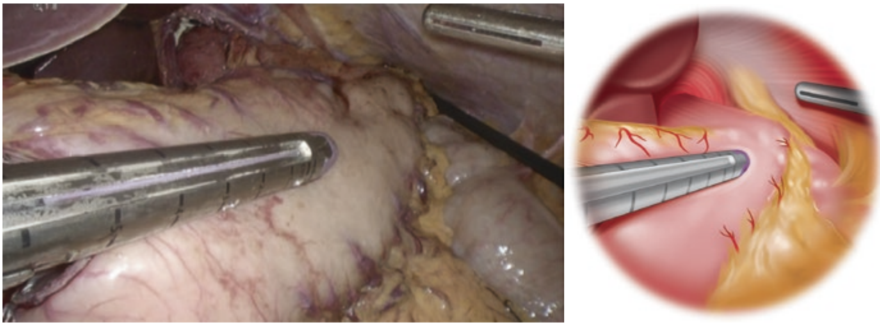


Fig. 6.6 Creation of the gastric conduit: *Serial endovascular staplers are used to make a 4–5 cm gastric conduit that begins just proximal to the pylorus on the lesser curve and continues towards the fundus*

occurs, which should prompt temporary desufflation of the pneumoperitoneum and repositioning of the patient supine to allow anesthesia to adjust ventilatory parameters and blood pressure. Placement of a chest tube is rarely required. Communication of these potential complications with anesthesia should occur before the start of the case.

6.4.1.5 Creation of the Gastric Conduit

The orogastric tube is pulled back to prevent stapling across it as tubularization of the stomach is performed. A 4–5 cm wide gastric conduit is then created using serial endovascular staplers starting just proximal to the pylorus on the lesser curvature and continuing towards the fundus. The assistant can aid the primary surgeon in the step by providing retraction of the fundus in conjunction with retraction of the lesser curve as stapling occurs. The distal margin is preserved and sent to pathology for frozen section analysis (Fig. 6.6).

Troubleshooting/Pearls: *It is important to stretch the conduit from the fundus to the pylorus in order to avoid spiraling of the gastric staple line. It is also important to ensure that the conduit is not twisted when it is eventually brought into the chest, as this would cut off the blood supply to the conduit and lead to conduit necrosis or obstruction.*

6.4.1.6 Creation of the Feeding Jejunostomy

The colon is lifted superiorly to expose the ligament of Trietz. A mobile portion of proximal jejunum is grasped and elevated to the left abdominal wall. A diamond pattern surrounding the intended jejunostomy site is created with four absorbable sutures, which are then brought through the abdominal wall utilizing a Carter-Thompson fascial closure device. A percutaneous jejunostomy is then created using a Seldinger technique, and the four anchoring sutures are tied externally within the subcutaneous layer of the abdominal wall. The tube is advanced into the bowel lumen and distal jejunum (Fig. 6.7)

Troubleshooting/Pearls: *Proximal and distal stitches adjacent to the jejunostomy can be utilized to prevent twisting.*

Fig. 6.7 Feeding jejunostomy creation: *The jejununostomy site is created with a diamond pattern of four absorbable sutures, then a percutaneous jejunostomy is created utilizing a Seldinger technique*

Fig. 6.8 Thoracic phase positioning: *The patient is placed in a modified left lateral decubitus position where they are slightly rotated towards a prone position. Four ports are placed: 10 mm posterior axillary line in seventh intercostal space, 5 mm camera port in ninth intercostal space posterior to the first port, 10 mm port along mid axillary line in third or fourth intercostal space, and 5 mm port in seventh intercostal space between the spine and scapula*

6.4.2 Thoracic Phase

6.4.2.1 Positioning and Trocar Placement

The patient is placed in a left lateral decubitus position and then slightly rotated towards a prone position, utilizing a bean bag for security on the table, along with an axillary roll and arm support. The table can be flexed at the hip so that the hip is level with the ribs, ensuring that instrumentation will not be limited by the hip's curvature. Four ports are utilized during the thoracic portion—a 10 mm port along the posterior axillary line in the seventh intercoastal space, a 5 mm camera port placed posteriorly to this in the ninth intercostal space, another 10 mm port along the mid axillary line in the third or fourth intercostal space, and a 5 mm port in the seventh intercostal space posteriorly between the spine and scapula (Fig. 6.8).

Troubleshooting/Pearls: *CO_2 can be used to insufflate the chest at 8 mmHg in order to flatten the diaphragm and collapse the lung towards the anterior mediastinum. This can help minimize movement of the mediastinum from ventilation of the contralateral chest during dissection. In cases where the spine is protruding significantly into the chest the most posterior assisting port should be moved slightly anteriorly to avoid hitting the spine while trying to retract the esophagus.*

Fig. 6.9 Anterior and posterior pleural dissection of the esophagus: *Anterior dissection is carried to the level of the azygos vein. Posterior dissection is then performed back down to the transhiatal dissection performed during the abdominal phase*

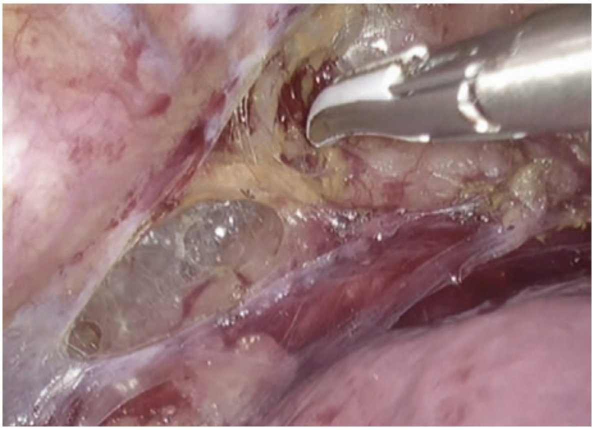
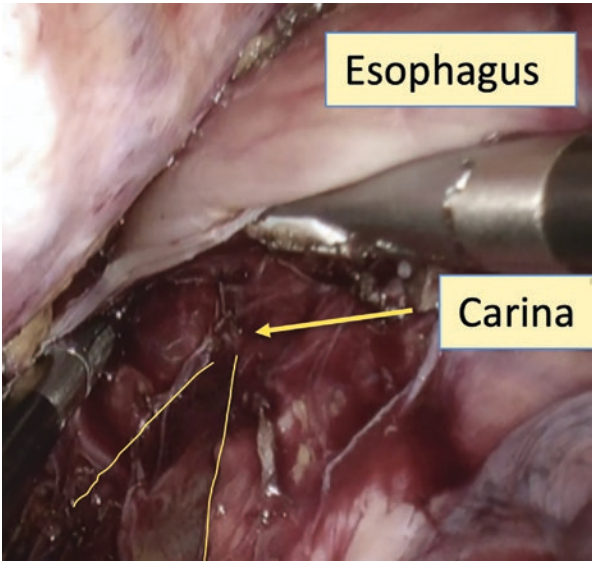


Fig. 6.10 Identification of airways, subcarinal lymphadenectomy: *Membranous portions of the mainstem bronchi and carina can be easily missed and injured during the dissection, and thus identification is crucial (shown). A subcarinal lymph node dissection is performed*



6.4.2.2 Opening of the Anterior and Posterior Pleura

The inferior pulmonary ligament is divided up to the level of the inferior pulmonary vein and its associated lymph node is resected. The mediastinal pleural is dissected anteriorly along the esophagus up to the level of the azygos vein and the vein is divided using a vascular load stapler. This dissection is then carried posteriorly and inferiorly, until it meets the transhiatal dissection performed during the abdominal phase of the operation (Fig. 6.9).

Troubleshooting/Pearls: *Precise dissection close the esophagus should be performed to avoid injury of the thoracic duct or aorta. The mediastinal pleura above the azygos vein is preserved in order to be used to cover the anastomosis.*

6.4.2.3 Circumferential Mobilization of the Esophagus, Identification of Airways, and Subcarinal Lymphadenectomy

The penrose drain that was placed during the transhiatal dissection can be used to aid in the circumferential dissection of the esophagus from the mediastinum. During this step, meticulous dissection will allow for the adequate identification, control, and clipping of lymphatic branches from the thoracic duct and arterial branches from the aorta. It is important to identify the airways during this dissection, as the membranous portions of the mainstem bronchi and carina can be easily missed and injured (Fig. 6.10). The esophagus is divided with linear staplers just above the azygos vein or higher if required by tumor margins. A subcarinal lymph node dissection is then easily performed with complete exposure of the airways and pericardium once the esophagus is pushed away from the posterior mediastinum.

Troubleshooting: It is easier to identify the airways by doing first an anterior dissection starting at the level of the vagus nerve and moving behind the esophageal wall. Unless there is a tumor invading the infracarinal nodes it is better to leave the nodes down in the pericardium while identifying the left main bronchus from behind the esophageal wall. The left inferior vein should be identified as well in order to avoid injury. Before dividing the esophagus, it is wise to ensure that the orogastric tube and/or esophageal temperature probes are removed.

6.4.2.4 Passage of the Orvil

The esophageal stump is then dissected from the pleura, the trachea and lateral mediastinal attachments for about 2 cm to allow free movement of the Orvil within the stump. The anesthesiologist then advances the oral anvil for the Orvil so that the tip of the tubing reaches the proximal staple line, which is being stabilized with graspers on both sides, and cautery is utilized to create an opening above the center of the staple line where the anvil is passed through.

Troubleshooting: *The opening for the Orvil should be just next to the staple line of the esophageal stump to avoid leaving devascularized tissue at the anastomotic site. We also prefer to pass the Orvil at the anterior corner of the staple line so that there is only 1 point of crossing between lineal and circular staple lines where a potential area of ischemia can lead to leakage. The Orvil can get stuck at the passage behind the larynx. Deflating the ET tube balloon and lifting the patient's jaw can help ease the passage into the esophagus. Pulling too hard on the NG tube will cause disassembly between the NG and the anvil.*

6.4.2.5 Gastric Conduit Pullup

The distal esophagus is then pulled up, so that the specimen and the conduit enter the chest without twisting or tension, with the staple line orientation remaining on the patient's right (Fig. 6.11). Perfusion of the conduit can be assessed using

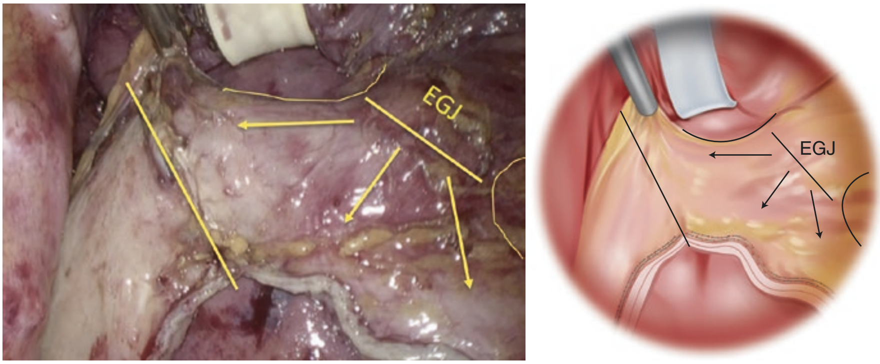


Fig. 6.11 Gastric pullup: *The gastric conduit is pulled into chest without twisting with the staple line oriented to the patient's right*

fluorescence imaging. If an area of poor perfusion is noted, efforts are made to avoid using this area for the anastomosis. The specimen is divided from the gastric conduit using a linear stapler, leaving adequate length for the insertion of the circular stapler so that an end to side esophagogastric anastomosis can be created. The specimen is then removed using a bag, and sent for pathologic assessment of margins.

Troubleshooting: The specimen can have a difficult time passing the hiatus if the tumor is large or if there is a large amount of fatty tissue along the greater curvature. It is important to pull with constant and low pressure rather than using a lot of force. Gentle pull on the greater curvature fat while protecting the gastroepiploic arcade from injury can help ease the stomach in the chest.

6.4.2.6 Anastomosis

Once the proximal and distal margins are determined by pathology to be negative for disease, the proximal conduit staple line is opened so that a circular stapler can be inserted and an anastomosis is created (Fig. 6.12). Once the circular stapler is removed, a linear stapler is inserted to transect the open end of the proximal conduit. The anastomosis can be secured in place using absorbable tacking sutures to the proximal mediastinal pleura. Anesthesia places a nasogastric tube which is advanced under direct vision, and a chest tube is placed before lung expansion (Fig. 6.13).

Troubleshooting: *The anastomosis and gastric staple line should be at least 1–2 cm apart to avoid ischemia. The vessels of the greater curvature should be on the tracheal side of the anastomosis in order to protect the airway in case of a leak. Omentum or pericardial fat can buttress the vertical staple line and protect it from the airway. The anastomosis should be tension free.*

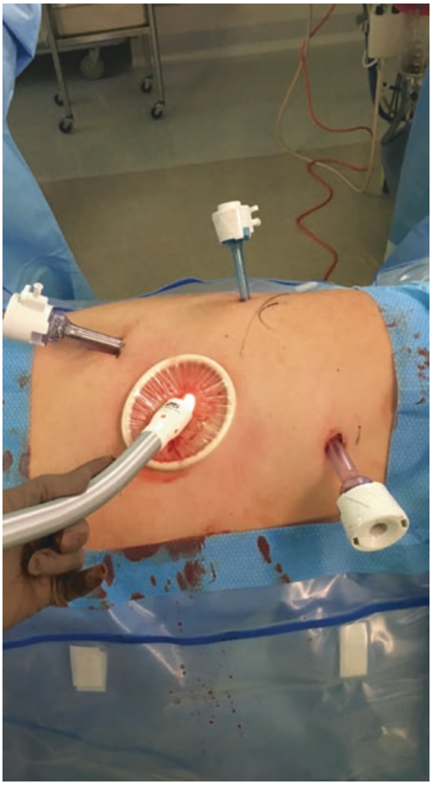


Fig. 6.12 Anastomosis: *Insertion of circular stapler*

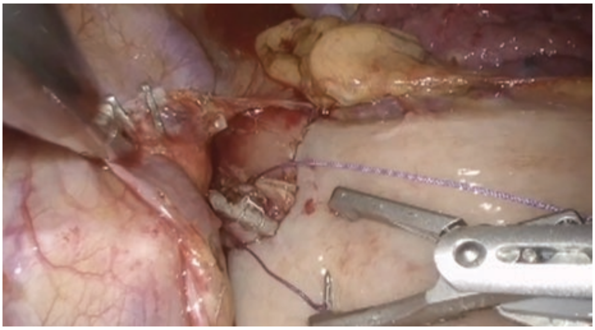


Fig. 6.13 Anastomosis: *the proximal conduit staple line is opened so that the circular stapler can be inserted and an anastomosis can be created. This is then secured in place using absorbable tacking sutures to the proximal mediastinal pleura*

6.5 Postoperative Course

Patients are managing according to a protocol used at our institution. Extubation takes place in the operating room. The nasogastric tube (NGT) is kept to suction and the patient is NPO to help prevent tension on the new anastomosis immediately after surgery. Tube feeds start on post-operative day two and slowly advanced per protocol. The NGT is removed by the third or fourth day, unless output is abnormal or there is significant conduit distension on the x-ray, along with the chest tube, unless a chyle leak is present. A clear liquid diet is started on post-operative day five. Patients are typically discharged on post-operative day seven. Diet is further advanced in the outpatient setting, along with a wean from tube feeds. The jejunostomy is typically removed at the two-week follow-up visit.

6.6 Conclusions

Minimally invasive Ivor Lewis esophagectomy is a technically demanding operation requiring meticulous dissection and purposeful post-operative care. This approach, when performed in practiced hands, can offer a reduction in the morbidity and mortality associated with esophagectomy.

Conflict of Interest The authors have no conflict of interest to declare.

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Chapter 7
Minimally Invasive Transhiatal Esophagectomy

Colette S. Inaba and Brant K. Oelschlager

7.1 Introduction

Although the transhiatal esophagectomy (THE) was popularized by Orringer and Sloan in 1978, it was first described in 1913 [1]. In contrast to the Ivor-Lewis esophagectomy that involves a right transthoracic esophageal dissection with an intrathoracic anastomosis, the THE involves a cervical anastomosis and blunt upper esophageal mobilization without any thoracic incisions. These two approaches are used primarily for adenocarcinomas of the distal esophagus and gastroesophageal junction (GEJ). The McKeown approach includes a cervical anastomosis similar to the THE, but also involves direct intrathoracic mobilization of the esophagus similar to the Ivor-Lewis esophagectomy—it is thus commonly referred to as a "three-hole" esophagectomy. The McKeown is primarily used for squamous cell carcinomas of the middle third of the esophagus, when delicate dissection between the tumor and airway is required.

Minimally invasive techniques have gradually been used in all approaches to esophagectomy in hopes of reducing the morbidity of these high-risk procedures. We have used laparoscopy to assist with THE for over two decades, with excellent results. We use laparoscopy for its benefits (visualization of the lower half of the esophagus/mediastinum, improved radial and lymph node dissection, reduction of blood loss, and decreased incision size) and employ a small laparotomy to accelerate and safely complete the operation in a timely fashion, usually 3.5–4.5 h. The open part of the procedure includes performing a Kocher maneuver, completing the upper mediastinal dissection, and safely constructing the gastric conduit.

The focus of this chapter will be the technical approach to a hybrid minimally invasive THE. We will briefly review the common indications/contraindications and

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perioperative management of the patient, but the majority of the discussion will highlight the key steps to the procedure and technical tips to consider.

7.2 Indications/Contraindications

A THE can be performed for most benign and malignant diseases of the esophagus, but there are a few contraindications that must be considered. A THE should be avoided in any situation that may cause difficulty with mobilizing the upper half of the thoracic esophagus (e.g. a T3 tumor abutting the airway). In such cases, a transthoracic approach must be used to safely address any fixation of the esophagus, usually with a three-field (McKeown) esophagectomy [2]. Another contraindication for THE is prior gastric surgery or disease that prevents adequate mobilization and/or length of the stomach to the neck. In these situations, an intrathoracic anastomosis is preferred to the cervical anastomosis of a THE.

7.3 Preoperative Preparation

During patients' preoperative evaluation, we perform a nutritional assessment to determine whether the patient would benefit from placement of a jejunostomy feeding tube to optimize nutritional status prior to esophagectomy. In addition, patients are also referred to physical therapy as needed to maximize their preoperative physical conditioning. We have also implemented preoperative carbohydrate loading. On the day of surgery, patients receive a thoracic epidural and prophylactic heparin prior to heading to the operating room. Sequential compression devices are placed on the bilateral lower extremities to minimize the risk of deep vein thrombosis. After induction, a foley catheter is placed and the patient is then positioned.

7.4 Operative Steps

7.4.1 Patient Positioning

The patient is positioned supine on a split-leg table. Arms are tucked and legs are secured with hip straps to support severe reverse-Trendelenburg positioning. The neck is rotated 30° to the right and positioned in extension with towels beneath the shoulders. The patient is prepped widely from mandible to pubis and is draped to expose the left neck to below the umbilicus (Fig. 7.1).

Troubleshooting:

- An underbody warming blanket should be use to ensure adequate warming during the surgery. The standard lower and upper-body warmers cannot be applied to these patients due to the split-leg positioning and thoracic/neck exposure.

Fig. 7.1 Positioning and draping

After the laparoscopic portion of the procedure, we put the legs together and add a lower-body warmer under the drapes. We also place a fresh drape over the lower extremities to ensure that we maintain sterility of the field.

- A gel donut placed under the occiput helps to stabilize the head and minimize rotational movement of the neck during the procedure. It also helps to ensure proper neck extension without suspending or hyperextending the neck, which could result in spinal cord injury.
- After tucking the arms but prior to prepping and draping, the bed rails should be checked to ensure there is adequate clearance for the retractors without causing undue compression on the patient's arm.

7.4.2 Port Placement and Diagnostic Laparoscopy

Entry to the abdomen is made using a Veress needle and 10 mm, 0-degree optical trocar in the midline, 10 cm below xiphoid. The viscera and parietal peritoneum are inspected for metastases and frozen biopsy is sent of any suspicious lesions. A 5 mm working port is placed in both the left and right upper quadrants, and a 5 mm

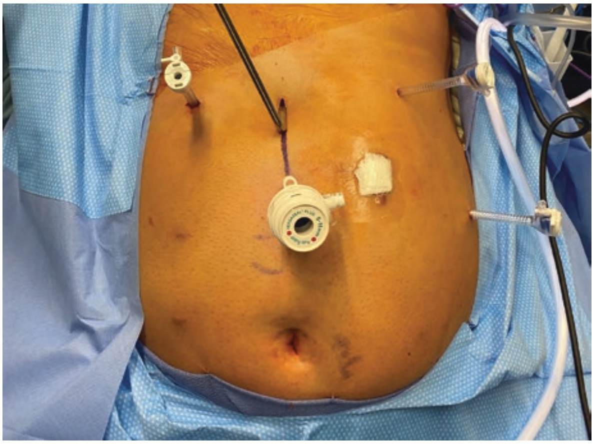


Fig. 7.2 Port placement

assistant port is placed in the patient's left lateral abdomen. Finally, a 5 mm incision is in placed in the midline epigastrium for the Nathanson liver retractor (Fig. 7.2).

Troubleshooting:

- The midline port incisions should be made vertically so that they can be connected later in the procedure to make an upper midline incision.
- The tip of the Nathanson retractor should be within view at all times during insertion, as it can inadvertently traumatize the diaphragm or even the pericardium.

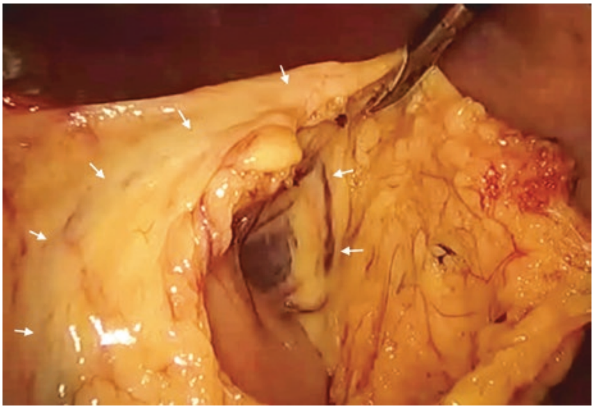
7.4.3 *Mobilization of the Greater Curve of the Proximal Stomach*

This dissection starts approximately at the level of the mid-body along the greater curve. This is distal to the left gastroepiploic artery insertion, and is chosen to take advantage of the visualization of the left upper quadrant provided by laparoscopy compared to the limited visualization through a small laparotomy. The gastrocolic ligament is opened to enter the lesser sac, taking care to preserve the gastroepiploic arcade (Fig. 7.3, arrows). Ligation then proceeds cephalad along the greater curve with ligation of the left gastroepiploic artery and the short gastric arteries. The lesser sac surfaces should be inspected for any evidence of metastases.

Troubleshooting:

- The greater curve should be opened relatively distally to avoid having to mobilize around the splenic flexure through a small midline incision during the open phase of the procedure.

Fig. 7.3 Mobilization of the proximal greater curve with preservation of the gastroepiploic arcade (*arrows*)



- Care should be taken to ensure preservation of the right gastroepiploic arcade at all times, and to minimize any trauma to the stomach/conduit.
- Take note of adhesions in the lesser sac that fuse the omentum to the posterior surface of the gastroepiploic arcade. These adhesions should be divided to elongate the omentum, allowing for visualization of the arcade while minimizing inclusion of omentum with the conduit.

7.4.4 Mobilization of the Gastroesophageal Junction

The left phrenoesophageal membrane is opened to enter the mediastinum and is then extended anteriorly and posteriorly to begin mobilization of the distal esophagus. Once the left lateral aspect of the hiatus has been mobilized, the gastrohepatic ligament is entered and the right phrenoesophageal membrane is entered. The dissection plane is continued anteriorly and posteriorly until the GEJ is circumferentially free of attachments. A penrose is then placed around the GEJ to assist with retraction.

Troubleshooting:

- The GEJ fat pad can be used for retraction until the penrose can be placed.
- In the case of a large GEJ tumor, part of the crus can be divided and included with the GEJ for adequate radial margins.

7.4.5 Mobilization of the Celiac, Hepatic, and Left Gastric Lymph Nodes (for Malignancy)

Laparoscopy provides excellent, magnified visualization of the celiac, hepatic, and left gastric lymph node basins, which are the main basins for GEJ tumors. With the GEJ retracted anteriorly toward the abdominal wall and inferolaterally, the peritoneum is divided at the superior border of the pancreas and opened along the inferior edge of the hepatic artery (Fig. 7.4a). The peritoneum overlying the lymph nodes and the surrounding fat are lifted en bloc from the hepatic artery (Fig. 7.4b). Dissection along the hepatic artery is followed proximally to the celiac trunk and the base of the left gastric artery, which can then be ligated (Fig. 7.4c).

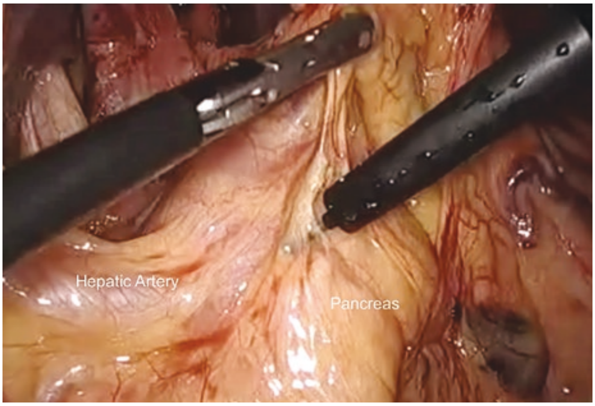


Fig. 7.4a Entering the retroperitoneum

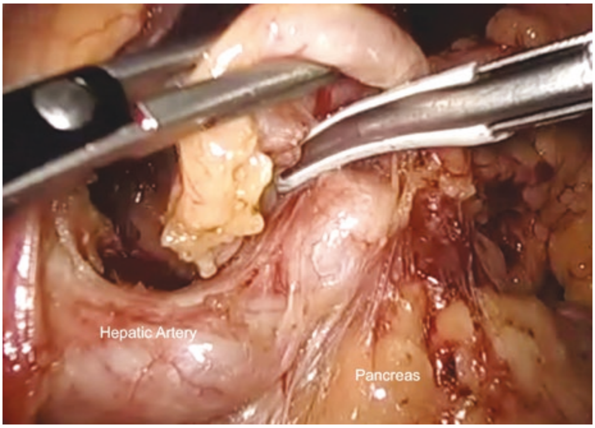


Fig. 7.4b Hepatic lymph node dissection

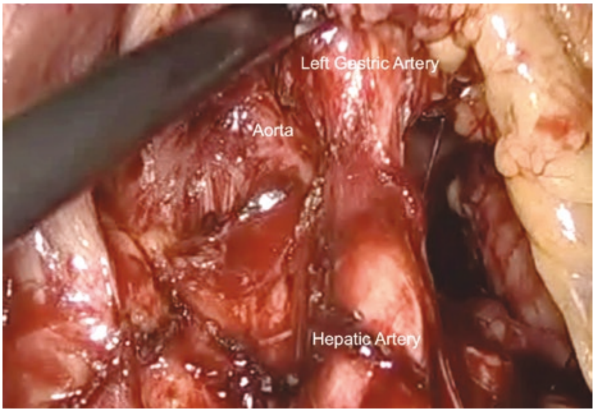


Fig. 7.4c Identification of the base of the left gastric artery

Troubleshooting:

- While we typically use a bipolar vessel-sealing device to ligate the left gastric artery, other options include dividing between clips or using a vascular-load stapler.

7.4.6 Mediastinal Dissection

The esophagus is dissected circumferentially as high as possible, typically to the level of the carina. Using the laparoscopic transhiatal approach, dissection can occur right on the aorta, pericardium, and bilateral pleura to maximize radial margins. Prior to completion of the laparoscopic portion of the procedure, the liver retractor is removed and the left lateral segment of the liver is mobilized.

Troubleshooting:

- Switching to a 0-degree laparoscope can improve visibility in the proximal aspects of the mediastinum.
- If the surgery is being performed for cancer and tumor is noted to invade the pleura, pericardium, or diaphragm (T4a) during the mediastinal dissection, en-bloc resection can be performed. However, the procedure should be aborted if tumor is noted to invade the aorta, vertebral bodies, or trachea (T4b), although this should be apparent on preoperative imaging.

7.4.7 Cervical Dissection

Cervical dissection is performed prior to opening the abdomen in order to keep the patient warm and decrease insensible fluid losses. The patient's legs are repositioned to supine and covered with a lower-body warmer under the drapes, as well as a new half-sheet drape on top to ensure continued sterility of the field. Attention is then turned to the neck. A 4–5 cm oblique incision is made parallel to the left sternocleidomastoid muscle along its medial border (Fig. 7.5). The deep cervical fascia is incised medial to the carotid sheath, which is kept intact, and the middle thyroid vein is ligated. A 34F tapered bougie is inserted into the esophagus and blunt finger dissection is performed to create plane lateral to the thyroid down to the prevertebral fascia posterior to the esophagus, which should be easily palpable with the bougie in place. Once the esophagus has been identified and bluntly mobilized anteriorly, posteriorly, and to the patient's left, the bougie should be backed out so that only the thin part near the tip remains at the level of dissection. The esophagus may then be bluntly mobilized circumferentially, with dissection staying along the esophagus to remain within the avascular plane and avoid injury to the recurrent laryngeal nerve. A penrose drain is placed around the esophagus to assist with retraction. The bougie is advanced as circumferential dissection of the esophagus continues distally along

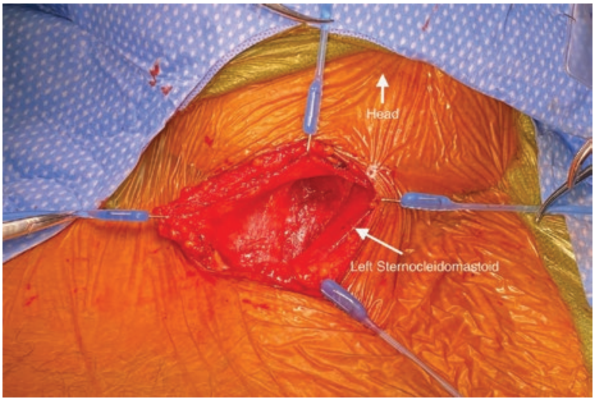


Fig. 7.5 Cervical incision

the avascular plane into the thoracic inlet as inferiorly as possible. Attention is then returned to the abdomen.

Troubleshooting:

- The omohyoid muscle may need to be divided during the cervical dissection, but often it can be preserved in a thin patient positioned with adequate neck extension.
- The recurrent laryngeal nerve should be in its own tissue plane adjacent to the trachea. If this plane is disrupted in an attempt to identify the nerve, there is an increased risk of traction injury to the nerve. Typically, contact with the recurrent laryngeal nerve can be avoided altogether by staying right on the esophagus in the avascular plane throughout the dissection.
- Whereas rigid metal retractors can be relatively bulky, the use of elastic retraction hooks attached to the drape allows for maximal retraction in the small cervical incision.

7.4.8 Kocher Maneuver and Completion of the Gastric Mobilization

A midline incision is made by connecting the epigastric and camera port sites and the abdomen is entered. The duodenum is mobilized with an extensive Kocher maneuver to allow the stomach to easily reach the neck. The distal greater curve is then mobilized taking special care to preserve the right gastroepiploic artery and vein, as well as the right gastric artery. The pulse of the right gastroepiploic artery should be verified by palpation. The key to this is dividing the ubiquitous adhesions in the lesser sac that hold the omentum to itself, especially underneath the gastroepiploic vessels (Fig. 7.6).

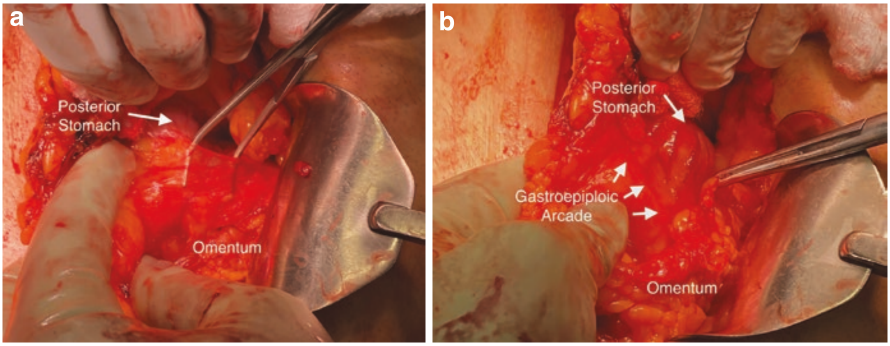


Fig. 7.6 Completion of gastric mobilization. Division of adhesions between the posterior stomach and the omentum (**a**) allow better visualization of the gastroepiploic arcade (**b**), which can then be preserved while minimizing inclusion of excess omental fat on the gastric conduit

Troubleshooting:

- The lesser sac adhesions mentioned above tend to fold the omentum to itself, closing the gastroepiploic vessels like a book. By identifying these adhesions and dividing them, the "book" is opened, and the vessels are more easily identified and preserved without including excess omental fat. These adhesions are rarely mentioned in anatomy books, chapters, or papers, but I am convinced they are key. This subtle recognition protects gastric conduit perfusion, and as a result, we have had no cases of conduit ischemia in 500+ cases.

7.4.9 Completion of the Esophageal Mobilization

The esophagus receives axial tension from an assistant pulling cephalad on the cervical esophageal penrose drain while the surgeon uses their non-dominant hand to pull distally on the esophagus. With the bougie advanced to the distal esophagus, the surgeon places a hand through the hiatus and bluntly dissects along the avascular plane posterior and anterior to the esophagus up until the dissection meets the assistant's fingers placed through the cervical incision above. The danger is lateral, so this is saved for last and gentle finger dissection is performed right along the esophageal wall by trapping the esophagus between the index and middle fingers while "raking" inferiorly to perform the lateral blunt dissection. These adhesions should divide easily, and any resistance should halt the dissection. The bougie is then removed and an 18F nasogastric tube is placed.

Troubleshooting:

- For GEJ cancers, err on the side of staying as close to the esophagus as possible, even if this means causing some esophageal muscle tearing.

7.4.10 Pyloromyotomy

A pyloromyotomy is created by making a longitudinal incision across the anterior pylorus, extending from 2 cm on the anterior stomach to 1 cm on the proximal duodenum. Stay sutures placed superior and inferior to the myotomy site allow for improved countertension during the myotomy and can later be clipped for future radiographic localization (Fig. 7.7).

Troubleshooting:

- If the mucosa is injured during the pyloromyotomy, a pyloroplasty can be performed by closing the pylorus transversely with a series of interrupted, absorbable, full-thickness sutures, followed by 3–0 silk Lembert sutures.

7.4.11 Construction of the Gastric Conduit

An endoscopic stapler with 4–5 mm staples is used to begin construction of the conduit starting at the incisura of the lesser curve. The staplers are fired sequentially and proximally along the lesser curve, always staying at least 5 cm away from the GEJ. This should result in a 5 cm conduit with gradual narrowing more proximally

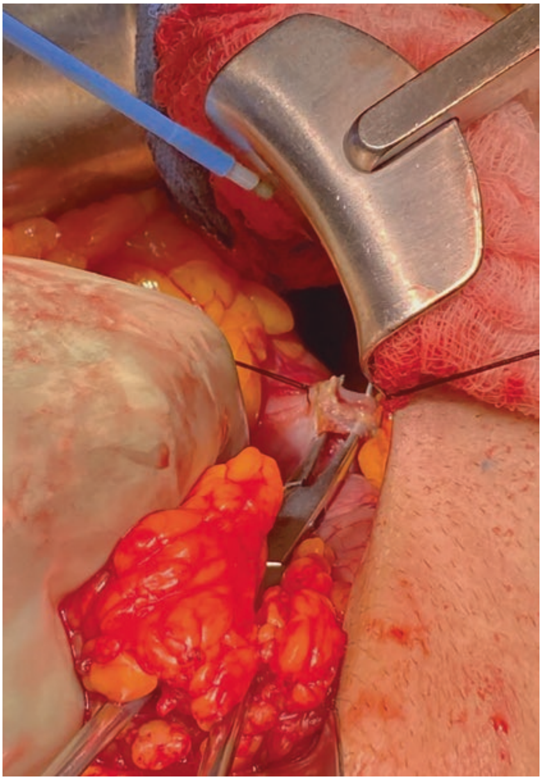


Fig. 7.7 Pyloromyotomy

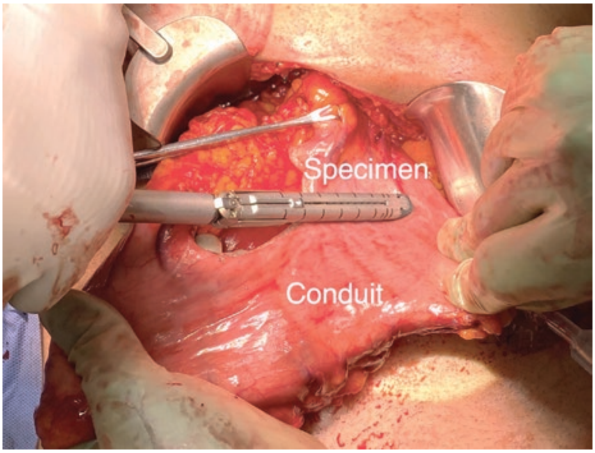


Fig. 7.8 Construction of the gastric conduit

toward the fundus (Fig. 7.8). A stapler load with 3–4 mm staples is used to complete the conduit across the gastric fundus, which is thinner than the antrum and body. The staple line is then oversewn with a series of 3–0 silk Lembert sutures. A full-length penrose drain is stitched between the distal aspect of the specimen and the proximal conduit. The bougie is removed and the esophagus is then pulled out through the cervical incision until the penrose is identified. The conduit is then pushed up through the posterior mediastinum while removing slack out through the neck incision.

Troubleshooting:

- The posterior stomach naturally has greater surface area than the anterior stomach. Any redundant posterior gastric tissue should be excluded by the stapler during conduit construction such that the anterior and posterior surfaces of the conduit remain equal. This is accomplished by pulling on the greater curve while stapling. This technique will also help minimize spiraling of the conduit.
- Adequate length of the conduit is confirmed by bringing it out of the abdomen and laying it across the chest past the cervical incision. Ideally the tip of the conduit will be redundant and can be transected prior to creation of an esophagogastrostomy. If there is insufficient length, check for adequate gastric and duodenal mobilization.
- The conduit should be pushed into the thorax, not pulled. Throughout the maneuver, the orientation of the conduit must be checked and rechecked to avoid any twisting that could compromise the vascular supply to or from the conduit. If there is ever any uncertainty as to the orientation of the conduit, it should be returned to the abdomen and the maneuver should be reattempted from the beginning.
- The left lobe of the liver is typically retracted cephalad for most of the procedure, but the position of the retractor can interfere with passage of the conduit into the thorax. To move the liver and the retractor out of the way, the left lobe can be gently folded under itself (if the triangular ligament is divided) and then retracted toward the right upper quadrant to open up space around the hiatus.

7.4.12 Construction of the Esophagogastrostomy

Once the conduit has been properly positioned and oriented in the thorax, the penrose drain is removed from the tip of the conduit. The conduit tip itself is resected with a stapler (3–4 mm staple height) to ensure there is healthy, well-perfused tissue at the anastomosis. The nasogastric tube is pulled back and the distal esophageal margin is sharply transected. A 3–0 silk traction stitch is placed at the anterior edge of the esophagus to maintain orientation. The esophagus lays anteriorly over the stomach, so that a linear anastomosis can be created with the posterior wall of the esophagus and anterior wall of the conduit. Two stay sutures are placed on each side between the esophagus and gastric conduit, one set at the lateral corners of the open esophagus, and another set near the proximal tip of the conduit (Fig. 7.9a). A 1 cm gastrotomy is made between the two stiches next to the mouth of the esophagus. A 30 mm stapler (3–4 mm staple height) is positioned with the anvil in the conduit and the staple load in the esophagus. The stapler is then left in place while a series of additional 3–0 silk Lembert reinforcing stitches are placed along the entire length of the interface between the esophagus and conduit medially and laterally (Fig. 7.9b). The stapler is then fired to create a side-to-side, functional end-to-end posterior anastomosis between the posterior esophagus and the anterior conduit. The tip of the nasogastric tube is carefully directed through the anastomosis and is advanced distally along the conduit. The open edge of the esophagogastrostomy is closed in layers with a full-thickness, running 3–0 absorbable monofilament suture and an outer layer of 3–0 silk interrupted Lembert sutures. A drain is left near the anastomosis and into the thoracic inlet.

Troubleshooting:

- Any ischemic tissue at the tip of the gastric conduit should be resected and the tip re-inspected for viability before creation of the anastomosis. We routinely resect the tip of the conduit as we always have excess conduit length due to extensive gastric and duodenal mobilization.

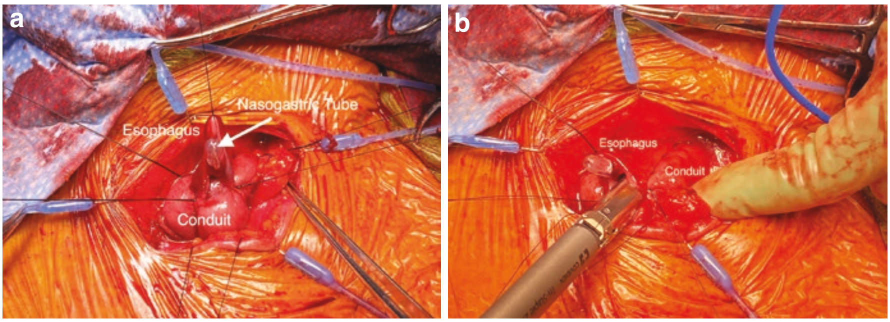


Fig. 7.9 Construction of the esophagogastrostomy. Multiple stay stitches are used to maintain the orientation of the anastomosis, with the gastric conduit positioned posterior to the esophagus (**a**). The staple line is reinforced bilaterally with interrupted Lembert stitches (**b**)

- To minimize anastomotic ischemia, the anastomotic staple line should be positioned several centimeters away from the lesser curve staple line of the gastric conduit, directly between the staple line and the greater curve.
- The reinforcing Lembert stitches across the anastomosis should be placed obliquely on the esophagus so as to not tear through the longitudinal fibers.

7.4.13 Closure of the Hiatus

Excess slack in the conduit is reduced into the abdomen and the gastric conduit is secured bilaterally to each crus, as well as anteriorly to both crura to prevent a postoperative hiatal hernia.

Troubleshooting:

- Caution should be taken to avoid creating undue tension on the anastomosis when reducing the redundancy of the gastric conduit.

7.4.14 Placement of Feeding Jejunostomy Tube

A 3–0 silk pursestring suture is placed followed by an enterotomy on the antimesenteric aspect of the jejunum, 25–30 cm distal to the ligament of Treitz. A 12F silastic feeding tube is introduced through the left abdominal wall and advanced through the enterotomy. Several silk Witzel sutures are placed over the tube, which is then secured to the abdominal wall in four quadrants around the tube entry site. An additional antivolvulus stitch is placed several centimeters distally between the jejunum and the abdominal wall.

Troubleshooting:

- The jejunostomy tube entry site should be at least 20 cm from the ligament of Treitz and the loop of bowel should be able to reach the abdominal wall without tension or bowel angulation.
- We prefer to trim the jejunostomy tube such that there is no more than 30 cm of intraluminal length, as additional length merely serves to increase resistance of anything administered through the tube.
- We use a tube with an intraluminal balloon, but we only place 1 cc of fluid and do not pull it back against the jejunum and abdominal wall. This is to prevent obstruction or bowel wall ischemia.
- Care should be taken to avoid any technical errors that could narrow the lumen, such as placing Witzel sutures too wide or placing tacking sutures too far from the jejunostomy.

7.5 Postoperative Management

The patient is admitted to the floor postoperatively with a thoracic epidural and intravenous acetaminophen for pain control. The nasogastric tube is kept to low intermittent suction and the patient remains strictly nil per os. On postoperative day (POD) 3, we start limited ice chips and jejunal tube feeds. When output from the nasogastric tube is low (usually POD 2–3), the nasogastric tube is removed and patient is started on clear liquids and crushed medications. We do not perform a routine esophagram, but rather selectively order it if there are signs or concerns for an anastomotic leak. All patients get a routine nutrition consultation and are typically discharged by POD 5–6 with a slowly progressive soft diet and 28 days of enoxaparin for prophylaxis against postoperative venous thromboembolism. Patients follow up in clinic within 2 weeks postoperatively.

7.6 Complications

Complications of THE include bleeding, infection, anastomotic leak, conduit necrosis, thoracic duct injury or chyle leak, recurrent laryngeal nerve injury, pleural effusion or pneumothorax, pulmonary embolism, aspiration pneumonitis, and cardiac dysrhythmias.

7.7 Conclusions

A hybrid approach to a THE allows the avoidance of any thoracic incisions while allowing for maximal radial dissection of the lower-to-middle mediastinum and superior visualization during the proximal gastric mobilization and the lymph node dissection. Patients overall do well postoperatively and are typically home within a week of surgery.

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Part II
Bariatric Surgery

Chapter 8
Laparoscopic Roux-en-Y Gastric Bypass

Francisco Schlottmann and Rudolf Buxhoeveden

8.1 Introduction

Overweight and obesity prevalence have risen dramatically over the last decades and currently affect around 30% of the world's population (2.1 billion people) [1]. In the United States (US), obesity is the second most preventable cause of mortality and it is estimated that 36% of US adults and 17% of youth are obese [2]. Unfortunately, these percentages are expected to increase, with linear time trend forecasts indicating that by 2030, 51% of the American population will be obese [3].

8.2 Clinical Presentation

Body mass index (BMI) calculation, which is the ratio between weight (kg) and height squared (m^2), is the most utilized method to diagnose and classify obesity. Obesity is categorized into the following types:

- Obesity class I: BMI 30.0–34.9 kg/m^2
- Obesity class II: BMI 35.0–39.9 kg/m^2
- Obesity class III: BMI $\geq$ 40.0 kg/m^2

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The National Institute of Health states that patients must have a BMI of 35–39.9 with an obesity-related comorbid condition (e.g. type 2 diabetes, hypertension, heart disease, sleep apnea, non-alcoholic fatty liver disease, osteoarthritis, lipid abnormalities, gastrointestinal disorders) or a BMI ≥ 40 with or without a comorbidity to be considered for bariatric surgery [4, 5].

Currently, Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy are the most frequently bariatric operations performed. The laparoscopic RYGB has proven to be a safe and effective weight-loss procedure, with successful long-term outcomes in morbidly obese patients [6, 7]. A careful patient selection, a comprehensive preoperative work-up, and a properly executed operation are key for the success of the operation.

8.3 Preoperative Work-up

Patient education: Key during the preoperative phase. Most patients hold unrealistic expectations, without a complete understanding of the operation and the subsequent long-term implications. Postoperative lifestyle modifications, psychosocial consequences, and need for long-term follow up should be thoroughly discussed with the patients.

Medical Evaluation and Clearance: A complete medical evaluation should include a detailed history taking, a thorough physical examination, and a review of the cardiovascular, pulmonary and gastro-intestinal systems. The metabolic and nutritional status should also be assessed.

Psychological evaluation and Clearance: A comprehensive psychological evaluation is recommended in order to identify risk factors that may affect surgical outcomes and weight loss goals.

Abdominal ultrasound: Particularly important to investigate biliary tract pathology considering that obese patients have a high incidence of cholelithiasis. In addition, rapid weight loss after RYGB further increases the risk of gallstones formation. This study is also useful for assessing steatosis, fibrosis, and the presence of nonalcoholic steatohepatitis (NASH).

Upper endoscopy: Although the routine use of this study in the preoperative evaluation of RYGB candidates is controversial, we believe that all patients should undergo a preoperative upper endoscopy because obesity represents a risk factor for several gastrointestinal diseases (e.g. gastroesophageal reflux, Barrett´s esophagus) that can be detected in this study. In addition, as the remnant stomach will no longer be accessible to endoscopic surveillance, ruling out malignancy of the stomach is critical.

8.4 Surgical Technique

8.4.1 Position of the Patient and Surgical Team

After induction of general endotracheal anesthesia, the patient is positioned supine in low lithotomy position with the lower extremities extended on stirrups with pneumatic compression stockings, and knees flexed 20°–30°. Both arms are left abducted and secured on a board with adequate padding. The surgeon stands on the patient's right side, and the 1st and 2nd assistant on the patient's left side and between the legs, respectively.

Troubleshooting: Obesity, increased abdominal pressure secondary to the pneumoperitoneum, and steep Trendelenburg position required during the procedure are all risk factors for deep vein thrombosis and venous thromboembolism. Pneumatic compression stockings and subcutaneous heparin are strongly recommended to prevent these complications.

8.4.2 Pneumoperitoneum and Trocar Placement

The Veress needle is placed at Palmer's point (3 cm below the left costal margin in the mid-clavicular line) and pneumoperitoneum is established at 12 mmHg. Six ports are used for the procedure. A 12 mm optical port is inserted 10–12 cm below the xiphoid process and about 2 cm to the left of midline. The remaining five ports are then placed as shown in Fig. 8.1.

Troubleshooting: Bladeless trocars are strongly recommended to reduce the risk of port-site incisional hernias and bleeding.

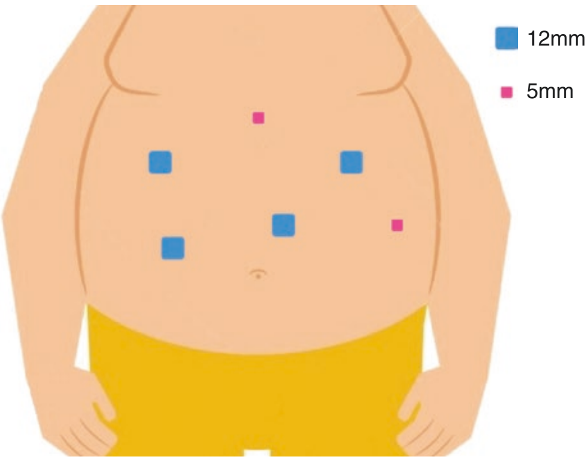

Fig. 8.1 Ports placement for laparoscopic Roux-en-Y gastric bypass

8.4.3 Creation of the Gastric Pouch

Initially, the fat pad located over the gastroesophageal junction is removed with the harmonic scalpel. The angle of His is exposed and dissected up to the base of the left crus. The gastrohepatic ligament is then incised between the 2nd and 3rd branch of the left gastric artery and the lesser sac is entered. The gastric section is started horizontally using 40–50 mm of a 60 mm blue load linear stapler (Fig. 8.2). A 36-Fr gastric lavage tube is advanced by the anesthesiologist towards the horizontal staple line, and the gastric section is completed with additional firings of 60 mm blue loads in a vertical direction towards the previously dissected angle of His (Fig. 8.3). The pouch should have a length of approximately 6 cm. The gastric remnant staple line is reinforced with an absorbable running suture (e.g. polyglactin 2.0) to prevent bleeding.

Troubleshooting: Verifying the complete transection of the stomach is critical to prevent future communication (i.e. fistula) between the gastric pouch and gastric remnant.

8.4.4 Creation of the Biliopancreatic and Alimentary Limbs

The greater omentum and the transverse colon are retracted cephalad in order to expose the ligament of Treitz and the inferior mesenteric vein. The jejunum is divided 60 cm (patients with BMI < 50 kg/m^2) or 100 cm (patients with

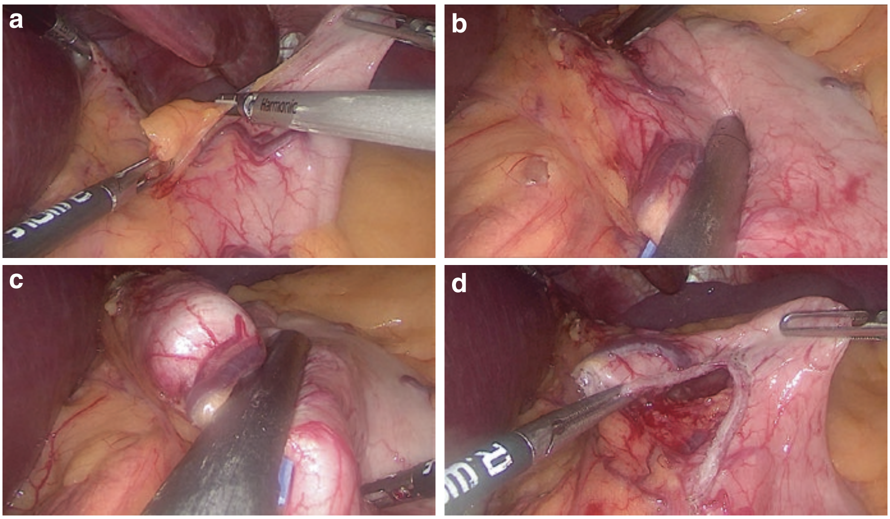

Fig. 8.2 Horizontal gastric section (A = Removal of the fat pad located over the gastroesophageal junction; B, C, D = Horizontal gastric section with linear stapler)

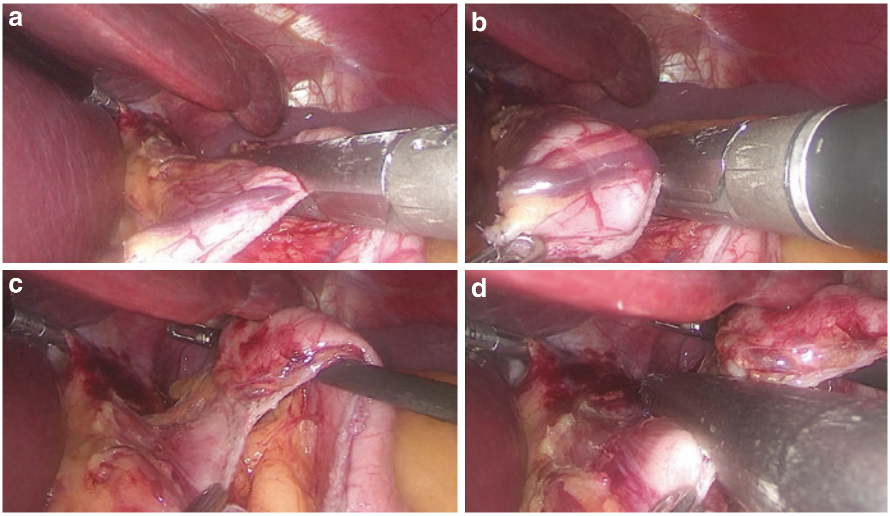

Fig. 8.3 Creation of gastric pouch (A, B, C, D = Vertical gastric section with sequential firings of 60 mm blue loads)

BMI > 50 kg/m^2) distal to the ligament of Treitz using a white load linear stapler. The biliopancreatic limb is marked with a metallic clip to avoid suturing the incorrect limb to the pouch. The alimentary limb is then raised with the stapler line orientated towards the left upper quadrant in an antecolic-antegastric manner.

Troubleshooting: The greater omentum is often thick and bulky and needs to be divided vertically using the harmonic scalpel to facilitate bringing the Roux limb up to the gastric pouch. A tension-free alimentary limb is critical to prevent anastomotic leaks. Rarely, the division of the omentum is insufficient to release tension, and thereby the Roux limb needs to be placed in the retrocolic-retrogastric position.

8.4.5 Gastrojejunostomy

The gastric pouch is opened just under the staple line with harmonic scalpel. An enterotomy is then performed also with harmonic scalpel on the anti-mesenteric border of the alimentary limb about 5 cm away from the stapled end. A side-to-side gastrojejunostomy is created with a blue load linear stapler. No more than 3 cm of the stapler should be used in order to create a small anastomosis (Fig. 8.4).The 36-Fr tube is passed through the anastomosis by the anesthesiologist and the anterior wall of the anastomosis is then closed with two layers of running suture using absorbable material (e.g. polyglactin 2.0) (Fig. 8.5).

Troubleshooting: The 36-Fr tube is key to both calibrate the anastomosis and avoid suturing the posterior wall inadvertently. A methylene blue test is recommended to rule out anastomotic leaks.

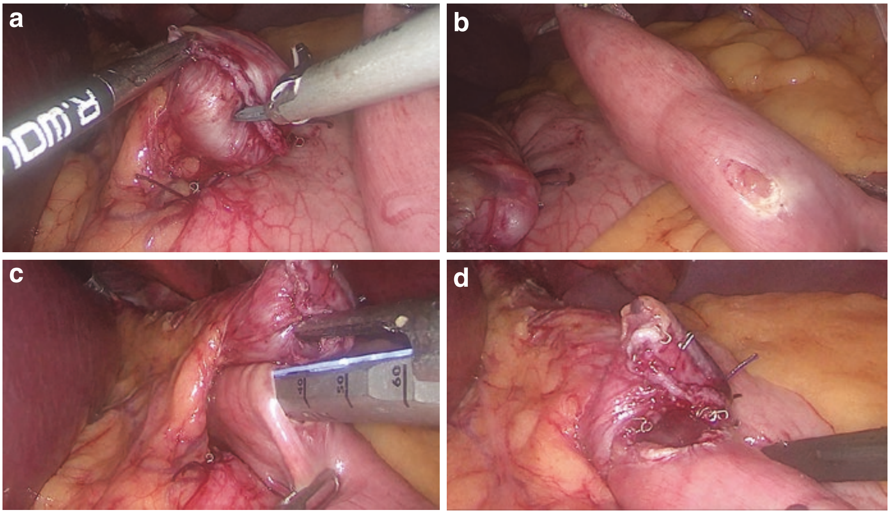

Fig. 8.4 Initial steps of the gastrojejunostomy (A = The gastric pouch is opened just under the staple line; B = The alimentary limb is opened approximately 5 cm away from the stapled end; C = Side-to-side gastrojejunostomy; D = A 36-Fr tube is passed through the anastomosis by the anesthesiologist)

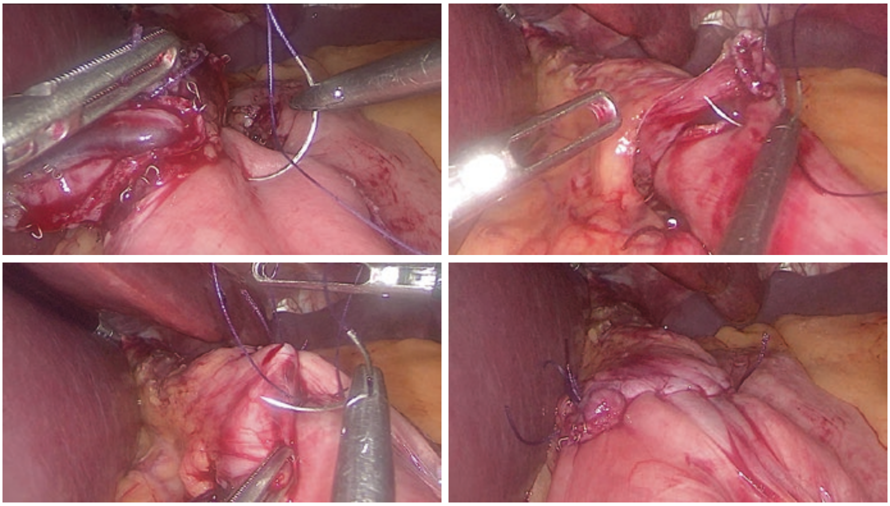

Fig. 8.5 Final steps of the gastrojejunostomy

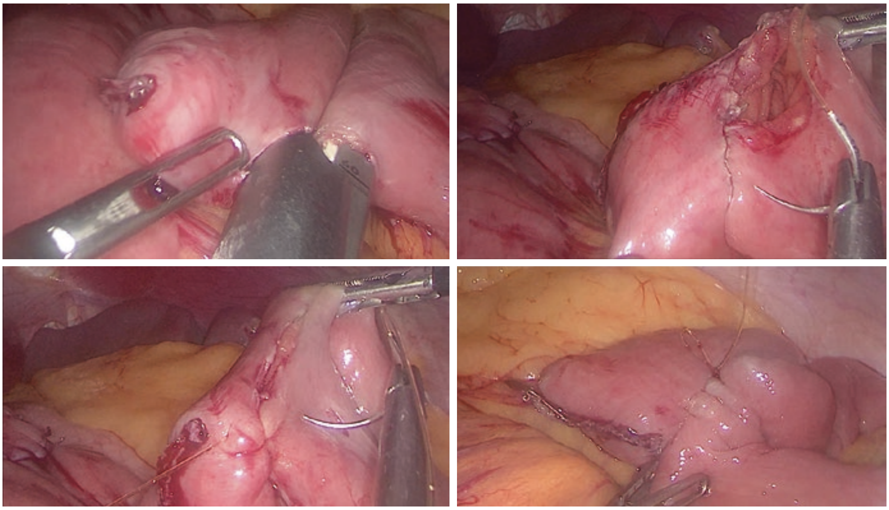

Fig. 8.6 Side-to-side jejunojejunostomy

8.4.6 Jejuno-jejunostomy

A 120 cm (BMI < 50 kg/m^2) or 150 cm (BMI > 50 kg/m^2) Roux limb is measured to determine the site of the jejuno-jejunostomy. The site chosen for the anastomosis is placed next to the proximal jejunum with the stapled end of the biliopancreatic limb oriented towards the patient's right side and cephalad to the distal Roux limb. Enterotomies are performed using the harmonic scalpel at the anti-mesenteric border of both limbs. A side-to-side jejuno-jejunostomy is created using the full length of a white 60 mm linear stapler (Fig. 8.6). The enterotomy is then closed in one layer by running an absorbable suture (e.g. polyglactin 3.0).

Troubleshooting: The mesentery of both limbs should be properly aligned without twists when performing this anastomosis. Self-locking barbed sutures are very useful for the jejuno-jejunostomy.

8.4.7 Closure of Mesenteric and Petersen Defect

The mesenteric defect is closed towards the root of the mesentery by running a non-absorbable material (e.g. polyester 2.0) (Fig. 8.7). The Petersen's space, limited posteriorly by the transverse colon and anteriorly by the alimentary limb, is also closed with non-absorbable suture material.

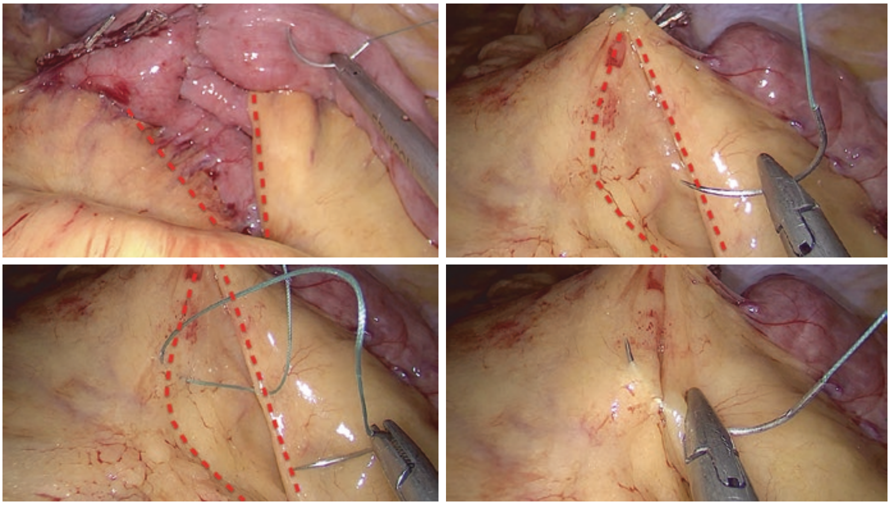

Fig. 8.7 Closure of the mesenteric defect

Troubleshooting: Internal hernias are a cause of reoperation after a laparoscopic RYGB. The closure of both the mesenteric and Petersen defects are key to prevent these complications.

8.5 Final Inspection

After adequate hemostasis is achieved, instruments and trocars are removed from the abdomen under direct vision. We do not routinely place any abdominal drain [8].

8.6 Postoperative Care

Patients are extubated immediately after completion of the procedure. Patients are fed the morning after the operation with clear liquids and usually discharged after 24–48 hours, with instructions to continue with full liquid diet for the following two weeks. The time to full recovery ranges between two and three weeks.Conflict of InterestThe authors have no conflict of interest to declare.

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Chapter 9
Laparoscopic Sleeve Gastrectomy

Ivy N. Haskins and Timothy M. Farrell

9.1 Introduction

Obesity is endemic in the United States [1]. As of 2016, 39.8% of all adults in the United States were considered obese [2]. Currently, the only long-term durable treatment for obesity is bariatric surgery [1, 3]. In 1999, the vertical sleeve gastrectomy (SG) was performed as the first part of the bilio-pancreatic diversion (BPD) and duodenal switch (DS) [4]. Interestingly, many patients who underwent SG as a staged procedure were noted to have lost enough weight that the BPD-DS did not need to be performed [4]. Therefore, by 2000, SG was being performed as a stand-alone bariatric procedure [1]. Since that time, the laparoscopic SG has gained popularity over the Roux-en-Y gastric bypass (RYGB) due to its technical ease, lower associated morbidity and mortality rates, and effective co-morbidity resolution [1, 5, 6]. Currently, the laparoscopic SG is the most commonly performed bariatric operation in the United States [1, 4]. Herein, we detail our approach to patient selection for laparoscopic SG, the important technical steps of the laparoscopic SG, as well as the postoperative care and long-term follow-up of patients who have undergone a laparoscopic SG.

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9.2 Clinical Presentation

In 1991, the National Institutes of Health (NIH) published consensus guidelines for gastrointestinal surgery for severe obesity. These guidelines stated that adult patients who were believed to have a low probability of weight loss success with nonsurgical interventions with a body mass index (BMI) >40 kg/m^2 or those with a BMI ≥ 35 kg/m^2 with at least one obesity-associated comorbidity, such as obstructive sleep apnea, Pickwickian syndrome, type 2 diabetes mellitus (DM), or osteoarthritis, could be considered for bariatric surgery [7]. Since these initial patient guidelines were published, bariatric surgery has been expanded to include teenage patients who meet similar criteria [8]. Nevertheless, for the purposes of this chapter, we will discuss adult bariatric surgery patients only.

9.3 Preoperative Evaluation and Patient Selection

There are both institutional requirements and patient selection criteria for bariatric surgery. With respect to institution requirements, it is important to understand the history of bariatric surgery. Prior to the development of designated bariatric accredited centers, the mortality rate following bariatric surgery was reported to be as high as 9% [9]. In response to this unacceptably high rate of mortality, designated bariatric accredited centers were proposed [9–11]. This recommendation was proposed by both the American College of Surgeons and the American Society for Metabolic and Bariatric Surgery [11]. In order for an institution to be designated as an accredited bariatric center, there is a minimum number of stapled bariatric cases required that must be performed per year as well as requirements for navigating patients through the bariatric surgery process, including a bariatric surgery medical director as well as specialized nursing staff and bariatric equipment. Currently, close to 90% of all bariatric procedures in the United States are performed at bariatric accredited centers, which includes a robust review process of all morbidities and mortalities experienced by bariatric surgery patients with an emphasis on improving the quality of care delivered to bariatric surgery patients at these accredited centers [12].

Once clinical indications and institutional criteria for bariatric surgery have been met, it is important that bariatric providers follow a multidisciplinary approach, including medical, psychological and dietary counseling prior to considering surgery. When patients are deemed to be surgical candidates, a personalized approach is important when considering what type of bariatric operation to recommend. Ultimately, the type of bariatric procedure (RYGB versus SG) that a patient undergoes is based on a combination of both personal preferences and patient-specific factors. We believe that the long-term success of any bariatric surgery is based on a comprehensive and personalized informed consent process.

First and foremost, it is important to remember that SG is a restrictive procedure only, while the RYGB is both a restrictive and malabsorptive procedure [4].

Therefore, in patients with a BMI > 40 kg/m^2 without the specific comorbidities that we will discuss below who need assistance with portion control only, a laparoscopic SG is a reasonable procedure to offer to a bariatric patient. The determination of RYGB versus SG becomes more complicated as a patient's BMI increases, in patients who have had extensive previous abdominal surgery, and in those patients with specific medical comorbidities. For patients with very high BMIs (≥60 kg/m^2) and/or for patients with extensive previous abdominal surgery, one must consider the ability of the mesentery of the small intestine to reach the gastric pouch without undue tension or disruption of the blood supply to the alimentary limb [13]. For women of child-bearing age who wish to become pregnant following bariatric surgery, we often recommend SG rather than RYGB due to an increased risk of vitamin and nutrient deficiencies following RYGB [14]. Furthermore, while not common, the diagnosis of acute, post-bariatric surgery pathology, such as marginal ulcer perforation or internal hernia formation, can be challenging in the pregnant patient. Finally, patients with either gastroesophageal reflux (GERD) or type-2 DM warrant special consideration when determining the most appropriate bariatric procedure. For patients with already established GERD, the creation of a gastric sleeve can worsen GERD symptoms and lead to esophagitis [15]. We perform preoperative upper endoscopy to screen patients for esophagitis. Furthermore, while bariatric surgery in general has been associated with better glycemic control versus intensive medical therapy for type-2 DM, RYGB has been shown to have higher rates of type-2 DM remission over the long-term [16]. For these reasons, we strongly encourage patients with either GERD or type 2-DM to undergo RYGB and for patients with significant GERD-related pathology, including Barrett's esophagus or severe esophagitis, we do not offer sleeve gastrectomy as a bariatric surgery option.

9.4 Surgical Technique

This section will highlight the key steps for performing laparoscopic SG, as performed at our institution. We recognize that there may be variation in the technical aspects of this procedure and we recommend that variations to the steps below be adopted by surgeons as needed in an effort to maximize both patient safety and surgeon comfort.

1. Routine preoperative interventions are performed, including the administration of preoperative antibiotics and deep venous thrombosis prophylaxis as recommended by the Surgical Care Improvement Project (SCIP) guidelines.
2. Patients are placed supine on the operating room table and both arms are left comfortably abducted.
3. General anesthesia is induced after which we request that an orogastric tube be placed to decompress the stomach prior to gaining access to the abdominal cavity. We also perform selective Foley catheterization.

4. Access to the abdominal cavity is obtained using a Veress needle technique, usually in the left upper quadrant. It is important to pay attention to the opening pressure when insufflation is begun. If the opening pressure is >12 mm of Mercury (mm Hg) it is important to consider that either the patient is not fully relaxed or the Veress needle is either preperitoneal or has penetrated an intra-abdominal structure. If intraabdominal pressures remain high after troubleshooting these potential causes, an alternative approach to intra-abdominal access, such as with the use of an optical trocar or open, Hasson technique should be employed.
5. We place five trocars: one 15-mm trocar 20 cm from the xiphoid process along the mid-abdominal line near the umbilicus, one 12-mm trocar in the left mid-clavicular line along the rectus muscle approximately 5 cm above the periumbilical/mid-abdominal trocar, one 5-mm port in the left subcostal location along the anterior axillary line, one 5-mm port in the right subcostal location along the rectus muscle just medial to the anterior axillary line, and one 5-mm port just lateral to the falciform ligament (Fig. 9.1).
6. The patient is placed in a reverse Trendelenburg position to allow the small intestine and transverse colon to fall away from the stomach. A liver retractor is positioned through the right lateral port and beneath the left lobe of the liver.
7. The lesser sac is opened and the omental attachments to the greater curvature of the stomach are taken down with the use of an energy device (Fig. 9.2). We begin this dissection at least four centimeters proximal to the pylorus in order

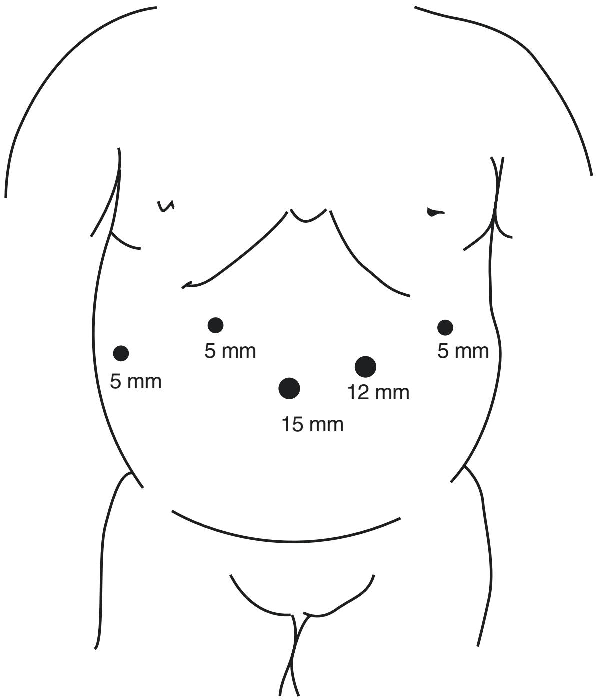

Fig. 9.1 Location and sizes of port used. The right lateral port is used for placement of an articulating liver retractor. The left lateral port is used by the first assistant. The right and left mid-clavicular ports are working ports. The periumbilical port is used for both the camera and as a working port

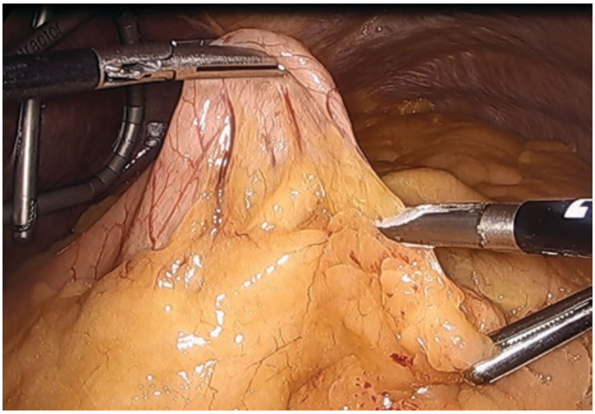

Fig. 9.2 We use the LigaSure™ Device to gain access to the lesser sac and to take down the omental adhesions to the greater curvature of the stomach. This dissection should begin at least four centimeters proximal to the pylorus of the stomach and extend to the angle of His. In this picture, the operating surgeon has placed upward and cranial retraction on the stomach while the assistant has placed downward and caudal retraction on the greater omentum to aid in access to the lesser sac

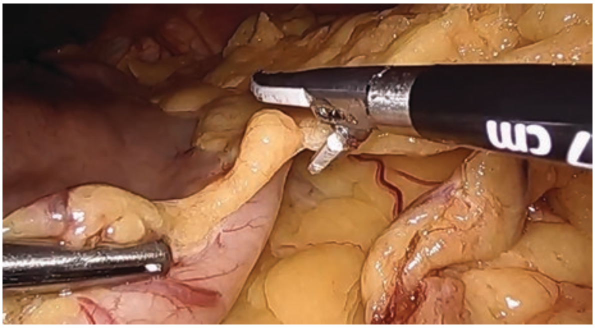

Fig. 9.3 Access to the lesser sac has been achieved. With the use of an energy device, the omentum is completely dissected off of the greater curvature of the stomach, starting near the pylorus and working cephalad towards the hiatus

to minimize the risk of dehydration postoperatively [1]. This dissection along the greater curvature of the stomach is carried proximally to the angle of His (Figs. 9.3 and 9.4). If the patient has a thick omentum that is difficult to retract with just one assistant port, and additional port can be placed in the left upper quadrant to help facilitate better retraction of omentum.

8. Once the greater curvature of the stomach is mobilized, the orogastric tube is withdrawn from the stomach. Once the orogastric tube is withdrawn from the stomach, we confirm with the Anesthesiology team that there are no other foreign objects remaining in the stomach prior to beginning creation of the gastric sleeve.
9. The beginning of the gastric sleeve is started at least four centimeters proximal to the pylorus. We use the end of our atraumatic bowel grasper (2.5 cm when open) to help measure this length (Fig. 9.5).

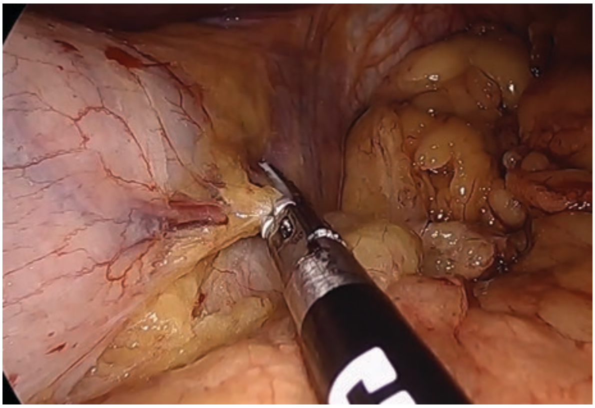

Fig. 9.4 The most cephalad extent of the dissection along the curvature, which releases the hiatal attachments to the angle of His

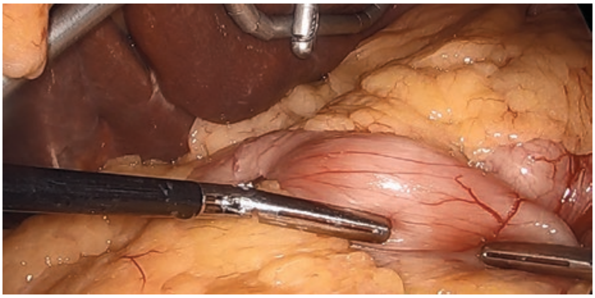

Fig. 9.5 The end of the atraumatic bowel grasper measures 2.5 cm when wide open. This instrument is used to measure the distance from the pylorus and to identify the site at which to begin the sleeve gastrectomy

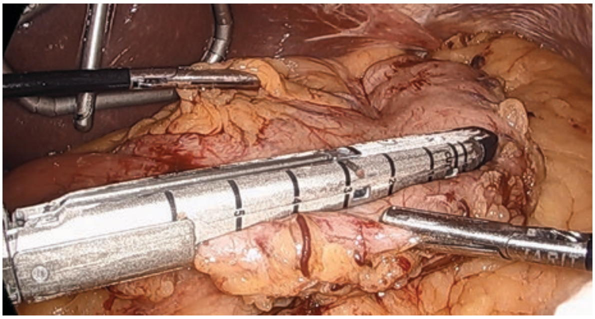

Fig. 9.6 The beginning of the sleeve gastrectomy is started with a thicker (5–6 mm) stapler load. The stapler is articulated as far to the right as possible to minimize encroachment of the incisura angularis

10. We use a thicker stapler load (5 to 6-mm height) to begin the gastric sleeve. In order to prevent postoperative narrowing of the gastric sleeve, this stapler load is articulated as far to the right as possible so that the stapler is oriented parallel to the lesser curvature to minimize the risk of encroachment of the incisura angularis (Fig. 9.6).
11. A blunt-tipped Bougie is introduced by the Anesthesiology team through the mouth, down the esophagus, and into the stomach. The Bougie is guided by the surgical team to lay along the lesser curvature of the stomach (Fig. 9.7). If difficult is encountered during Bougie placement, a lighted Bougie or endoscope,

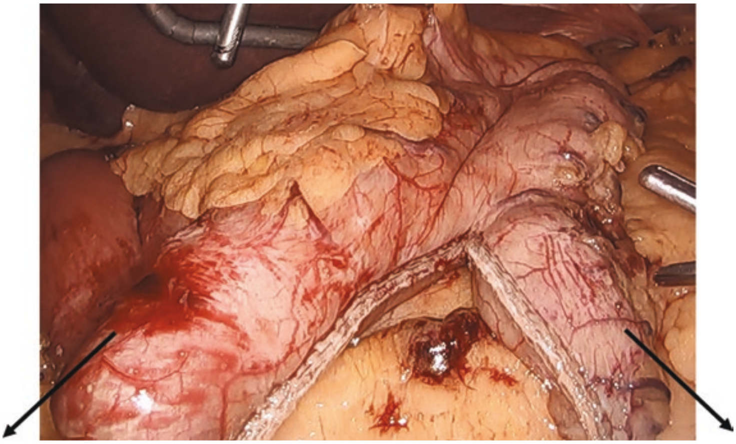

Fig. 9.7 In coordination with the Anesthesiology team, a blunt-tipped Bougie is placed through the mouth, down the esophagus, and into the stomach. The bougie should lay along the lesser curvature of the stomach with the distal aspect near the pylorus and adjacent to the beginning of the gastric sleeve staple line

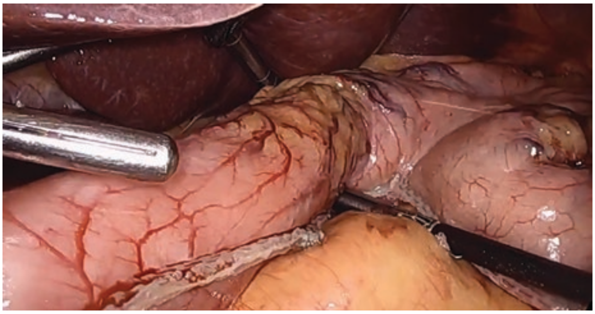

Fig. 9.8 This picture displays a partially created gastric sleeve. The right bowel grasper is pushing on the lateral aspect of the gastric sleeve to identify the Bougie to determine the location of the part of the staple line

depending on a particular institution's resources, can be used instead. We typically use a 40-French (Fr) bougie. The size of the Bougie varies somewhat across institutions but typically ranges from 32 to 50 Fr [1].

12. Using the Bougie (or endoscope) as a guide, creation of the gastric sleeve is continued proximal towards the angle of His using 4–5 mm stapler loads. The stapler firings after Bougie (or endoscope) placement are typically slightly angled to the left. The stapler should be close enough to the Bougie (or endoscope) to create a small sleeve but should not be too close as to risk stapler misfiring or tension on the staple line.
13. We complete the sleeve gastrectomy approximately 2 cm lateral to the esophagogastric junction, using the gastroesophageal fat pad as a landmark (Figs. 9.8 and 9.9). If bleeding is encountered at any point during staple firing, first we

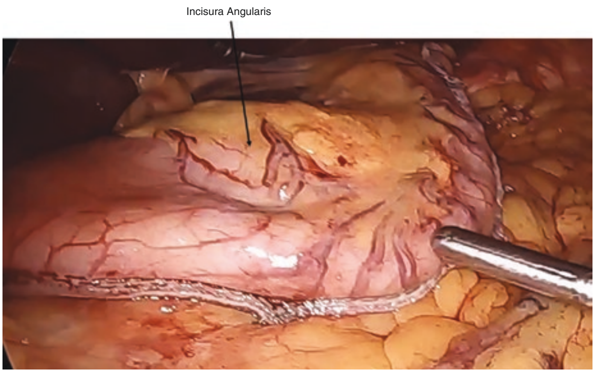

Fig. 9.9 A completed gastric sleeve, with adequate distance between the incisura angularis and the gastric sleeve staple line

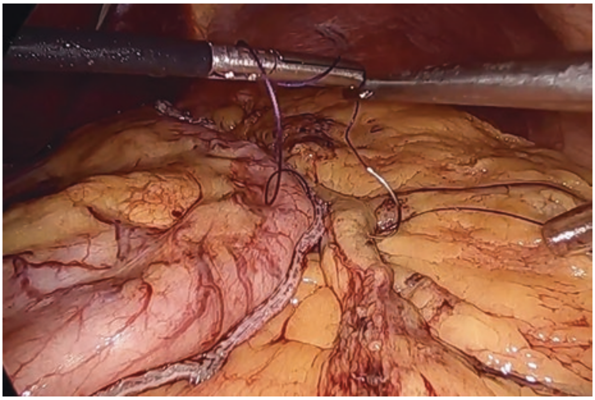

Fig. 9.10 Anchoring of the greater omentum to the gastric sleeve. This helps to prevent twisting or kinking of the gastric sleeve and improves postoperative staple line hemostasis

ensure that the stapler did in fact staple. Next, we ask our Anesthesiology colleagues to lower the patient's blood pressure if it is safe to do so while we hold pressure with an atraumatic grasper at the site of bleeding. If there is brisk bleeding or bleeding persists despite these interventions, we have a low threshold for oversewing the site of the bleeding.

14. The excluded stomach is removed through the 15 mm trocar site. We typically do not use a specimen retrieval bag to remove the excluded stomach.
15. Under laparoscopic visualization, the Bougie is removed from the gastric sleeve by the Anesthesiology team.
16. In order to assist with staple line hemostasis, we anchor the greater omentum to the gastric sleeve using Vicryl suture (Figs. 9.10 and 9.11) [17]. It has been our experience that this intervention also helps to minimize angulation or twisting of the sleeve in the early postoperative period.

9.5 Postoperative Management and Long-Term Follow-Up

Postoperatively, most patients can be safely transitioned to a surgical floor without continuous monitoring. It is important that patients are either transferred to a bariatric specific surgical floor or that they are taken care of by a nurse who has received

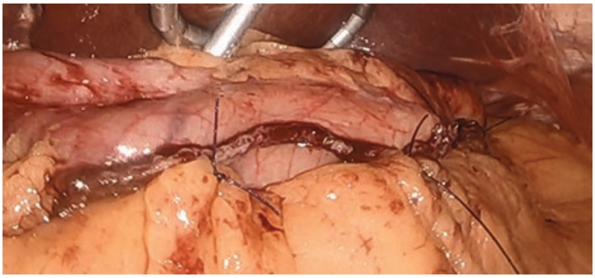

Fig. 9.11 Gastric sleeve staple line reinforcement. This is achieved by placing several interrupted stitches using absorbable sutures from the greater omentum to the lateral aspect of the gastric sleeve

specialty training in caring for postoperative bariatric patients. Our standard postoperative management of bariatric patients is consistent with published recommendations by Telem et al. [18] and includes:

1. Postoperative Diet. Patients are initially made nil per os (NPO). If patients appear well in the afternoon of their surgery day, they are advanced to phase one of our bariatric diet, which includes one ounce per hour of clear, non-carbonated liquids. Prior to discharge from the hospital, patients must be tolerating phase three of our bariatric diet, which includes three ounces per hour of full, non-carbonated liquids and protein shakes. We recommend that all patients drink 60–80 ounces of fluid in addition to a protein intake of at least 60 g in a 24-h period. Once discharged from the hospital, a patient's diet is slowly advanced over the course of the next several weeks, first to a pureed diet then to a soft diet and finally a regular consistency diet of small, frequent meals and snacks by 4–6 weeks postoperatively.
2. Management of Home Medications. All diuretic medication and long-acting insulins are held while patients are in the hospital. There have been few occurrences where a patient has had persistently elevated blood pressure or blood sugar postoperatively. In these instances, we have a low threshold to consult our Internal Medicine or Endocrinology colleagues for further assistance. We instruct patients that they should check their blood pressure and/or blood sugar at least daily after discharge and that they should schedule an appointment with their primary care physician within 2 weeks of their bariatric operation for further management of their home medication regimen.
3. Use of Non-Invasive Ventilation. Patients with obstructive sleep apnea who undergo bariatric surgery should continue to use their continuous positive airway pressure (CPAP) or bilevel positive airway pressure (BiPAP) machines postoperatively. We encourage patients to have their machine re-fitted prior to surgery and for them to bring their own machine for use postoperatively [19].
4. Postoperative Pain Management. We encourage a multi-modal pain regimen with the minimization of narcotic pain medication, as possible.
5. Postoperative Venous Thromboembolism (VTE) Prophylaxis. While in the hospital, all patients are either administered subcutaneous Heparin 7500 units three times daily or subcutaneous enoxaparin 40 mg daily. We use the risk calculator developed by Aminian et al. to identify those patients who would benefit from

extended VTE prophylaxis [20]. For patients who are identified as having a high-risk for developing postoperative VTE, they are instructed to self-administer enoxaparin 40 mg daily for 4 weeks postoperatively. Of note, there is currently no consensus as to the type or duration of extended VTE prophylaxis, and these practices may be different by institution [21, 22]. Patients are provided with home enoxaparin teaching prior to discharge from the hospital.

6. Postoperative Protein, Vitamin, and Mineral Supplements. Patients are instructed to begin bariatric protein supplements immediately postoperatively with the addition of a bariatric vitamin/mineral supplement by the first postoperative visit.
7. Postoperative Follow-Up. All patients are evaluated by their bariatric surgeon within the first 7–10 days postoperatively. Thereafter, patients are seen in the bariatric surgery clinic by a certified bariatric surgery nurse practitioner and dietician. Patients are seen in the bariatric surgery clinic at 1, 3, 6 months, and 1 year postoperatively and then annually thereafter. Bariatric vitamin and mineral panels are checked at each of these visits and vitamin and mineral supplementation is tailored, as appropriate.
8. Reporting of Postoperative Outcomes. Weight loss outcomes and improvement and resolution of cardiometabolic comorbidities are documented based on the standard definitions proposed by Brethauer et al. [23]

9.6 Conclusions

The long-term success of any bariatric procedure depends on appropriate patient selection, a thorough informed consent process, and sound surgical technique. It is our intention that this chapter serves as a guide to the perioperative management of patients undergoing laparoscopic SG. While we recognize that there will be some variation in surgical technique, the key steps described in this article are essential to producing long-term and durable outcomes following laparoscopic SG.

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Chapter 10
Robotic/Laparoscopic Duodenal Switch

Andres Narvaez, Neil Sudan, and Ranjan Sudan

10.1 Introduction

Bariatric surgery has been practiced for over six decades to treat obesity effectively [1]. However, the rates of obesity in the United States (US) have never been higher than they are today with a projected estimate of nearly one of every two adults having obesity and progressing to severe obesity by 2030 [2]. These predictions suggest that more aggressive surgical approaches may be indicated to treat severe obesity.

During the late 70s, Nicola Scopirano introduced the Biliopancreatic Diversion (BPD) for the first time as an alternative to the Jujenoileal Bypass (JIB) with the purpose of generating selective fat malabsorption for weight loss [3]. Later, in the 1980's Tom DeMeester described for the first time the stand-alone Duodenal Switch procedure for pathologic duodenogastric reflux, by preserving the pylorus to prevent marginal ulceration [4]. In the late 80's Douglas Hess modified the Scopirano's BPD combining it with the DeMeester's procedure making this new hybrid procedure known as the Biliopancreatic Diversion with Duodenal Switch (BPD-DS) which decreased the complications associated with the BPD [5]. In the year 2000, Ren et al. [6] described for the first time a BPD-DS using a laparoscopic approach while Sudan et al. [7] performed the first robotic BPD-DS the same year.

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Nowadays, Hess's hybrid procedure is commonly known by surgeons as the Duodenal Switch (DS). Even though is still the least common primary bariatric procedure performed in the US, it is usually indicated for patients with higher BMIs (>50 kg/m^2) and uncontrolled comorbidities, most notably diabetes type II. Robotic DS has shown to be a feasible technique with low technical complications rates and with reduced operative times [8].

10.2 Clinical Presentation

The DS can be offered to patients meeting the criteria for any bariatric operation which include a Body Mass Index (BMI) ≥35 kg/m^2 or more with a significant comorbid condition or a BMI >40 kg/m^2. However, in practice, DS is more commonly offered to patients with a BMI ≥50 kg/m^2, in which a more extensive weight loss is needed, and for diabetes of severe control or hypercholesterolemia [9].

10.3 Pre-Operatory Evaluation

Patients considered for DS must undergo a series of preoperative multidisciplinary metabolic, nutritional, and psychological evaluations with the focus on understanding the malabsorptive nature of the procedure and likelihood of compliance with instructions. Nutritional and clinical follow-up with measurements of vitamin levels is extremely important to prevent deficiency states and optimizing with us results. Preoperative Nutritional deficiencies must be addressed and corrected before the surgery, as it can be harder to do so later. A liver shrinking diet may be recommended for up to 2 weeks prior to surgery to improve visualization of the operative field when performing the sleeve gastrectomy or the duodenal-ileal (DI) anastomosis [10]. We follow current guidelines of Enhanced Recovery After Surgery (ERAS) for every patient. Preoperative weight loss, smoking and alcohol cessation, withholding of glucocorticoids and nonsteroidal anti-inflammatory drugs, a preoperative liquid diet with carbohydrate loading beverage the morning of the surgery are employed as part of this process [11].

10.4 Technique

10.4.1 Position of the Patient

Patients are routinely administered peri-operative antibiotics and deep venous thrombosis (DVT) prophylaxis using sequential compression devices as well as low molecular weight heparin. The patient is positioned supine with outstretched arms, ensuring all pressure points are suitably padded and protected, and there is no stretch on the brachial plexus or the wrists. After induction of general anesthesia, the patient is intubated and a urinary bladder catheter is placed, under sterile conditions. The surgical field is prepped and draped exposing the upper abdomen from the umbilicus to the xiphoid and the right anterior axillary line to the left. Typically, the barrier between the surgical field and the anesthesiologist is lowered to allow the surgeon to stand above the patient's shoulders and be ergonomically more comfortable when operating in the lower abdomen.

10.4.2 Trocar Placement

Our preference is to use the robot for ease of suturing and dissection and we will primarily describe that technique here. However, the same port system is used to perform a laparoscopic duodenal switch. In addition, this chapter describes how to perform a conventional duodenal switch with a Roux en Y configuration but the operation can easily be adapted for the single anastomosis version. All port sites are pre-injected with long-acting local anesthetic (lipoidal bupivacaine with a mixture of plain bupivacaine) to decrease the need for narcotic medication for pain control. Pneumoperitoneum is achieved using a Veress needle in the left subcostal area insufflating up to 15 mmHg of CO_2. The abdominal cavity is accessed with a 5 mm laparoscope through an 8 mm robot optical trocar in the midline supra-umbilical region 15 cm inferior to the xiphoid. Absence of injury related to the Veress needle and trocar is confirmed. Under direct visualization, an 8 mm robot trocar is placed in the right anterior axillary line at the edge of the right lobe of the liver and another 8 mm robotic trocar is placed a few centimeters lateral to the left midclavicular line. A 12 mm port is then placed in the left midclavicular axillary line and a 15 mm the right midclavicular at the level of the camera port, and the liver retractoris placed in the xiphoid area [7, 8].

Troubleshooting: sometimes the liver retractor needs to be adjusted to optimize view of the duodenum or the hiatus particularly, if a hiatal hernia needs to be repaired.

10.4.3 Setup of the Robot

The patient is placed in Trendelenburg position and the small bowel is measured laparoscopically starting from the ileocecal valve and marked at 100 and 250 cm with sutures, the later one being anchored to the anterior abdominal wall for later mobilization. The patient is placed in slight reverse Trendelenburg position and if the robotic is utilized, the Xi version of the robot is docked on the right side of the patient while the Si version is docked over the right shoulder with arm boards brought as close to the patient as possible. The arms of the robot are properly spaced to provide full range movement to avoid collision between them. The robot arms are attached in the Xi version starting from left to right, to the right anterior axillary (arm 1), right midclavicular line (arm 2), supraumbilical port is used for the camera (arm 3) and left subcostal port (lateral to the left midclavicular line) is attached to arm 4. In the fully laparoscopic approach, the robot is not docked. The camera port is the same and the surgeon positions their laparoscopic instruments depending on the quadrant in which they are operating.

10.4.4 Overview of the Procedure

The DS has 3 main steps: a sleeve gastrectomy with the preservation of the pylorus, the ileoileal anastomosis, and the duodeno-ileal anastomosis. A 150–200 ml stomach pouch, along with a 150 cm alimentary limb (AL), and 100 cm common channel (CC) are created [7, 8]. We prefer to do a simultaneous cholecystectomy before we start with the procedure (Fig. 10.1). Even though the open surgeons routinely performed an appendectomy without an increase in the risk of complications, it has fallen into disuse due to low risk of appendicitis after DS and widespread knowledge on how to perform a laparoscopic appendectomy.

Troubleshooting: a cholecystectomy at the time of DS is optional, as some surgeons do not practice routine cholecystectomy. However, in our opinion the risk of gallstone formation is higher after a DS because of more wasting of bile salts and access to the bile ducts is more difficult if the patient develops choledocholithiasis. In addition, should a patient develops acute cholecystitis, it may be more challenging to perform a cholecystectomy in the area of the DI anastomosis due to formation of scar tissue. Hence, we perform a concomitant cholecystectomy at the time of the DS procedure.

Fig. 10.1 Robotic cholecystectomy

10.4.5 Sleeve Gastrectomy

First, the stomach is mobilized 4 cm distal to the pylorus and divided using a medium leg length 60 mm linear stapler at the level of the first portion of the duodenum where it crosses at the level of gastroduodenal artery (GDA). The surgeon should be careful not to damage the GDA, the portal structures, or the duodenum. The grater curvature of the stomach is mobilized to the angle of His using an energy device that seals and divides the vessels of the greater curvature while preserving the lesser curvature blood supply and vagal innervations. A bougie is placed along the lesser curvature of the stomach to serve as a guide for the sleeve gastrectomy (SG) and the preserved stomach is typically sized to be about 40 French. The stomach resection is performed starting at about 5 cm proximal to the pylorus and extending to the Angle of His, with the intention of creating a 150 cc pouch using linear stapler loads. The staple lines are typically reinforced and the choice of buttress material with either reabsorbable strips, suture, clips or glue is up to individual surgeon preference. The stapling is performed by the bedside assistant through the right midclavicular line port. The stomach specimen is retrieved at the end of the case (Fig. 10.2).

Troubleshooting: To avoid any leaks in the gastroesophageal (GE) junction, it is important to avoid lateral spread of thermal energy to this area. It is also important not to leave the large amount of fundus as this may lead to reflux or poor weight loss.

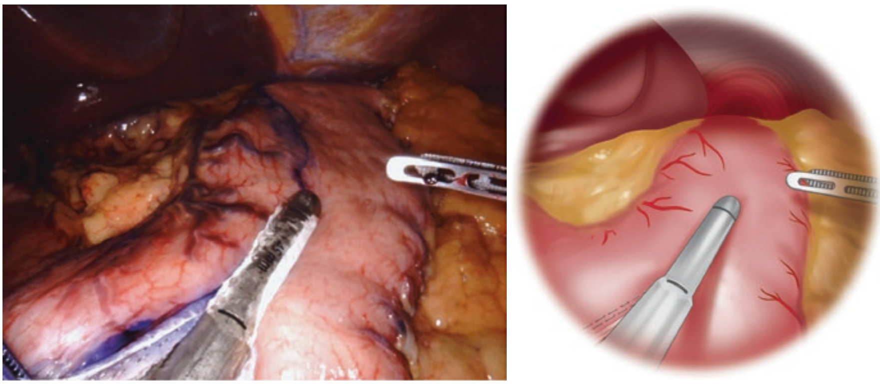

Fig. 10.2 Sleeve gastrectomy

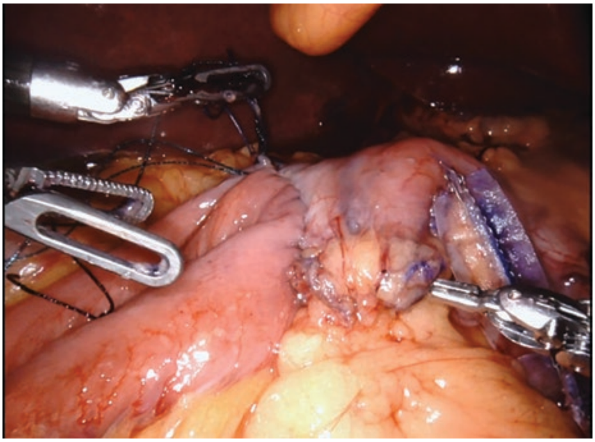

Fig. 10.3 Duodenal-ileal anastomosis

10.4.6 Duodenal-Ileal Anastomosis

The small bowel marked at 250 cm and anchored at the abdominal wall is released and brought up for anastomosis to the proximal stapled end of the divided duodenum. The duodenal-ileal (DI) anastomosis begins using a 3–0 running absorbable suture in the posterior seromuscular layer. Two enterotomies are then made, one in the duodenum and one in the ileum using an energy device. The surgeon then completes a hand-sewn antecolic or retrocolic 2-layer DI anastomosis in an end-to-side fashion, using 3–0 barbed absorbable suture in an Omega loop configuration [7, 8, 10]. The antecolic approach is our preference. Through an orogastric tube, methylene blue or indocyanine green for fluorescence, can be introduced in the stomach to test for leaks (Fig. 10.3). In the single anastomosis version the bowel is anastomosed a longer length of about 300 cm.

Troubleshooting: It is important to maintain correct orientation of the small bowel in order to prevent a twist that could result in an internal or even a closed loop obstruction.

10.4.7 Ileo-Ileal Anastomosis

In the conventional DS operation, the bowel previously marked 100 cm on the ileum, is approximated to the biliary limb (BL) to complete the Roux-en-Y configuration. Two ileostomies are performed, one in the BL, and another in the ileum, soon to be the common channel (CC) using a robotic hook cautery. The BL is then anastomosed to the ileum at the 100 cm mark using a 60 mm medium leg-length linear stapler. The enterotomy is hand sewn by the console surgeon using running 3–0 absorbable barbed suture (Fig. 10.4).

Finally, distal to the DI anastomosis the bowel is divided using a linear 60 mm cutter stapler. The bowel proximal to the 250 cm mark becomes the BL and the portion distal to it becomes the alimentary limb (AL).

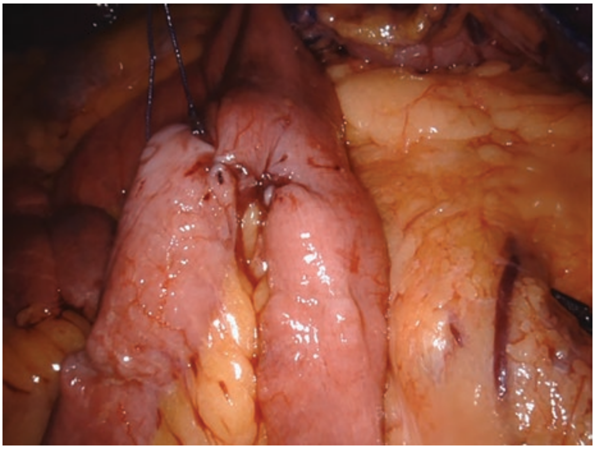

Fig. 10.4 Ileo-ileal anastomosis

An esophagogastroduodenoscopy (EGD) with air insufflation may be performed to check for patency, leaks, and bleeding. Specimens are retrieved and the abdominal cavity is irrigated and suctioned. The liver retractor is removed under visual guidance and ports are removed after all the CO_2 gas is evacuated. Larger port sites are closed with a port closure device, and a transversus abdominis plane (TAP) block can be done using lipoidal bupivacaine for pain control, if it was not done preoperatively.

Troubleshooting: To reduce the risk of internal hernia formation a running 3–0 nonabsorbable barbed suture is used for the closure of mesenteric defects [7, 8].

10.5 Post-Operative Course

With the implementation of ERAS, the standard care is removal of Foley catheter upon case completion, continuous monitoring in a fully equipped unit with trained staff, liquid diet, and restricted narcotic use. Liquids are initiated in small quantities and then progressed to protein shakes over a period of 2 weeks. A more consistent diet can then be considered over the next 3 months. Vitamins are supplemented according to the ASMBS guidelines for malabsorptive procedures [12]. Early ambulation is always encouraged. According to the individualized assessment of the patient, anticoagulation may be indicated after discharge, to prevent deep venous thrombosis. Imaging studies are not usually required if an intraoperative leak test was performed, unless there is concern for a complication. Discharge criteria are met when an appropriate amount of liquid diet is tolerated, patients are ambulating well, and their pain is under good control.

Troubleshooting: Leaving an intact pylorus in a SG can cause some degree of gastroparesis or pylorospasm making the patient nauseous. This may require the use of anti-emetics such as scopolamine patches. High-volume emesis is a concern in these patients when initiating oral intake, since they have larger stomach pouch, which may predispose to aspiration. Although most patients will have 2–3 bowel movements a day, urgency and frequency of stool may occur soon after patients resume their bowel function. However, if bowel movements are excessive (more than 2–3 soft bowel movements per day) infectious colitis should be ruled out prior to the use of loperamide or diphenoxylate-atropine.

10.6 Conclusions

Even though the DS requires a dedicated learning curve, a safe and effective operation has proven to resolve comorbid conditions such as diabetes, hypertension, and hyperlipidemia at high rates.

Conflict of Interest The authors have no conflicts of interest to declare.

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Part III
Hepatobiliary

Chapter 11
Laparoscopic Cholecystectomy

Laura N. Purcell and Anthony Charles

11.1 Introduction

The first laparoscopic cholecystectomy was performed in Germany in 1985 by Dr. Erick Muhe [1]. Over the last three decades, it has become the standard of care operation for the majority of gallbladder pathology, including biliary colic, acute and chronic cholecystitis, symptomatic cholelithiasis, choledocholithiasis, and biliary dyskinesia.

11.2 Clinical Presentation

Gall bladder disease, including acute cholecystitis, typically presents with symptoms which include nausea, emesis, fever, right upper quadrant pain (RUQ) tenderness, and Murphy's sign. Murphy's sign is the physical exam maneuver performed when the examiner elicits the arrest of inspiration when applying pressure to the patient's RUQ overlying the gallbladder, which results in pain from the inflamed gallbladder as it incites the peritoneal somatic pain fibers. The celiac axis innervates the gallbladder. Therefore, the pain often presents as epigastric pain, which transitions to RUQ pain as the parietal peritoneum is irritated from gallbladder inflammation. The fever is induced by cytokine release due to inflammation of the gallbladder. Occasionally, patients with gallbladder disease may present with jaundice, either

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due to necrotic or gangrenous gallbladder, or the presence of stone in the neck of the gallbladder that concomitantly compresses the common hepatic duct or choledocholithiasis.

11.3 Preoperative Workup

11.3.1 Laboratory Tests

Preoperative laboratory tests before performing a laparoscopic cholecystectomy should include a complete blood count, as an elevated white blood cell count is associated with acute cholecystitis. A liver function test is also imperative. Laboratory derangements due to biliary pathology will be evident in the levels of bilirubin, alkaline phosphatase, and serum transaminase. If there is concern about the level of biliary obstruction or biliary pathology, fractionation of the bilirubin may assist. Increases in conjugated bilirubin are due to reduced intracellular transport, excretion of conjugated bilirubin, or obstruction of the biliary tree. Alkaline phosphatase is seen in pathology with cholestasis, and elevated serum transaminase is non-specific and seen with hepatocellular injury [2]. If concerned for gallstone pancreatitis, amylase and lipase may be added. Lipase has a higher sensitivity and specificity than amylase for acute pancreatitis [3, 4].

11.3.2 Imaging

The gold standard initial imaging for biliary disease is a right upper quadrant ultrasound. Ultrasound findings indicative of acute cholecystitis include impacted stone in the neck of the gallbladder, positive sonographic Murphy's sign, thickened gallbladder wall (>3 mm), pericholecystic fluid, or distended or hydropic gallbladder.

The role computed tomography (CT) in the evaluation of biliary disease is expanding. It is especially useful when the presenting symptoms are unclear or when suspected gallbladder disease complications are present, such as gallbladder perforation or emphysematous cholecystitis. CT findings consistent with acute cholecystitis include gallstones, gallbladder distension, thickening of the gallbladder wall, as well as pericholecystic inflammation and fluid.

A hepatic iminodiacetic acid (HIDA) scan, otherwise known as biliary scintigraphy, cannot be used for anatomical delineation but can be used to examine the flow of bile from the liver. After injection of the iminodiacetic acid, it is processed in the liver and secreted in the bile. Failure of the gallbladder to fill on the HIDA scan within two hours indicates there is obstruction of the cystic duct, and therefore can assist with diagnosing acute cholecystitis. Also, it can identify obstructions in the biliary tree and bile leaks. It is the gold standard for diagnosing biliary dyskinesia, as it determines the physiologic ejection of the gallbladder when used with an injection of cholecystokinin.

The current, primary role of Endoscopic retrograde cholangiopancreatography (ERCP) is to treat patients in whom a gallstone has blocked the bile duct, causing jaundice, pancreatitis, or cholangitis. An ERCP is indicated before taking the patient to the operating room if concerned for choledocholithiasis.

11.4 Operative Technique

Performing a laparoscopic cholecystectomy can be divided into 11 steps as follows.

11.4.1 Step 1: Patient Positioning

The patient should be positioned supine on the operating table with both arms tucked. An operating room seatbelt should be placed across the patient's proximal thigh, so they do not slide when placed in reverse Trendelenburg. The monitors should be placed at eye level, cephalad to both patient shoulders for ease of viewing for the surgeon and first assistant. Place an orogastric tube for stomach decompression. The skin is initially prepared with chlorhexidine from just below the nipple line to the inguinal ligaments and laterally to the anterior superior iliac spine. Drape the operative field with sterile drapes. The surgeon stands on the left side of the patient.

Troubleshooting: Make sure that the patient is firmly placed in the bed, and the strap is appropriately tight to prevent the patient from sliding during reverse Trendelenburg. When tucking the arms, confirm all bony prominences are well padded to avoid complications such as neuropraxia and decubitus ulcers.

11.4.2 Step 2: Insufflation and Port Placement

There are two methods for acceptable insufflation of the perioneal cavity, the first is theVeress needle needle technique with a blind trocar placement or via optical access trocar or second, the Hasson open technique. For the Veress approach, make a 1 cm skin incision in the location of the desired Veress needle placement. The Veress needle can be placed in the left upper quadrant lateral to the epigastric vessels, overlaying the stomach or at the umbilicus. For patients without prior abdominal surgeries, our preference is at the umbilicus because the shortest distance between the abdominal wall and the peritoneal cavity is at the umbilical stalk. The location of placement will be determined by previous surgical incisions. Once the incision has been made, elevate the abdominal wall with two pairs of penetrating towel clamps, and the Veress needle is inserted in the incision. After the two clicking sounds are heard, an appropriate intraperitoneal location is confirmed by the free flow of saline through the needle after aspiration to exclude succus or blood. Once abdominal pressures have reached 8–10 mmHg, and the abdomen is tympanic, a 5 mm port can be placed at the umbilicus via blind trocar placement or an optical access trocar. The port is placed by twisting and applying pressure while aiming the trocar towards the pelvis [5].

To perform a Hasson open technique, make a vertical or transverse, 10–12 mm incision at the umbilicus. The incision can be made inferior or superior to the umbilicus. Exact placement should be determined by the patient's body habitus and previous surgical scars. Dissect the subcutaneous fat and tissues using finger retractors and blunt dissection. Once the external fascia is identified, use a Kocher clamp to grasp the reflection of the linea alba onto the umbilicus and elevate it cephalad. Make a 10 mm vertical incision with the scalpel through the fascia. Once the fascia is incised, utilize blunt dissection to identify the peritoneum. The peritoneum is elevated with hemostats and carefully incised to open the peritoneal space. Confirm access to the peritoneal space by visualizing bowel or omentum.

Place two U stitches, one on either side of the fascial incision, are placed with 0 polyglactin suture on a curved needle and set aside to secure the Hasson port. Place a finger within the peritoneal cavity, and perform a sweeping motion to ensure peritoneal entry and release any adhesions near the port site. The port is placed within the incision and secured it with the tails of the stay sutures [6].

Troubleshooting: The location of the initial peritoneal access depends on whether the patient has previously had an abdominal operation. If performing a Veress access, avoid the umbilicus if the patient has had a prior midline abdominal surgery and instead attempt access in the left upper quadrant. In patients with prior abdominal surgeries, we strongly recommend performing a Hassan approach.

After placement Veress needle, if saline does not flow freely or if high pressures are being recorded when the gas is turned on, the Veress needle should be removed. A careful attempt at repositioning can be made. If repositioning was unsuccessful, a transition to a Hassan access is warranted.

Finally, if the patient becomes hypotensive or bradycardic upon insufflation, open the insufflation port and remove the CO2 connection to allow the intraabdominal pressure to return to normal.

11.4.3 Step 3: Peritoneal Inspection

Once the scope port is placed and the peritoneal cavity is insufflated, use the 5 mm, 30-degree scope if a 5 mm port was placed at the umbilicus or a 10 mm, 30-degree scope in at the umbilicus if a Hasson open technique was performed. Focus and white-balance the laparoscope before advancing it slowly into the abdominal cavity. Inspect the bowel inferior to port placement to ensure no bowel injury during port placement. Subsequently, visualize all four quadrants of the abdomen to confirm the diagnosis and rule out other simultaneous intraabdominal pathology.

Troubleshooting: Occasionally, you may insufflate the preperitoneal space or the falciform ligament. This will reduce and is not of consequence. Make sure to examine the abdomen to look for succus to rule out a bowel injury, or any signs of bleeding that does not appear to be drop-down from the abdominal wall.

11.4.4 Step 4: Port Placement and Exposure

With your camera placed through the umbilical port, place three ports at the subxiphoid, right anterior axillary line, and the right midclavicular line in the subcostal region. The first port to be placed is in the subxiphoid (midline) region. A 1.2-cm incision is made three fingerbreadths below the xiphoid process and deepened into the subcutaneous fat. An 12-mm trocar is advanced into the abdominal cavity under direct vision in the direction of the gallbladder through the abdominal wall, with care taken to enter just to the right of the falciform ligament. The table is then adjusted to place the patient in a reverse Trendelenburg position with the right side up to allow the small bowel and colon to fall away from the operative field.

A 5-mm grasper is placed through the 12-mm subxiphoid port and applied to the fundus of the gallbladder. The gallbladder is then elevated cephalad over the dome of the liver to facilitate the surgeon's choice of the optimal positions for the lateral 5-mm ports. The third port (5 mm) should be inserted at the midclavicular line, one fingerbreadth below the costal margin. This port is used to access the neck of the now-retracted gallbladder. The fourth port (5 mm) should be placed four fingerbreadths below the second port at the anterior axillary line. The fourth port will be used to elevate the fundus of the gallbladder with a locking traumatic grasper, over the dome of the liver, toward the right shoulder to expose the infundibulum and porta hepatis (Fig. 11.1). With a Hunter grasper in port#2 (Fig. 11.2), grasp the gallbladder infundibulum and retract in the inferolateral direction. This maneuver straightens the cystic duct to expose Calot's Triangle (i.e., retracts it at 90° from the common bile duct [CBD]) and helps protect the CBD from inadvertent injury) (Fig. 11.3) [7].

Troubleshooting: This step is critical; otherwise, you will struggle for the remainder of the case. Remember, the gallbladder will be retracted cephalad; therefore, the midclavicular line port has to have a direct shot to Calot'sTriangle. The midclavicular and anterior axillary line ports cannot be directly vertical to each other, or the two instruments to perform the retraction will clash. If the gallbladder is distended

Fig. 11.1 Internal Port Placement

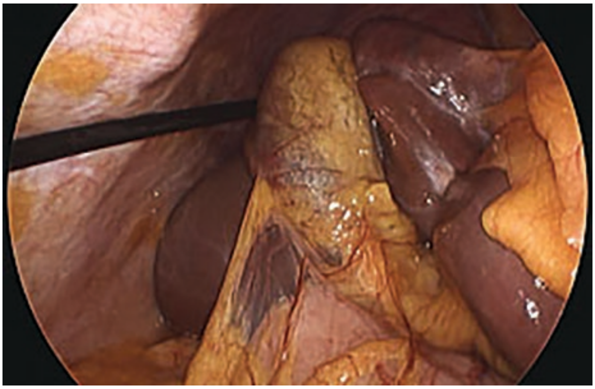

Fig. 11.2 Retracting the Fundus Over the Dome of the Liver Showing Adhesions and the Duodenum

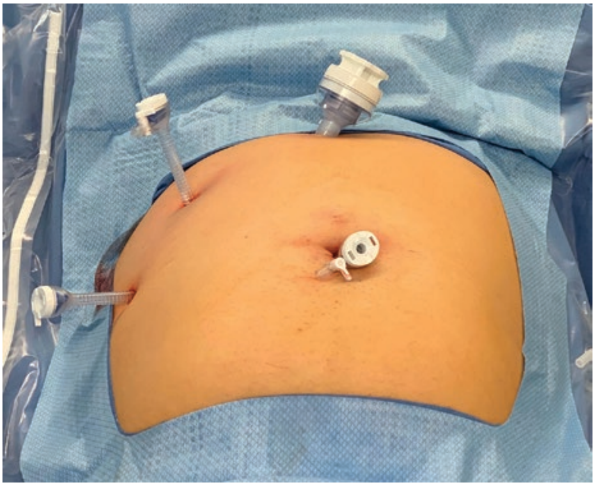

Fig. 11.3 External Port Placement

and it is challenging to manipulate the gallbladder with the graspers, perform a gallbladder decompression with an endoscopic needle attached to suction or a syringe.

11.4.5 Step 5: Adhesion Release

Once the ports are placed, use atraumatic graspers to remove the adhesions between the gallbladder and the omentum, duodenum, or colon. Then use graspers to grasp the adhesions close to the gallbladder and pull them towards the infundibulum to release the adhesions. Grasp as close to the gallbladder as possible to reduce bleeding or carefully lysed with a hook cautery. The authors prefer to use an L-hook electrocautery, which allows a very clean and delicate dissection. Continue until the gallbladder is free from all adhesions, and the colon and duodenum are removed from the operative field.

Troubleshooting: If the adhesions are challenging, you may need to utilize the hook cautery to help release the adhesions.

11.4.6 Step 6: Visualizing Calot's Triangle

Calot's Triangle is the anatomical space that contains the cystic artery. The cystic artery's landmark is the lymph node that overlies it, known as Calot's node. Its borders are the cystic duct laterally, the common hepatic duct medially, and the edge of the liver superiorly. To best expose this area, use an atraumatic grasper, such as a Hunter grasper to retract the infundibulum and pull inferolateral. Using a Maryland or a hook cautery, incise the peritoneum overlying the infundibulum, to avoid injuring the cystic artery or duct. Pull the peritoneum inferiorly, in line with the infundibulum, to expose the cystic artery and the cystic duct (Fig. 11.4).

Troubleshooting: Begin dissection near the gallbladder neck. Retract and dissect from the known to unknown to prevent injuring critical structures, such as the common bile duct or the duodenum.

11.4.7 Step 7: Critical View of Safety

To obtain the critical view, continue dissecting the peritoneum as was initiated in Step 6 until the cystic plate is taken down, and the inferior 1/3 of the gallbladder is separated from the liver. Once the peritoneum is taken down, clean carefully the tubular structures. This can be accomplished with careful dissection using the Maryland dissector and Kittners (Endo Peanut). Dissection is complete when the cystic duct and the cystic artery are the only two structures seen entering the gallbladder, and the liver is visible in the background. At this point, the critical view of safety has been achieved. This critical view must be obtained before any structures are clipped or transected (Fig. 11.5).

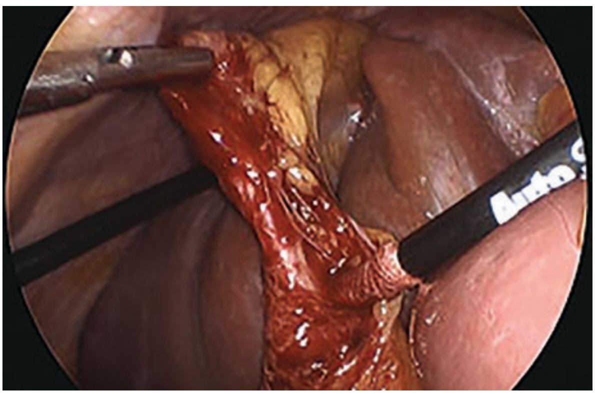

Fig. 11.4 Visualizing Calot's Triangle

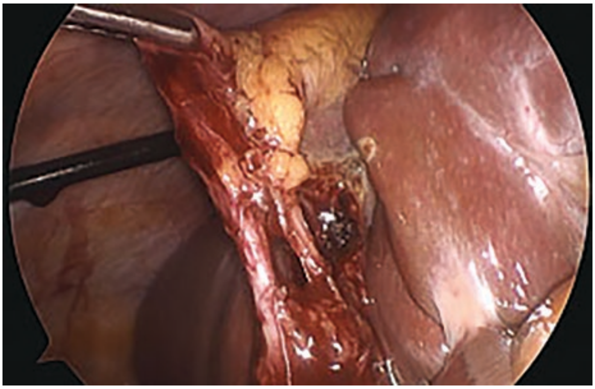

Fig. 11.5 Critical View of Safety

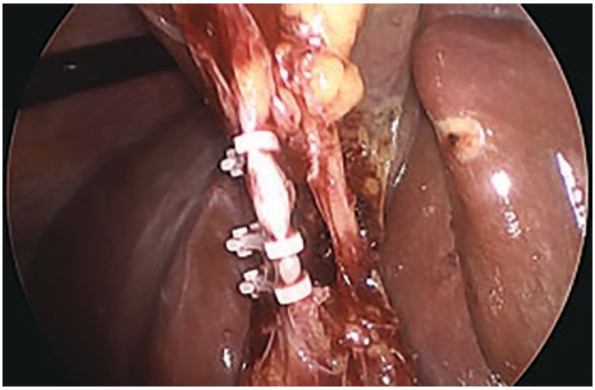

Fig. 11.6 Clipping the Ductal Structures

Troubleshooting: This step takes time and requires patience. Translucent tissues can be cut or cauterized without issue, those which cannot, need to be thinned until structures can be identified within.

11.4.8 Step 8: Clip and Transect Cystic Duct and Cystic Artery

After obtaining the critical view, place two clips on the cystic duct. If the anatomy is not clear and ductal structures are not clearly delineated or if the patient had choledocholithiasis and an ERCP was not performed, at this time, perform a cholangiogram and potentially a laparoscopic common bile duct exploration. Otherwise, place three clips on both the cystic artery duct and artery, two clips on the patient side, and one clip on the specimen side. Transect the tubular structures between the clips with the endoscopic scissors (Fig. 11.6).

Troubleshooting: Occasionally, the cystic artery bifurcates prior to entering the gallbladder, clip before the bifurcation, or clip each branch separately. When the cystic duct is large, several options may be considered, including an endoscopic stapler, Endoloops, and the Hem-o-lock clip technique.

11.4.9 Step 9: Mobilization and Removal of Gallbladder off the Gallbladder Fossa

Using electrocautery, remove the gallbladder from the gallbladder fossa of the liver. This can best be performed by using an atraumatic grasper in the midclavicular line port and retract the gallbladder neck. Using the hook cautery in the subxiphoid port, cauterize from side to side at the lines of tension moving from the gallbladder neck towards to the gallbladder fundus peeling the gallbladder off the fossa. Use the atraumatic grasper to reposition the gallbladder as you progress and apply traction and gain new lines of tension. As in any surgical procedure, traction-countertraction is essential. To minimize wasted motion, peel the gallbladder as far as can go before changing positions of the atraumatic grasper.

Before the last strands connecting the gallbladder to the liver are divided, perform a final inspection of the gallbladder fossa and the clipped cystic structures. Any bleeding points in the gallbladder fossa should be controlled at this time before the gallbladder is completely separated from the liver (Fig. 11.7).

Troubleshooting: This portion of the operation is challenging. You may encounter bleeding from the gallbladder fossa as the gallbladder is removed. If you encounter bleeding, turn the electrocautery up to 60 watts and ensure hemostasis as you encounter bleeding. If the gallbladder is inadvertently perforated and there is bile and stone spillage, make every effort to thoroughly irrigate the right upper quadrant and extract the stones. Retained stones can cause future problems, such as chronic abscesses, fistulas, wound infections, and bowel obstructions. If unable to find the stones, look at Morison's pouch or the retrohepatic space by the abdominal wall.[22] Take care not to injure the diaphragm with the cephalad retraction of the gallbladder and the use of electrocautery near the diaphragm.

Fig. 11.7 Mobilization of Gallbladder off the Gallbladder Fossa

11.4.10 Step 10: Remove Gallbladder from the Peritoneal Space

Using a grasper in port #3 or #4, grasp the gallbladder and hold it over the right upper quadrant over the liver. Place the endoscopic retrieval bag through the 10/12 port, either at the umbilicus or the subxiphoid port. Place the gallbladder into the endoscopic retrieval pouch. Follow the manufacturer's instructions to close the bag. The authors prefer to leave the bag suspended from the subxiphoid trocar while they replace the camera through the same port and perform the final inspection and washout. Return the table to the neutral position. The gallbladder bed and the perihepatic spaces are irrigated and suctioned to ensure adequate hemostasis and removal of any debris or bile that may have spilled. The gallbladder is removed through the 10/12 mm port site after removing the trocar under direct visualization to ensure that stone spillage or bag perforation does not occur (Fig. 11.8).

Troubleshooting: If you have difficulties removing the gallbladder through the 10/12 mm port site, increase the port site with Kelly clamps or place Kelly on the top of the endoscopic retrieval pouch for an evenly distributed force on the bag. If the endoscopic retrieval pouch breaks, well irrigate the wound as the contamination predisposes the patient to wound infections.

11.4.11 Step 11: Close the Incisions

Remove the subcostal ports under direct visualization and desufflate the abdomen by removing the 10/12 mm port obturator. Remove the 10/12 mm port. Close the fascia at the 10/12 mm port site with the stay sutures placed during the Hassan port placement or use a #0 vicryl on a UR 6 needle to close the fascia. All of the skin incisions are closed with 4–0 absorbable monofilament suture, followed by cyanoacrylate tissue adhesive.

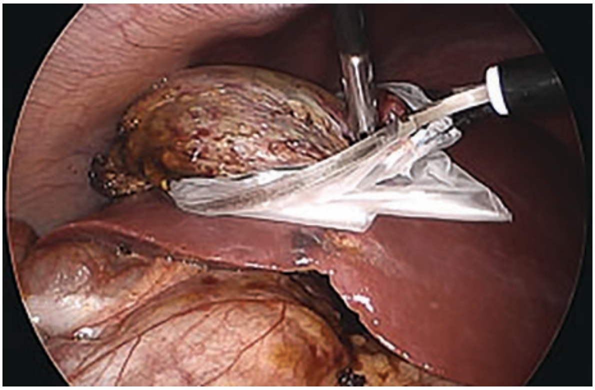

Fig. 11.8 Placing Gallbladder in Endoscopic Retrieval Bag

Troubleshooting: Make sure the fascia is identified as the 10/12 mm port site to ensure the fascia closed to prevent a hernia from occurring. If having challenges with a UR 6 needle, a Ranfac needle can be used to obtain adequate bites of the fascia.

11.5 Indications to Convert to an Open Cholecystectomy

The majority of gallbladder disease can be managed with laparoscopic cholecystectomy, and rarely an open operation will need to be performed. However, conversion from laparoscopic to open cholecystectomy needs to occur if the intraperitoneal adhesions are too dense, when the gallbladder and biliary anatomy is unclear, or when dissection progress is stalled to safely operate or if the gallbladder is to friable to grasp. Also, if a bile duct injury is identified or uncontrolled bleeding occurs during a laparoscopic procedure, conversion to an open procedure needs to occur to obtain visualization, control hemorrhage or to repair injured common bile or hepatic ducts.

11.5.1 Complications

Complications after laparoscopic cholecystectomy are rare but can include bleeding, retained gallstones, or common bile duct injury [8]. Complications that present themselves within the first two days include bleeding and bile duct injury. Most postoperative bleeding after laparoscopic cholecystectomies is self-limited. If a patient's hemoglobin continues to drop, interventional radiology is warranted. However, if the patient becomes hemodynamically unstable, they need to return to the operation room to find the source of the bleeding, usually from the cystic artery stump.

The most feared complication is a bile duct injury, which is primarily due to poor visualization due to inflammation, inappropriate exposure, and aggressive hemostasis during the operation. After identification of the bile duct injury, which usually occurs post-operatively, the first steps are to obtain infection control with percutaneous drainage of biloma and antibiotics. After identification of the injury location with ERCP or MRCP, consult interventional gastroenterology or a hepatobiliary surgeon to obtain biliary-enteric continuity.

Within the first week after cholecystectomy, a bile leak can result in a biloma. Patients may present with fever, chills, right upper quadrant pain, jaundice, bile leakage from the incision or in a drain, persistent anorexia, or bloating. Bile maybe from the Ducts of Luschka, accessory bile ducts that drain from the liver directly into the gallbladder, or from a cystic duct stump leak. The management includes an endoscopic retrograde cholangiopancreatography (ERCP) to identify the source of the leak. If it is due to a cystic duct stump leak, place a stent in the common bile duct to the common hepatic duct, and a sphincterotomy should be performed to reduce the intraductal pressure. A percutaneous drain should be placed in the biloma.

Long term complications from cholecystectomies can be due to retained biliary stones, spilled stones, and port site hernias. Retained biliary stones can be present up to two years after a cholecystectomy. It can present with choledocholithiasis with hyperbilirubinemia and elevated alkaline phosphatase in the setting of a previous cholecystectomy. The treatment is ERCP and removal of the retained stone. Port site hernias can occur at any time. There is a low risk of bowel herniation, but omentum can become incarcerated and cause pain and infection. Patients need to return to the operating room to fix the port site herniation.

11.5.2 Postoperative Management

For patients undergoing uncomplicated elective operations, patients can be discharged home from the post-anesthesia care unit with scheduled follow up if tolerating oral intake and their pain is controlled. If patients have urgent or emergent operations or have concern for complicated operations, patients should be admitted overnight with oral pain medications and a general diet before discharge on postoperative day one.

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Chapter 12
Robotic Hepatectomy

Kevin P. Labadie, Lindsay K. Dickerson, and James O. Park

12.1 Introduction

Since the first laparoscopic liver resection was reported in 1991 [1], indications for laparoscopic hepatectomy have expanded to be nearly equivalent to that of open hepatectomy, with secondary metastases, and primary hepatic and biliary tract malignancies being the most common [2]. While lesion size and location remain important determinants of when laparoscopic hepatectomy is appropriate, minor resections such as laparoscopic left lateral sectionectomy have become standard of care [3, 4]. Long-term survival data are limited, however, recent studies demonstrate shorter operative time and length of stay, lower blood loss and transfusion rate, and decreased major morbidity, with similar overall complication rates for laparoscopic compared to open hepatectomy [4–6].

Robotic-assisted laparoscopic hepatectomy, or Robotic hepatectomy, is a newer approach to minimally invasive liver resection, with its use growing in parallel to the expanded application of robotic surgery across surgical subspecialties. Current literature comparing robotic to laparoscopic hepatectomy points to no significant differences in complication rates, length of stay, negative margin rate, reoperation, readmission, morbidity, or mortality, as well as overall survival or disease-free survival for oncologic resection, but arguably longer operating time and higher cost [6–8]. Potential benefits over conventional laparoscopic hepatectomy include decreased rate of conversion to open approach, better surgeon ergonomics, ability to perform higher complexity cases, and a shorter learning curve, presumably due to improved optical visualization and operative dexterity for suturing [9, 10]. With these technical advantages, recent studies have suggested its superiority to

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conventional laparoscopic resection of hepatic segments that are difficult to access laparoscopically, including segments 1, 4A, 7 and 8 [11, 12]. Our group's experience of over 250 robotic hepatectomy cases confirm these observations, however, additional prospective trials are needed to clarify many of these observations [13].

Herein we describe our institutional robotic approach to commonly performed hepatectomies. Note that while the following procedures are described based on the Intuitive Surgical Xi platform, the general principles are applicable to other robotic platforms.

12.1.1 Clinical Presentation and Preoperative Evaluation

Clinical presentation can be quite variable depending on the integrity of the liver parenchyma, and the location and size of the tumor(s) and effect on the vasculature or biliary tract. Subcapsular lesions can cause pain, biliary obstruction can result in jaundice, and venous invasion can lead to ascites. Treatment planning is heavily reliant on imaging. High-quality, contrast-enhanced, multi-phase, cross-sectional imaging with computed tomography (CT) or magnetic resonance (MR) imaging should be performed to outline the vascular anatomy along with any aberrancies, and to evaluate the tumor size, location and relationship with the surrounding vasculature prior to proceeding to the operating room.

Surgical resectability is assessed and defined based on the physiologic (patient protoplasm), oncologic (tumor biology), and technical (ability to obtain a negative margin while maintaining adequate liver remnant) considerations.

12.2 Technique and Steps of Operations

12.2.1 Patient Preparation and Positioning

The patient is brought to the operating room having received oral carbohydrate loading and subcutaneous heparin venous thromboembolism prophylaxis, and is placed supine on the operating table. The patient's core body temperature is maintained with an under-body warming pad and upper-body Baer hugger device, and a sequential-compression device is placed and activated. After completion of a safety timeout, the patient undergoes general anesthesia with endotracheal intubation. A Foley urinary catheter, large bore peripheral or central venous and radial arterial catheters are inserted as necessary, and prophylactic antibiotics are administered.

For most procedures, the patient is placed in split-leg, modified French position with both arms abducted, all pressure points padded, and secured at the chest, thighs and legs. For resection involving the posterior segments, the patient is placed in left lateral decubitus position. The patient is prepped and draped with the anatomic landmarks (xiphoid process, costal margins, and anterior superior iliac spine) exposed. After a second safety check list, access to the abdomen for routine cases is obtained through a 12 mm AirSeal™ port placed in the supraumbilical position via Hasson technique. The patient is placed in 20–30° reverse Trendelenberg and partial left or right lateral decubitus position as necessary. The peritoneal cavity is insufflated to 15 mmHg of CO_2 initially and inspected to rule out metastases.

Troubleshooting:

Prevention of subcutaneous emphysema—The 12 mm AirSeal port is secured to the skin with 0 polysorb suture to prevent migration of the insufflation outlets into the subcutaneous tissue.

12.2.2 Port and Instrument Placement

After anesthetizing the skin and peritoneum, four robotic ports are sequentially placed, the first being the camera port to confirm optimal visualization. The camera is placed in arm #3 for left-sided hepatectomies (LSH) and arm #2 for right-sided hepatectomies (RSH) with the port 10–15 cm from the target anatomy. The robotic patient cart is deployed for an upper abdominal case and docked on the patient's left or right side. The bedside assistant stands between the patient's legs, with the scrub nurse opposite the patient cart. The bedside assistant uses the 12 mm AirSeal port, and an additional 5 mm port if necessary. The Tip-Up fenestrated grasper for retraction is placed in arm #4 (LSH) or #1 (RSH). The energy device [monopolar curved shears (MCS)/harmonic scalpel (HS)]and needle driver are placed in arms #2 (LSH) or #3 (RSH), and the Cadiere forceps in arm #1 (LSH) or #4 (RSH) (Figs. 12.1 and 12.2).

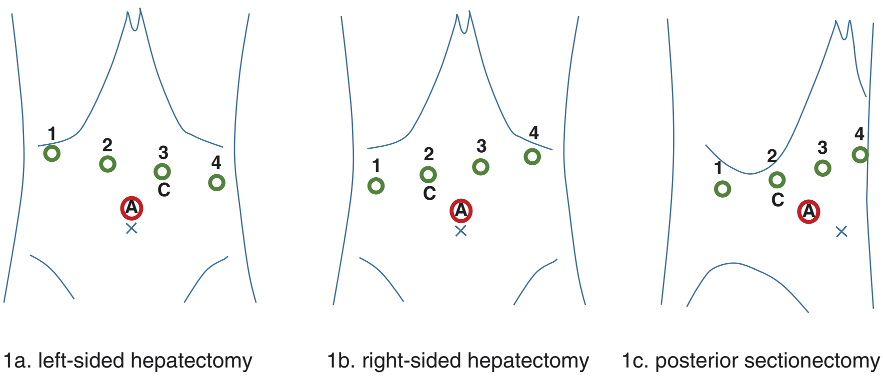

Fig. 12.1 Port placement. (**1a**, **1b**) #1: R anterior axillary, #2: R parasternal, #3: L parasternal, #4: L anterior axillary. (**1c**) #1:R mid-axillary, #2: R anterior axillary, #3: R parasternal, #4: L parasternal. A: Assistant port

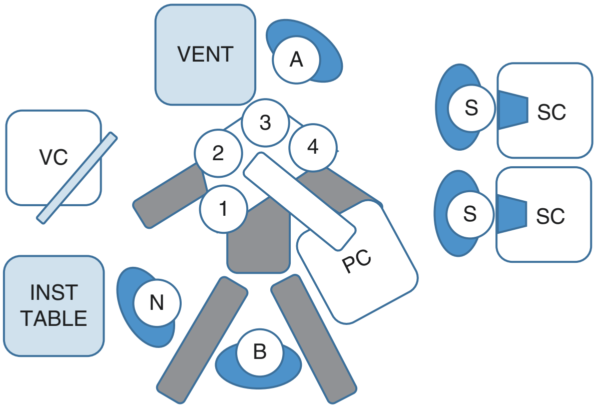

Fig. 12.2 OR set-up and robot docking from patient's left side. A: anesthesia, B: bedside assistant, N: scrub nurse, S: surgeon, PC: patient cart, #1–4: robotic arms, SC: surgeon console, VC: vision cart, VENT: ventilator, INST TABLE: instrument table

Troubleshooting:

Optimal port placement—It is important to ensure that the most superior and posterior aspects of the parenchymal transection are adequately visualized and can be reached by the instruments, especially when using the HS which is the shortest robotic instrument, and for lesions located in the superior segments, i.e. S2, S4A, S7, S8.

Adhesions—Significant adhesions from prior abdominal surgery may be encountered on initial diagnostic laparoscopy. Additional ports should be placed (ideally using planned robotic port sites) and laparoscopic shears with electrocautery can be used for adhesiolysis to allow for sequential port placement. Further lysis of adhesions is performed robotically following docking, however, extensive adhesions may warrant conversion to an open approach.

Challenging body habitus—Patients with low and/or narrow costal margins, and those with obese abdominal girth may present unique challenges to achieving optimal access to and exposure of the target anatomy due to lack of adequate space for optimal port placement or due to poor insufflation. Careful assessment of accessibility via laparoscopy prior to placement of the robotic ports is advised as the likelihood of conversion is relatively high given the steeper instrument angles and/or insufficient space for optimal port placement or visualization.

12.2.3 Liver Mobilization

The ligamentum teres hepatis is divided using MCS close to the abdominal wall to prevent visual obstruction by its remnant, and used to retract the liver to facilitate parenchymal transection. The falciform ligament is divided with MCS to the hepatic venous confluence, and the left or right coronary and triangular ligaments are divided with MCS to fully mobilize the left or the right liver lobe, respectively. For the left side, this is best initiated from above the liver by retracting the left lateral

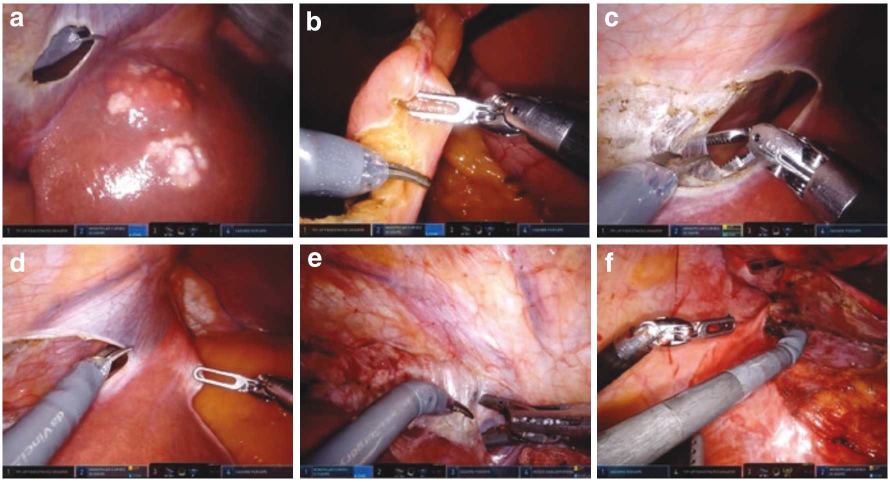

Fig. 12.3 Mobilization of the liver. Division of (**a**) falciform ligament, (**b**) ligamentum teres hepatis. Division of (**c**) left coronary, (**d**) left triangular ligaments to mobilize the left liver lobe. Right triangular ligament divided from (**e**) above and (**f**) from below to mobilize right lobe

sector inferiorly and anteriorly, and finding a transparent region in the mid-portion of the coronary ligament which is divided, taking care not to injure the esophagus. The triangular ligament is then divided laterally. The liver is then lifted superiorly and anteriorly, and the remaining coronary ligament is divided toward the IVC taking care to avoid injury to the left inferior phrenic vein. For the right side, the coronary ligament is divided from above the liver, taking care not to injure the right hepatic vein. The majority of the mobilization is performed from inferiorly by retracting the liver anteriorly and dividing the triangular ligament with MCS toward the IVC. Attention should pay to avoid injury to the adrenal gland and its drainage into the IVC (Fig. 12.3).

Troubleshooting:

Friable liver parenchyma—For patients with significant steatosis, the liver parenchyma can be quite friable and may lead to fracturing during retraction. A vaginal pack can be used to pad the Tip-Up grasper to aid in the retraction to mitigate this problem when encountered.

12.2.4 *Ultrasound Examination*

Ultrasonography is routinely performed to outline the vascular anatomy and flow, to rule out unexpected lesions, to delineate the relationship between the tumor(s) and the surrounding vasculature and bile ducts, and to plan the transection plane. The robotic drop-in ultrasound probe is introduced through the 12 mm assistant port and

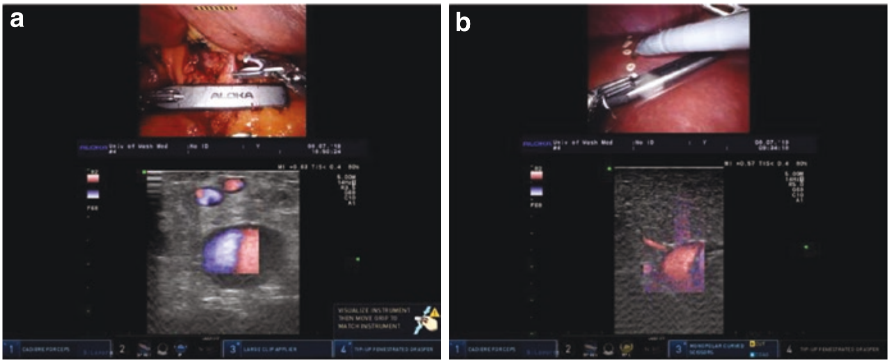

Fig. 12.4 Ultrasound images visualized on TilePro display. (**a**) Confirmation of the hilar structures by ultrasound. (**b**) Ultrasound guided marking of surgical margin

controlled using the Cadiere forceps, with the sonographic images broadcast through the TilePro display on the surgeon console and the laparoscopic monitors for real-time visualization (Fig. 12.4).

12.2.5 Indocyanine Green Fluorescence

Indocyanine green (ICG) can be used to aid in tumor identification, accurate delineation of the surgical margin, and preservation of the liver remnant. To identify the tumor, ICG (7.5 mg) is injected intravenously 48 h prior to surgery. Margin and remnant assessment can be evaluated by occluding the portal pedicles of interest and administering ICG (2.5 mg) intravenously. Fluorescence within the vascularized liver parenchyma is visualized within 10–15 minutes using the Firefly™ fluorescence imaging system. ICG fluorescence can also be used to identify bile leaks (Fig. 12.5).

12.2.6 Parenchymal Transection

The transection plane is based on preoperative cross-sectional imaging, intraoperative ultrasound examination and if necessary ICG fluorescence. The transection line is marked on the liver capsule with the MCS under ultrasound guidance. Prior to parenchymal transection, the abdominal insufflation pressure is lowered to 7–12 mmHg to minimize risk of CO_2 embolism. The parenchyma is divided using the HS. Cavitron ultrasonic surgical aspirator (CUSA™) can also be used to divide the parenchyma. Small portal pedicles and hepatic venules can be controlled effectively using the HS or small titanium clips. Larger portal pedicles and hepatic veins are defined using clamp-crush tissue fracture technique with the HS, encircled using

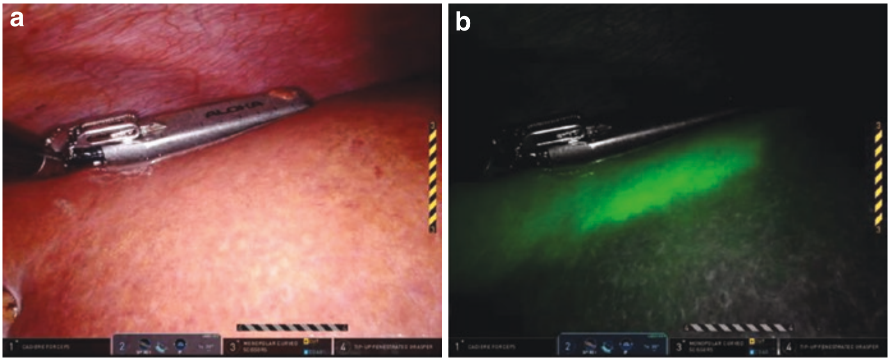

Fig. 12.5 Viable liver parenchyma highlighted with ICG fluorescence. (**a**) Parenchymal demarcation following division of portal pedicle is visually non-apparent. (**b**) Vascularized parenchyma is clearly visualized using ICG FireFly fluorescence imaging

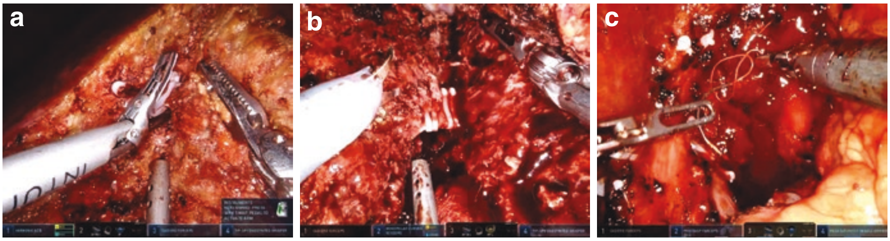

Fig. 12.6 Parenchymal transection. (**a**) Harmonic scalpel division of parenchyma and small left portal pedicle. (**b**) Division of main right hepatic vein with Hem-o-lok clips and MCS. (**c**) Suture control of branches to IVC following caudate lobe resection

MCS, then divided between Hem-o-lok™ clips, with suture reinforcement if necessary. The main portal vein and main hepatic veins are secured and divided using the EndoGIA or robotic stapler with vascular load (2–2.5 mm staple height) if too large for Hem-o-lok clips. 4–0 prolene or 3–0 polysorb sutures are used to control bleeding by direct repair of venotomies or by *en mass* closure, respectively. Hemostatic agents such as Surgicel and Fibrillar are applied if necessary (Fig. 12.6).

Troubleshooting:

Obtaining the optimal transection angle with the HS—Given that the HS does not have the ability to articulate or roticulate, it can be challenging to achieve the optimal angles for parenchymal division. The liver parenchyma can be gently manipulated via retraction to achieve the necessary angle for the HS.

Carbon dioxide (CO_2) embolism—Clinically significant CO_2 embolism is a rare but potentially fatal complication, with reported mortality as high as 28%. It occurs when CO_2 enters a hepatic venotomy and causes a sudden rise then precipitous drop in end-tidal CO_2 accompanied by oxygen desaturation, hypotension, arrhythmia, and ultimately cardiac collapse as a result of embolic right ventricular occlusion and reduction of pulmonary blood flow. The most sensitive test for detection is transesophageal echocardiogram. Treatment entails immediate desufflation of the abdomen, placement of the patient in Durant's position (left lateral decubitus and steep Trendelenburg) to prevent gas passage into the pulmonary artery, 100% O_2 ventilation to improve hypoxemia and ventilation-perfusion mismatch, hyperventilation to eliminate CO_2, attempted aspiration of CO_2 through a central line, and cardiopulmonary resuscitation if necessary. Significant CO_2 embolism can be avoided by end-tidal CO_2 monitoring, lower insufflation pressures during division of the liver parenchyma, and prompt repair of venotomies.

12.2.7 Inspection and Specimen Retrieval

The surgical bed is irrigated, and hemostasis is confirmed. A vaginal pack is used to check for bile leak. Ultrasound is performed to confirm preservation of vascular inflow and outflow of the remnant. The resected specimen is removed in an EndoCatch™ bag delivered through an extension of the assistant port site, or separate Pfannenstiel incision. The robot is undocked after gross margin assessment in Pathology, and following a period of desufflation to ensure complete hemostasis. After instrument, needle, and sponge counts are confirmed, all incisions are closed in layers (Fig. 12.7).

Troubleshooting:

Large tumor extraction—Especially following major hepatectomy, the specimen may be too large to place in the EndoCatch bag efficiently. The extraction incision can be made first and the specimen extraction can be assisted using the hand.

12.2.8 Left Lateral Sectionectomy

The patient is placed in supine, modified French position and the ports are placed as depicted in Fig. 12.1a. The ligamentum teres hepatis, falciform ligament, left coronary and triangular ligaments are divided with MCS to fully mobilize the left lateral

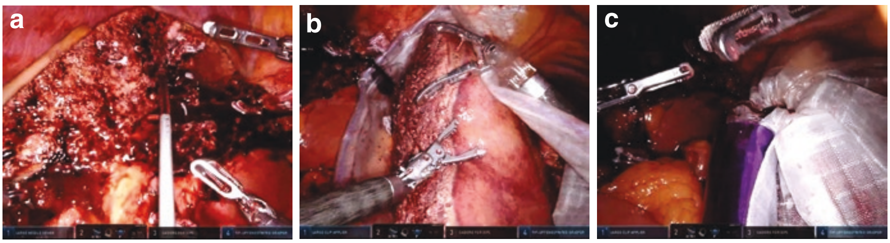

Fig. 12.7 Inspection and specimen retrieval. (**a**) Irrigation of surgical bed. (**b**, **c**) Placement of specimen in EndoCatch bag and closure

section. The parenchymal bridge between S3 and S4B if present, is divided using MCS or HS.

The transection line lateral to the falciform ligament is scored with MCS under ultrasound guidance, making note of the tumor and its relationship to the left main portal pedicle and take off of the S2/S3 portal pedicles and the left hepatic vein.

The liver parenchyma is divided using the HS, in a caudal-to-cranial and anterior-to-posterior trajectory. Small portal pedicles and hepatic venules are controlled using the HS or small titanium clips. The S3 followed by S2 portal pedicles are defined by clamp-crush tissue fracture technique using the HS or Cadiere grasper, and encircled using MCS, then sequentially divided between Hem-o-lok clips, with suture reinforcement if necessary.

The parenchymal transection is continued cephalad and posteriorly, and branches of the left hepatic vein are dissected with the HS and divided between Hem-o-lok clips. The main left hepatic vein is controlled with 4–0 prolene suture and Hem-o-lok clips, or EndoGIA or robotic stapler with vascular load if the vein is large. Hemostasis, inspection and specimen retrieval is performed as described above.

Troubleshooting:

Medial tumors—For tumors located more medially in the left lateral section, care must be taken to avoid damage to the left main portal pedicle and preserve inflow to segments 4A/B by ultrasound (Fig. 12.8).

12.2.9 Left Hepatectomy

The patient is placed supine, modified French position and ports are placed as depicted in Fig. 12.1a. The ligamentum teres hepatis, falciform ligament, left coronary and triangular ligaments are divided using MCS to fully mobilize the left liver lobe as described in the mobilization section.

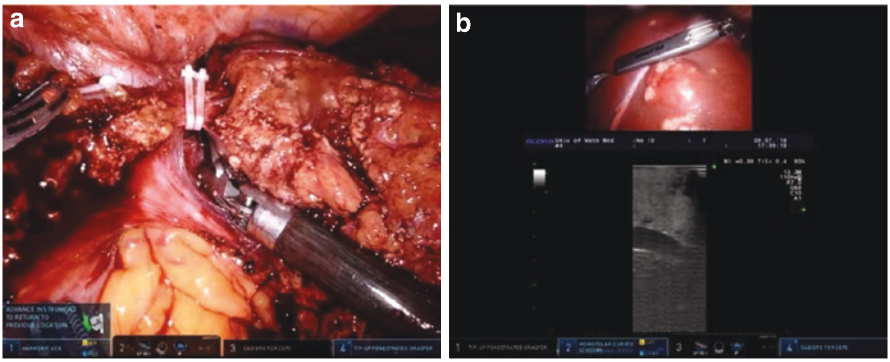

Fig. 12.8 Left lateral sectionectomy. (**a**) Main left hepatic vein divided using Hem-o-lok clips. (**b**) Medial tumor in close proximity to main left portal pedicle

The liver is retracted cephalad and anteriorly using the Tip-Up grasper. Cholecystectomy is performed if the gallbladder is present. The gastrohepatic ligament is divided using MCS to expose the hepatic artery, and if an accessory left hepatic artery is present, it is divided between Hem-o-lok clips. The porta hepatis is exposed by dividing lymphatics and opening Glisson's sheath with MCS. The hepatic arterial and portal venous course is visually identified and ultrasound is used to confirm the anatomy. With robust inflow to the right liver confirmed, the left hepatic artery and portal vein are encircled and divided between Hem-o-lok clips. An EndoGIA or robotic stapler with vascular load can be used for a large portal vein. The left bile duct is identified, encircled, and divided between Hem-o-lok clips.

After inflow is controlled, indocyanine green can be injected intravenously to enhance the parenchymal transection line. Under ultrasound guidance, the transection line preserving the middle hepatic vein is scored with MCS, making note of the tumor and its relationship to the portal bifurcation and the middle hepatic vein.

The insufflation pressure is lowered to 7–12 mmHg to minimize the risk of CO_2 embolism. The liver parenchyma is divided in layers, caudal-to-cranial, using the HS. Small portal pedicles and hepatic venules are controlled using the HS or small titanium clips. Larger branches of the middle hepatic vein and peripheral S4A/B portal pedicles identified by ultrasound are defined by tissue fracture technique using the HSor Cadiere grasper, and encircled using MCS, then sequentially divided between Hem-o-lok clips, with suture reinforcement if necessary.

The parenchymal transection is continued cephalad and posteriorly, and branches of the left and middle hepatic vein are dissected with the HS and divided between Hem-o-lok clips. The main left hepatic vein is controlled with 4–0 prolene suture and Hem-o-lok clips, or EndoGIA or robotic stapler with vascular load if the vein is large. Hemostasis, inspection and specimen retrieval is performed as described above.

Troubleshooting:

Preservation of the caudate lobe – Care is required not to injure the inflow to the left-side of the caudate lobe if goal is to preserve. The portal pedicle should be divided distal to the caudate branch (Fig. 12.9).

Fig. 12.9 Left hepatectomy. (**a**) Identification of the left portal vein. (**b**) Division of the left portal vein distal to the caudate branch take-off. (**c**) Preserved caudate lobe

12.2.10 Right Hepatectomy

The patient is placed in supine, modified French position and the ports are placed as depicted in Fig. 12.1b. The ligamentum teres hepatis, falciform ligament, right coronary and triangular ligaments are divided using MCS to fully mobilize the right liver as described in the mobilization section.

The liver is retracted cephalad and anteriorly using the Tip-Up grasper. Cholecystectomy is performed if the gallbladder is present. The porta hepatis is exposed by dividing lymphatics and opening Glisson's sheath with MCS. The hepatic arterial and portal venous course is visually identified and ultrasound is used to confirm the anatomy. With robust inflow to the left liver confirmed, the right hepatic artery and portal vein are encircled and divided between Hem-o-lok clips. An EndoGIA or robotic stapler with vascular load can be used for a large portal vein. The right bile duct is identified, encircled, and divided between clips.

After inflow is controlled, indocyanine green can be injected intravenously to enhance the parenchymal transection line. Under ultrasound guidance, the transection line preserving the middle hepatic vein is scored with MCS, making note of the tumor and its relationship to the portal bifurcation and the middle hepatic vein.

The insufflation pressure is lowered to 7–12 mmHg to minimize the risk of CO_2 embolism. The liver parenchyma is divided in layers, caudal-to-cranial, using the HS. Small portal pedicles and hepatic venules are controlled using the HS or small titanium clips. Larger branches of the middle hepatic vein and peripheral S5/S8 portal pedicles identified by ultrasound are defined by tissue fracture technique using the HS or Cadiere grasper, and encircled using MCS, then sequentially divided between Hem-o-lok clips, with suture reinforcement if necessary.

The parenchymal transection is continued cephalad and posteriorly, and branches of the middle and right hepatic vein are dissected with the HS and divided between Hem-o-lok clips. The main and accessory right hepatic veins are controlled with 4–0 prolene suture and Hem-o-lok clips, or EndoGIA or robotic stapler with vascular load if the vein is large. Hemostasis, inspection and specimen retrieval is performed as described above.

Troubleshooting:

Poor access to the inflow—When the right portal pedicles cannot be controlled extrahepatically, the liver parenchyma can be divided to expose these structures (Fig. 12.10).

12.2.11 Posterior Sectionectomy

The patient is placed in left lateral decubitus position and ports are placed as depicted in Fig. 12.1c. The ligamentum teres hepatis, falciform ligament, right coronary and triangular ligaments are divided using MCS to fully mobilize the right liver lobe as described in the mobilization section.

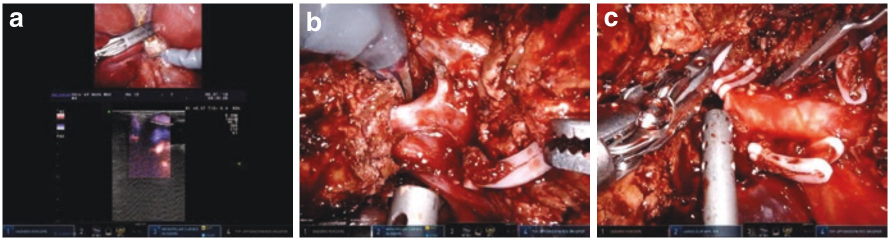

Fig. 12.10 Right hepatectomy. (**a**) Ultrasound visualization of intrahepatic right portal structures. (**b**) Isolation of anterior and posterior sectoral portal pedicles. (**c**) Division of the portal pedicles between Hem-o-lok clips

The liver is retracted cephalad and anteriorly using the Tip-Up grasper. The posterior portal pedicle can be accessed either through the fissure of Gans (Rouviere's sulcus) or following parenchymal transection. The hepatic arterial and portal venous course is visually identified and ultrasound is used to confirm the anatomy. With robust inflow to the anterior sectoral portal pedicle confirmed, the posterior portal pedicle is encircled and divided between Hem-o-lok clips. An EndoGIA or robotic stapler with vascular load can be used for a large portal vein.

After inflow is controlled, indocyanine green can be injected intravenously to identify the parenchymal transection line. Under ultrasound guidance, the transection line is scored with MCS, making note of the tumor and its relationship to the portal bifurcation and the right hepatic vein.

The insufflation pressure is lowered to 7–12 mmHg to minimize the risk of CO_2 embolism. The liver parenchyma is divided in layers, caudal-to-cranial, using theHS. Small portal pedicles and hepatic venules are controlled using the HS or small titanium clips. Larger branches of the right hepatic vein and peripheral S6/S7 portal pedicles identified by ultrasound, are defined by tissue fracture technique using the HS or Cadiere grasper, and encircled using MCS, then sequentially divided between Hem-o-lok clips, with suture reinforcement if necessary.

The parenchymal transection is continued cephalad and posteriorly, and branches of the right hepatic vein are dissected with the HS and divided between Hem-o-lok clips. The main and accessory right hepatic veins are controlled with 4–0 prolene suture and Hem-o-lok clips, or EndoGIA or robotic stapler with vascular load if the vein is large. Hemostasis, inspection and specimen retrieval is performed as described above.

12.2.12 Parenchymal Sparing Resection

Port placement and patient positioning dependent on location of the segment(s) being resected. Any segment(s) of the liver can be resected in isolation. The position and angle of the energy device is optimized for the segment of interest. The concepts for mobilization, parenchymal transection, hemostasis, and specimen retrieval are identical to the resection types described above.

12.2.13 Real-Time Navigation

The DICOM images from the patient's CT or MR imaging can be used to produce interactive three dimensional PDFs that can then be overlaid directly onto the surgeon console view. These PDF overlays can demonstrate the tumor's location in relation to the vascular and biliary structures in real-time. This technology can enhance the surgeon's ability to visualize the anatomy and perform a margin negative resection.

Video and images courtesy of Intuitive Surgical, Inc.. The da Vinci technology presented is still in development, is not 510(k) cleared and the safety and effectiveness of the product has not been established. The technology is not currently for sale in the US (Fig. 12.11).

12.2.14 Conversion to Open Surgery

Conversion from robotic hepatectomy to open hepatectomy has been reported to occur 0–55% of cases. In our series, we observed a conversion rate of 4.6% [13]. The most common reasons for conversion include challenging anatomy, prohibitive adhesions, hemorrhage control, and failure to progress. Conversion should not be viewed as failure, but should be performed promptly and without hesitation when indicated. Prior to conversion, a quick time-out should be performed to assign tasks and review a plan of action. It is critical to maintain calm, use direct, clear, and closed-loop communication with the nursing and anesthesia teams to ensure efficient conversion and adequate resuscitation during a potentially life-threatening scenario.

Troubleshooting:

Encountering massive hemorrhage—If rapid conversion is necessitated for hemorrhage that cannot be controlled robotically, the assistant should apply pressure to

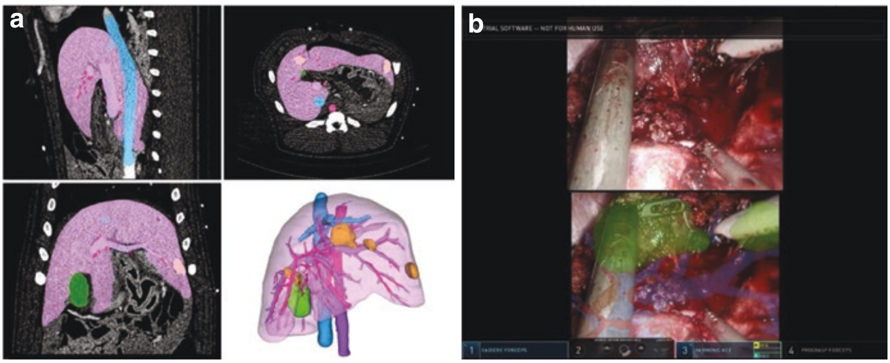

Fig. 12.11 Real-time navigation. (**a**) Interactive 3D PDFs generated from CT/MR DICOMs. (**b**) Real-time overlay of PDF onto console TilePro

the area with a vaginal pack to facilitate tamponade and temporarily minimize blood loss. A robotic instrument not in line with the planned incision, e.g. arm #4 can be used to assist in maintenance of pressure over the area of hemorrhage until the incision is made. Once open control of the hemorrhage has been obtained, the robot is undocked and removed.

12.2.15 Postoperative Course

Unless there was significant intra-operative hemorrhage, the patient is extubated in the OR, monitored for 1–2 h in the post-anesthesia care unit, and admitted to the acute care floor for recovery. Clear liquid diet is started postoperatively and advanced as tolerated on postoperative day 1. Based on our early recovery after surgery (ERAS) protocol, the patient is monitored with q1 hour x2, q2 hour x2, then q4 hour vitals with I + O's, and q8 hour hematocrit and INR measurements in the first 24 h. Daily comprehensive metabolic panel and complete blood counts are continued. The Foley catheter is removed on postoperative day 1 or 2, prophylactic subcutaneous heparin administration, aggressive ambulation and incentive spirometry is started on day 1. Hospital stay is typically 1–2 days for minor and 2–3 days for major hepatectomies.

12.3 Conclusions

Robotic hepatectomy can be performed safely with similar outcomes to laparoscopic hepatectomy with regard to length of stay, rate of complication and readmission. The steps of the operation are essentially unchanged from the conventional laparoscopic approach. The lower rate of conversion to open (compared to laparoscopy), presumably due to better visualization and hemostasis, may offset the increased costs of resources associated with the robotic approach. As experience with the robotic platform increases, the flatter learning curve for robotic hepatectomy is expected to continue to flatten further.

Conflict of Interest The authors have no conflict of interest to declare.

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Chapter 13
Laparoscopic Hepatectomy

Timothy M. Nywening, Samer Tohme, and David A. Geller

13.1 Introduction

Since the 2008 First International Laparoscopic Liver Consensus Conference, there has been a dramatic increase in minimally invasive liver resections reported worldwide [1]. As the field has evolved, laparoscopic major hepatectomies are also becoming more commonly reported and account for approximately 25% of reported minimally invasive liver resections. Overall, laparoscopic liver surgery has been demonstrated to be safe with a low postoperative mortality (0.3%) and rate of major complications (11%) [2]. The 2014 Second International Laparoscopic Liver Consensus Conference reviewed several studies which consistently reported that minimally invasive hepatectomy is associated with a decrease in hospitalization length of stay, improved postoperative pain, lower wound related complications, and reduced intraoperative blood loss compared to open hepatectomy [3]. Furthermore, minimally invasive techniques do not compromise oncologic outcomes and are associated with an improvement in time to return to intended oncologic therapy in patients with colorectal liver metastasis [4]. In the reported literature there has been no difference in margin status, recurrence rate, or overall survival following hepatectomy for primary or metastatic malignancies.

Several variations of the laparoscopic approach to hepatic resection have been described, including purely laparoscopic, hand assisted laparoscopic surgery (HALS), and the hybrid technique, in which the liver is mobilized laparoscopically

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and delivered through a small incision to complete the hilar dissection and parenchymal transection. Pure laparoscopic liver resection is the most commonly utilized approach (75%), followed by HALS (17%), with the hybrid technique being relatively uncommon (2%). A propensity score matched analysis from two high-volume centers found the HALS or hybrid techniques were not inferior with regards to morbidity or pain medication requirements compared to the pure laparoscopic approach for major hepatectomies [5]. While some surgeons advocate starting with a purely laparoscopic approach and converting to HALS or a hybrid technique when required, the authors prefer HALS as the initial procedure for planned laparoscopic hemi-hepatectomy as it facilitates mobilization, affords direct palpation of the liver parenchyma, and expediates ability to obtain vascular control if hemorrhage is encountered. The hand port may additionally be used to place and additional one to two trocars when not in use to facilitate progression laparoscopically [6].

13.2 Preoperative Assessment

At time of initial evaluation, it is paramount to remember that the indications for hepatectomy remain the same for both open and minimally invasive liver resection. For laparoscopic hepatectomy it is important to consider the patients overall health, comorbidities, ability to tolerate abdominal insufflation, risk of dense adhesions from prior surgery, and liver functional status.

Postoperative liver failure is a concern following both open and laparoscopic hepatectomy, particularly in patients with cirrhosis or liver damage secondary to chemotherapy. General recommendations to prevent postoperative liver failure from the INSTALL study reported that most experienced hepatobiliary surgeons require a functional liver remnant ≥40% [7]. INSTALL also found that most surgeons use a serum bilirubin cutoff of 2.0 mg/dL for minor (≤3 segments) and an upper limit of 1.5 mg/dL for major (>3 segments) resections to avoid postoperative liver failure. For malignant lesions, the ability to adhere to sound oncologic principles must also be considered. Tumors abutting major vascular structures, perihilar cholangiocarcinoma, and bulky tumors that may be difficult to manipulate laparoscopically are best reserved for open surgery. Additional anatomic considerations including replaced or accessory hepatic arteries and location of the target lesion within the liver are important to consider, with superficial lesions in right lobe (segments V, VI, & VIII) and left lateral (segments II & III) locations most amenable to the laparoscopic surgical approach.

13.3 Laparoscopic Right Hepatectomy

13.3.1 Patient Positioning

The patient is placed in the supine position with both arms out. Alternatively, some surgeons prefer the French lithotomy position. Like an open major hepatectomy, an orogastric tube and Foley catheter are placed, as well as a central and arterial line for intraoperative monitoring. To accommodate for the steep rotation required during the laparoscopic approach, the patient should be secured to the table using a safety strap and footboard.

13.3.2 Trocar Insertion

The authors prefer to use hand assisted laparoscopic surgery (HALS) to approach a formal right hepatectomy. First, a small (6–8 cm) upper midline incision is made, and a hand port placed, such as the GelPort laparoscopic system (Applied Biomedical). Pneumoperitoneum established (≤15 mmHg) utilizing a trocar placed through the hand port. Under direct visualization two additional 12 mm and two 5 mm ports are placed using the configuration illustrated in Fig. 13.1a.

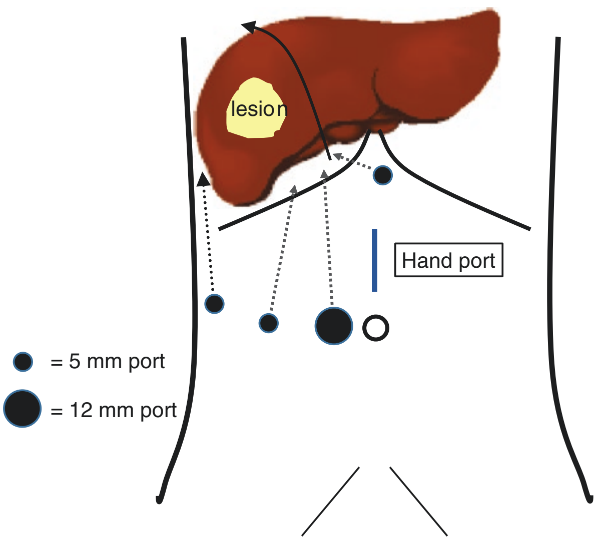

Fig. 13.1 (**a**) Port placement for laparoscopic hand assisted right hepatectomy

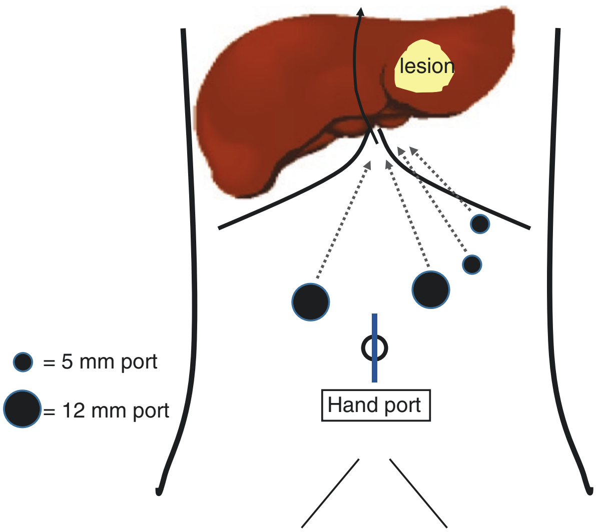

Fig. 13.1 (**b**) Port placement for laparoscopic hand assisted left hepatectomy

Troubleshooting: In the cirrhotic patient, care must be taken to avoid injury to periumbilical varices resulting from recanalization of the umbilical vein. If present, preferred trocar placement is infra-umbilical or lateral to the linea alba if supra-umbilical access is required. In the case of a petite patient (<68 inches) the hand port incision may also be moved to an infra-umbilical location. This hand port incision can also be rapidly extended if conversion to an open operation becomes required.

13.3.3 Liver Mobilization and Intraoperative Anatomical Assessment

First, the falciform is divided at the abdominal wall, leaving sufficient length to aid in retraction, and the round ligament is transected with a surgical energy device or laparoscopic stapler. Next, the right coronary and triangular ligaments are divided. Intraoperative ultrasound is used to assess the hilar structures and hepatic vein anatomy. The hepatic parenchyma should be assessed for any additional lesions and the precise location of the target lesion and its relationship to major vascular structures confirmed using color flow Doppler prior to proceeding with transection. For a right hepatectomy, the middle hepatic vein is used a landmark with the parenchymal transection plane marked with electro cautery lateral to the middle hepatic vein. For oncologic cases, wide margins should also be obtained. Following a complete laparoscopic ultrasound assessment, the plane of transection is scored along the liver capsule using electro cautery. The liver is further mobilized from the retroperitoneum by gently rotating the liver medially away from the inferior vena cava (IVC). The laparoscopic approach affords improved magnification and

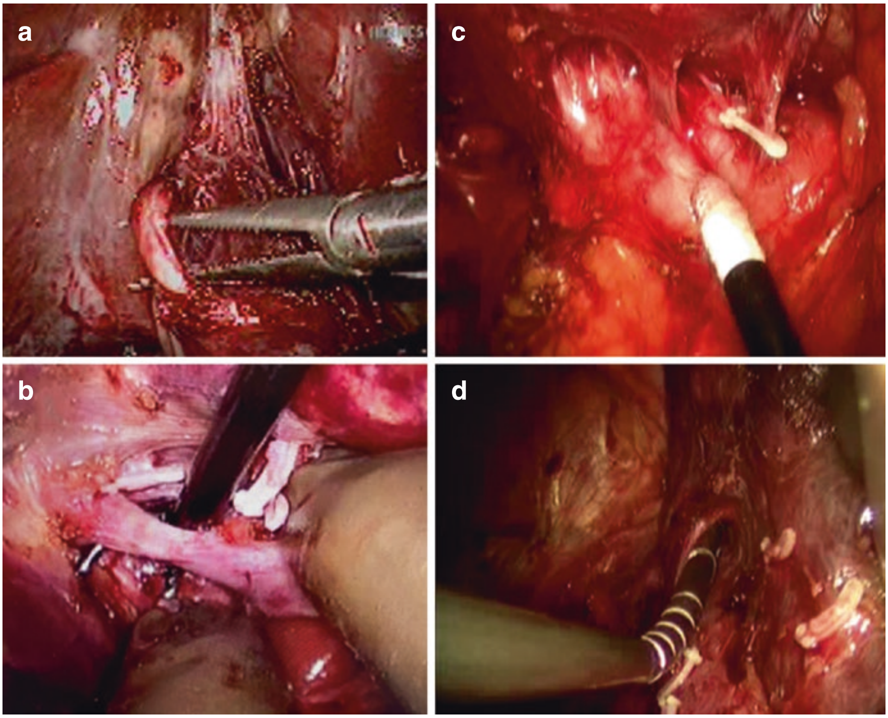

Fig. 13.2 (**a**) Right hepatic artery. (**b**) Right portal vein. (**c**) Short hepatic veins. (**d**) Inferior vena cava and right hepatic vein

exposure around the right adrenal gland and vena cava to facilitate identification of the Laennec capsule and Glissonian pedicle at the hilar plate. Using a caudal to cranial approach, the caval ligament is opened on the right, exposing the short hepatic veins arising from the IVC. These may be clipped with 5 mm hem-o-lock clips (Weck Closure System) or if small (<7 mm) can be taken using the LigaSure device (Medtronic). (Fig. 13.2c).

13.3.4 Hepatic Outflow Control

Following adequate mobilization of the liver the right hepatic vein is safely identified as it enters the retro-hepatic IVC. A window between the right and middle hepatic veins is carefully dissected. The right hepatic vein is encircled with umbilical tape (and eventually divided) at its confluence with the IVC using a laparoscopic stapler with a vascular load (Fig. 13.2d).

Troubleshooting: If exposure of the right hepatic vein is not optimal, division may be considered from an intraparenchymal approach following completion of parenchymal dissection.

13.3.5 Hilar Dissection

The round ligament remnant is used to retract the liver anteriorly toward the abdominal wall to facilitate exposure to the porta hepatis and the pars flaccida of the gastrohepatic ligament is opened, with care to avoid injuring an accessory or replaced right hepatic artery. An umbilical tape or vessel loop is placed through the foramen of Winslow to encircle the porta hepatis and may be used to perform a Pringle maneuver if required. Dissection of the right portal hilar structures begins with a standard laparoscopic cholecystectomy. After confirming a critical view of safety, the cystic artery and cystic duct are doubly clipped and divided. The cystic artery serves as a handle to expose the right hepatic artery. The right hepatic artery is secured and transected between two locking clips on the proximal aspect and a single clip distally (Fig. 13.1a). Next, the right portal vein is meticulously dissected circumferentially and transected with a laparoscopic stapler using a vascular load (Fig. 13.2b).

Troubleshooting: During the portal vein dissection, caution must be used to avoid tearing small branches draining from the caudate lobe. If the angle required for transection of the right portal vein cannot be safely obtained at this stage, an alternative approach is to use a laparoscopic vascular clamp, such as a Satinsky or bulldog, to control portal inflow and defer transecting the right portal vein until later in the parenchymal transection phase of the procedure.

13.3.6 Parenchymal Transection

As opposed to the anterior approach utilized in open hepatectomy, the laparoscopic major liver resection proceeds in a caudal to cranial fashion. This meticulous approachutilizes the improved laparoscopic magnification to optimally identify intraparenchymal structures for optimal division of the liver parenchyma. The superficial transection is started using an ultrasonic dissector and/or energy device such as the Harmonic scalpel (Ethicon), LigaSure (Medtronic), or Thunderbeat (Olympus) along the previously scored plane (Fig. 13.3c). The right hepatic duct is identified inside the liver parenchyma and transected using a laparoscopic surgical stapler. Deeper parenchymal dissection proceeds and bridging veins from the middle hepatic vein to segments V & VIII are encountered and divided with a vascular stapler load. Alternatively, some surgeons prefer the bipolar pinching forceps alone or in combination with a Cavitron ultrasonic surgical aspirator (CUSA). Like in an open hepatectomy, the central venous pressure (CVP) should be kept low (<5 mmHg) by judicious fluid management prior to initiating parenchymal transection to minimize blood loss. This can be further accomplished by placing the patient in steep Trendelenburg position to further reduce the CVP during liver parenchymal transection. Hemostasis from the cut edge of the liver surface is obtained using

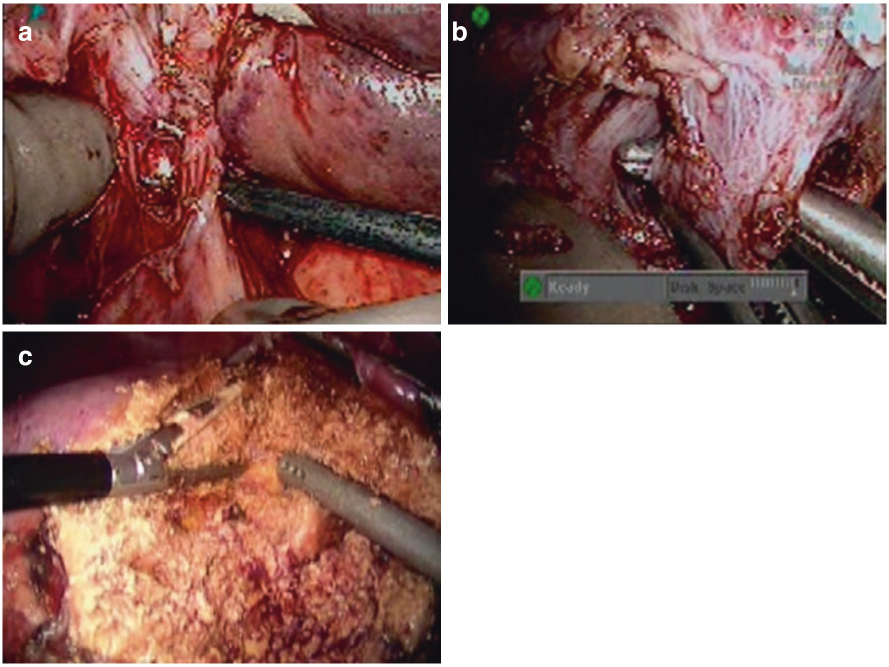

Fig. 13.3 (**a**) Left hepatic artery. (**b**) Left portal vein. (**c**) Liver parenchymal transection

electrocautery, or the laparoscopic Aquamantys system (Medtronic) combing bipolar cautery using radiofrequency in conjunction with saline to achieve hemostasis and tissue sealing. The right hepatic vein is divided last under direct vision. Note that some surgeons prefer to divide the right hepatic vein prior to mobilizing the right triangular ligament. All visible bile leaks are oversewn using a 4–0 absorbable suture. The resected right lobe is delivered through the handport for extraction. After hemostasis is confirmed, the authors place a closed suction drain terminating at the cut liver remnant edge that is brought out through a 5 mm trocar site at the completion of the case.

Troubleshooting: If the right hepatic vein has been ligated, a laparoscopic hanging maneuver may be performed by passing an umbilical tape anterior to the IVC to retract the liver away and facilitate parenchymaltran section. If the right hepatic and/or right portal veins have not been previously transected (as outlined in steps 5 & 6 respectively), this can be performedat their intraparenchymal location using a vascular staple load. If hemorrhage is encountered performing a Pringle maneuver will assist in slowing bleeding originating from a portal vein or hepatic artery. However, injury to a hepatic vein or retrocaval IVC will not be impacted by the Pringle maneuver and alternatively the intra-abdominal pressure may be increase temporarily to 20 mmHg, although this may predispose to an inadvertent air embolus.

13.3.7 Postoperative Considerations

In the immediate postoperative period, the patient should be vigilantly monitored for evidence of hemorrhage and post-operative liver failure. In addition, hypertrophy of the liver remnant will occur, and care should be taken to closely monitor and replete phosphorous levels as required. The closed suction drain should be vigilantly checked for bile to suggest an ongoing leak.

13.4 Laparoscopic Left Hepatectomy

Many of the techniques reviewed above regarding laparoscopic right hepatectomy are applied during a formal left resection. Steps that are unique to performing a laparoscopic left hepatectomy are outlined below.

13.4.1 Patient Positioning

Patient positioning is like that described for laparoscopic right hepatectomy.

13.4.2 Trocar Insertion

The position of trocar placement for a hand assisted laparoscopic left hepatectomy is modified as depicted in Fig. 13.1b.

Troubleshooting: A formal left hepatectomy may be amenable to using a purely laparoscopic approach, reserving the use of HALS for challenging cases.

13.4.3 Liver Mobilization and Intraoperative Anatomical Assessment

During mobilization and take down of the left triangular ligament, caution must be used to avoid injuring the left phrenic and left hepatic veins.

13.4.4 Hilar Dissection

The left hilar dissection starts with exposing the umbilical fissure by dividing the bridge of liver tissue connecting segment III and IVB at the base of the falciform ligament. Identifying the common hepatic duct and retracting laterally allows identification of the left hepatic artery, is secured with clips and transected (Fig. 13.3a). The hilar plate is lower to reveal the left hepatic duct and portal vein. Dissection of the left portal proceeds to obtain adequate length of the vein for division with using a vascular load (Fig. 13.3b). A hepatotomy in segment IVB is created at the lateral base of the umbilical fissure and the left hepatic duct transected with a laparoscopic stapler.

Troubleshooting: Dividing the left hepatic duct at the lateral base of the umbilical fissure avoids potential injury to a commonly aberrant right posterior sectoral duct arising from the proximal left hepatic duct.

13.4.5 Parenchymal Transection

Liver parenchymal transection using the laparoscopic approach occurs in a caudal to cranial approach along the Cantlie line medial to the middle hepatic vein, with technique similar to description for right hepatectomy (Fig. 13.3c). Use of intraoperative ultrasound greatly assists in staying in the correct transection plane.

13.4.6 Hepatic Outflow Control

In contrast to a laparoscopic right hepatectomy, the left hepatic vein is divided following completion of parenchymal dissection. The confluence of middle and left hepatic veins is identified and the left hepatic vein divided proximally, preserving outflow via the middle hepatic vein. Depending on tumor location, sometimes the middle hepatic vein and/or caudate lobe also need to be divided and removed with the formal anatomic left hepatic lobectomy.

Troubleshooting: Identifying the left hepatic vein trunk laparoscopically is often challenging. If a pure laparoscopic approach is being used, consideration should be given to using a hand port to ensure optimal identification of the left hepatic vein.

13.4.7 Postoperative Considerations

Care in the postoperative period is like that outlined previously following a laparoscopic right hepatectomy.

13.5 Summary

Overall, laparoscopic liver resection is increasingly being performed safely and offers several potential benefits compared to open surgery. Careful patient evaluation and selection, along with increasing laparoscopic liver experience allows for the application of minimally invasive surgical techniques in major hepatectomies.

Conflict of Interest Statement The authors have no conflicts of interest to declare.

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Chapter 14
Laparoscopic-Assisted Ablation of Liver Tumors

David A. Gerber

14.1 Introduction

Hepatocellular carcinoma is a world-wide clinical problem with >800,000 new cases diagnosed per year. According to the World Health Organization this cancer is the fifth most common tumor and the second most common cause of cancer-related deaths [1]. In the United States the incidence of hepatocellular carcinoma continues to rise secondary to prior viral infections with the hepatitis viruses and other conditions (e.g. nonalcoholic steatohepatitis, etc.) that lead to inflammation, liver fibrosis and cirrhosis [1, 2]. The approaches to successfully treat patients with hepatocellular carcinoma has expanded over the years and therapeutic plans can now be developed based on tumor stage and the underlying state of the patient's liver disease since the majority of patients developing hepatocellular carcinoma have chronic liver disease. Multiple investigators and societies have developed guidelines regarding management of patients with hepatocellular carcinoma. Both the American Association for the Study of Liver Disease (AASLD) and the European Association for the Study of Liver Disease (EASL) have practice guidelines which state that resection for patients with cirrhosis who are a Child-Pugh class A (patients with well compensated liver disease) can be performed with high degrees of success and low morbidity to the patient. There is also general consensus that those patients with advanced liver disease, Child-Pugh class C (i.e. large volume ascites, severe portal hypertension, etc.) are not candidates for surgical resection [1, 3, 4]. The Barcelona Clinic Liver Cancer (BCLC) algorithm also provides guidance in patient management based on tumor stage and the underlying liver disease. In this algorithm only

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patients with well-preserved liver function and small tumors are resection candidates. It essentially limits resection to those patients who are classified as Child-Pugh A cirrhosis while recommending liver transplantation for those patients with more advanced liver disease (e.g. patient with decompensated liver disease secondary to their cirrhosis). Unfortunately, in the United States and Europe the majority of patients presenting with hepatocellular carcinoma have already had progression of their chronic liver disease so resection is only an option for a small percentage of patients.

14.2 Clinical Presentation

Diagnosing hepatocellular carcinoma requires the clinician to proactively identify that a patient has significant clinical risks that contribute to the development of this malignancy and the single most important risk is the presence of cirrhosis. Not all patients with cirrhosis are at equal risk of developing hepatocellular carcinoma and not all patients with hepatocellular carcinoma have cirrhosis. Another way of analyzing this risk involves understanding that the incidence of hepatocellular carcinoma in patients with cirrhosis is approximately 2–4% per year after they have developed cirrhosis [1]. Other factors besides cirrhosis contribute to the risk of developing hepatocellular carcinoma and these include underlying hepatitis viral infections, alcohol consumption, age, persistent transaminitis, and gender. The challenge in diagnosing patients with hepatocellular carcinoma is the fact that the tumor typically has to be detected during a period of time when the patient is asymptomatic, because by the time a patient develops symptoms associated with the diagnosis of hepatocellular carcinoma they no longer have curative therapeutic intervention options. Improvements in radiographic imaging has allowed practitioners to develop a multi-modal surveillance strategy where they can make the diagnosis of hepatocellular carcinoma prior to progression of the neoplasm. The evidence supporting surveillance is driven by the demonstration of disease progression and that potentially curative treatments can more frequently be applied in screened populations. Another way of saying this is that active surveillance is the most common approach leading to the diagnosis of hepatocellular carcinoma at a time when therapeutic interventions can be performed.

14.3 Diagnostics

While ultrasound is used for initial surveillance the resolution of the study doesn't provide enough detail to confirm a diagnosis of hepatocellular carcinoma. In patients with cirrhosis and suspected hepatocellular carcinoma, cross-sectional imaging is used to noninvasively verify the presence of hepatocellular carcinoma (diagnosis) and determine the extent of disease (radiological staging). The intent of using CT or

MRI are to measure tumor burden and guide management. Unlike most other malignancies, the diagnosis of hepatocellular carcinoma can be established noninvasively, and treatment may be initiated based on imaging without a confirmatory biopsy. The rationale is that in patients with cirrhosis, the pretest probability of hepatocellular carcinoma is sufficiently high, and the pretest probability of lesions that may mimic hepatocellular carcinoma at imaging is sufficiently low such that a lesion meeting hepatocellular carcinoma imaging criteria can be assumed reliably and confidently to be hepatocellular carcinoma [5]. Although there is strong consensus that the imaging diagnosis of HCC requires multiphasic imaging, there is no agreement about which diagnostic imaging test to use [6]. Commonly used methods in clinical practice include multiphasic CT with extracellular agents, multiphasic MRI with extracellular agents (gadolinium-based compounds that stay in the extracellular space and permit characterization of blood flow), and multiphasic MRI with gadoxetate disodium (a specific gadolinium-based compound that accumulates in hepatocytes and permits characterization of hepatocellular function in addition to blood flow) [1, 6]. After making the diagnosis of HCC using cross-sectional imaging the decision-making for therapeutic intervention is based on the degree of portal hypertension and level of hepatic dysfunction.

The American Association for the Study of Liver Disease (AASLD) recently published guidelines regarding the diagnosis and treatment of hepatocellular carcinoma. Stage T1 and T2 hepatocellular carcinoma include a wide range of tumor sizes from <1 cm to 5 cm, and the effectiveness of available therapies depends on the size, number, and location of the tumors. Smaller single tumors (<2.5 cm) that are favorably located may be successfully treated by ablation or resection depending on the patient's underlying hepatic function while bilobar tumors or centrally located tumors are typically not resectable [1]. The most frequent presentation of HCC is in the setting of cirrhosis. These patients are not eligible for hepatic resection due to insufficient hepatic reserve and they are subsequently evaluated for alternative treatment options including thermal ablation [7]. Larger tumors defined as tumors >3 cm, multifocal lesions, or a tumor location near major vascular or biliary structures potentially limit ablative options.

14.4 Ablation Technology

Thermal ablation encompasses a broad set of technologies. Tissue temperatures of the tumor and the immediately surrounding liver parenchyma can be altered to high or low extremes to induce cell death. The most commonly used approaches in the liver are the heat induction modalities radiofrequency ablation (RFA) and microwave ablation (MWA) [8, 9]. Beginning in the 1990s there was growing enthusiasm for thermal ablation delivered by radiofrequency followed by the development of microwave technologies [10, 11]. RFA uses a flux of high-frequency alternating current passing through an insulated needle shaft to an unprotected needle tip in the tumor which dissipates into the surrounding tissue and subsequently generates a rapid vibration of ions in the tissue and frictional heat [11]. The radiofrequency generator provides an alternating current causing the oscillation of ions, resulting in a tissue temperature of up to 100° C. This energy is conducted into the surrounding tissue in a predictable manner resulting in coagulative necrosis. The increase in local temperature results in protein denaturation, ultimately leading to cellular destruction and tissue necrosis [12]. Unfortunately the presence of a heat sink can occur near medium to larger vessels along with an increase in the patient's core temperature. These unpredictable changes in temperature are issues that can limit the ability to achieve maximal tissue temperatures [11]. Microwave energy ablation functions through a different mechanism, however, it provides a similar result. Microwave ablation uses energy from collision of water molecules at microwave energy levels to release heat and cause degeneration of surrounding liver tissue [10]. The microwave generator produces electromagnetic radiation (EMR) within the microwave spectrum which is absorbed by water molecules. This electromagnetic radiation causes molecular rotation, resulting in the creation of thermal energy within the tissue leading to coagulative necrosis [13]. In both techniques the ablation zones are determined by regulating the amount of energy supplied and by the time the tissue is exposed to the energy source. Image-guidance via ultrasound, CT or MRI is a critical adjunct to successful ablation of hepatocellular carcinoma [8, 10].

While radiofrequency ablation technology has been around for a longer period of time microwave ablation has been adopted by many clinicians as the preferred treatment approach for primary and secondary malignancies in the liver since it is less impacted by "heat sinking" near blood vessels and the time to achieve complete ablation is quicker [10, 14]. The most common applications are in patients with hepatocellular carcinoma followed by an application for patients with hepatic metastases from colorectal carcinoma [10, 15–18]. Liver tumor ablation can be approached via a percutaneous route but in select cases will require laparoscopic assistance to perform the ablation. The indications for laparoscopic MWA can be divided into patient-specific and tumor-specific categories.

The first laparoscopic procedure was experimentally performed in 1901 and by the end of the twentieth century technological and engineering advancements in lens design and optical projection moved laparoscopy into a clinically integrated procedure with global acceptance [19]. The field has progressed from a purely diagnostic instrument to one capable of advanced intervention. Over the last 15 years, there has been a growing interest in utilizing laparoscopy to facilitate the delivery of thermoablative therapies for primary and secondary tumors of the liver and a laparoscopic approach is now well established for this patient population [10, 20]. In select patients with advanced liver disease complicated by ascites and severe portal hypertension there is a higher risk of complications if the clinician is taking a purely percutaneous approach. Performing the ablation with laparoscopic assistance allows the surgeon to reduce the impact of these risks but it requires the technical ability to identify target lesions using real-time intraoperative ultrasound.

When anatomic resections are not possible, the necessity for complete ablation is vital. Incomplete laparoscopic ablation rates can range between 5.6% and 13% [21, 22] and local recurrence rates range from 2.9% to 22% [21–23]. In addition to local recurrence intrahepatic recurrence and the development of de novo malignancies poses a significant clinical challenge. In a retrospective review of 92 patients undergoing laparoscopic RFA for hepatocellular carcinoma, Karabulut et al. noted a new liver recurrence in 57% of patients with a median follow-up of 19 months. This was in comparison to a 46% recurrence rate in 92 patients undergoing liver resection for HCC ($p = 0.167$) [23]. Similarly, Santambrogio published a regional recurrence rate of 30% after laparoscopic RFA for hepatocellular carcinoma in 102 patients during an unspecified time of follow-up [22].

Patient survival after laparoscopic-assisted thermal ablation has also been reported in the literature. Swan et al. published a 1 year survival rate of 72.3% in 54 patients with hepatocellular carcinoma and cirrhosis after laparoscopic MWA [21]. Berber et al. found a similar 1 year overall survival of 78% after laparoscopic RFA in 66 cirrhotic patients with hepatocellular carcinoma [18]. Ballem et al. describe a 3 year survival of 21% in 104 patients undergoing 122 ablations for hepatocellular carcinoma using radiofrequency [17]. In the 66 patients presented by Berber et al., a 3 year survival of 38% was achieved [18] while other groups have published five year survival rates ranging from 8.3% to 21% [17, 23]. Several authors have shown an increased survival advantage based on Child class [18, 21, 24]. Swan et al. show a 1 and 2 year overall survival rate of 71% and 63% for Child A patients, but this drops to 65% and 52% in Child B and Child C respectively [21]. Ballem et al., and Berber et al. found similar median survival in their respective subgroup analyses based on the degree of hepatic dysfunction. In both studies, median survival for Child A was 28–29 months, but only 5–5.9 months for Child C patients [17, 18].

14.5 Preoperative Assessment

Patients diagnosed with cirrhosis and hepatocellular carcinoma must be properly assessed to determine their risk of morbidity associated with a laparoscopic assisted ablation procedure. Portal hypertension can be assessed by several ways including endoscopic evaluation for the presence of varices, the degree of splenomegaly or severity of thrombocytopenia. There is general agreement that a platelet count ≤100 10 × 9/L is a surrogate for the diagnosis of severe portal hypertension. While the degree of portal hypertension and/or level of thrombocytopenia is a relative contraindication for open hepatic surgery the same degree of portal hypertension isn't a contraindication to proceeding with laparoscopic surgery although it is a variable that must be considered. From an experiential standpoint a platelet count >30 10 × 9/L is not associated with a higher bleeding risk at the time of laparoscopic ablative surgery if the degree of thrombocytopenia is only secondary to portal hypertension. It is important to differentiate those patients with severe thrombocytopenia secondary to splenomegaly from those patients with an underlying platelet disorder. In addition to the degree of thrombocytopenia the patient should undergo routine laboratory screening including serum albumin level, total bilirubin, coagulation studies and a serum alpha-fetoprotein level. In addition to bloodwork it is important to evaluate the patient for the presence of encephalopathy or ascites, both of which are common complications of chronic liver disease. Either before or after completing the clinical examination the provider should review the patient's medication list paying special attention to the prescription of diuretic agents. These are used to control a patient's ascites which can lead the provider to under appreciate the degree of liver dysfunction based on physical exam. The chemistries, physical exam and imaging provide an assessment of the degree of liver dysfunction and contribute to calculating a patient's Child-Pugh class along with their MELD score. Both scoring systems provide a mechanism to stratify the degree of hepatic dysfunction secondary to cirrhosis and allow the surgeon to determine the risks associated with surgery. Patients with large volume ascites are at higher risks of perioperative complications during the laparoscopic procedure. Therefore proactive strategies to manage the ascites, including diuretic therapy or performing a large volume paracentesis several days prior to the scheduled ablation, should be considered for the patient prior to undergoing ablation of the hepatocellular carcinoma. This approach helps minimize fluid shifts at the time of the operation and also lowers the risk of wound infection and bleeding secondary to the ongoing presence of ascites.

14.6 Technique

14.6.1 Patient Positioning and Port Placement

To perform a laparoscopic assisted liver ablation the surgical case is set-up using an approach that is similar to other abdominal laparoscopic procedures. The patient is positioned supine and should have adequate vascular access. These patients do not routinely need central venous access or arterial hemodynamic monitoring. The average duration of the procedure will vary based on experience of the primary surgeon, the number of lesions to be treated and the location of the lesions. We have treated >1000 tumors and the duration of the procedure averages <2 h. The patient undergoes general endotracheal anesthesia and receives a single dose of intravenous antibiotics prior to skin incision. We prep and drape the abdominal cavity to provide access for multiple port placement. The initial incision is made in an infraumbilical location for placement of a 12 mm laparoscopic port (Fig. 14.1). This port is selected so that the laparoscopic ultrasound probe can be introduced into the abdominal cavity and we can have access to all segments of the liver. The abdomen is insufflated to a pressure of 12 mm Hg allowing visual access throughout the abdominal cavity. The next port is a 5 mm port placed in either the right or left lower quadrant inferior to a horizontal line at the level of the umbilicus and lateral to a mid-clavicular vertical line (Fig. 14.1). We use a 30-degree 5 mm laparoscope to assist with achieving broad visualization of the liver. Additional 5 mm ports can be placed as needed based on the location of the tumor, morphology of the liver and the patient's body

Fig. 14.1 Intraoperative view demonstrating placement of an infraumbilical 12 mm laparoscopic port and a left lower quadrant 5 mm port

habitus. These ports can provide access for a retractor, suction catheter or to provide a different view of the dome of the liver.

Troubleshooting

Entering the abdomen of a patient with severe portal hypertension can have several challenges. The patient will likely have varices in the subcutaneous tissue as well as varices in the falciform ligament. An inadvertent laceration of a varix can lead to rapid blood loss which is difficult to control. This is the reason that our first port is placed using an open technique and we place this incision caudal to the umibilicus as the varices associated with the falciform ligament are commonly located cephalad to the umbilicus. Another challenge in the cirrhotic patient is the presence of ascites. Low volume ascites can be easily aspirated and for patients with moderate to severe ascites we have adopted the approach of performing a large volume paracentesis 2–4 days before the surgery. If the patient does have significant (>1 L) ascites at the start of the procedure the surgeon needs to take several steps to manage the intraoperative volume shifts as well as the increased bleeding risk. The first step is to aspirate as much of the ascites as possible while the anesthesia team infuses the patient with intravenous albumin. This helps minimize unintended hypotension which is exacerbated by acute fluid loss in the setting of a pneumoperitoneum. It is important to have the intraabdominal cavity as empty as possible at the end of the case as we have found that the presence of ascites can lead to ongoing bleeding from the ablation site and also causes incisional breakdown and dehiscence. In cases where we haven't been able to pre-drain the ascites and we found a large volume at the time of surgery we leave an intraabdominal surgical drain at the end of the ablation procedure so that we can daily paracenteses and keep the abdomen decompressed for the first week after surgery.

14.6.2 Laparoscopic Ultrasound

A critical step in performing the laparoscopic liver ablation procedure involves the ability to perform laparoscopic-assisted ultrasonography. This is a skill-set that requires the clinician to translate the location of a tumor(s) from cross-sectional imaging (e.g. MRI, CT) to the comparable segmental location in the liver. We use either a 4-way flexible laparoscopic ultrasound or a rigid laparoscopic ultrasound probe to identify the tumor and to subsequently target the ablation antenna into the tumor. The ultrasound probe is introduced through the infraumbilical port. To improve access to the liver and the tumor we frequently place the patient in a reverse Trendelenburg position with a maximum angle of 30°. The patient can also be rotated in a right- or left- lateral position, as needed. The liver can also be manipulated with a retractor if the tumor is located in a cephalad position (Fig. 14.2). The ultrasound probe is methodically swept across the surface of the liver with particular attention focused on the segment where the tumor was previously identified on the cross-sectional imaging (Fig. 14.3).

Troubleshooting
Ultrasonography is one of the most challenging portions of the operation as the patient's underlying cirrhosis makes it difficult to easily identify the suspicious nodule from surrounding regenerative nodules. Adjusting the frequency of the ultrasound and the depth of the signal is important as this allows the surgeon to achieve

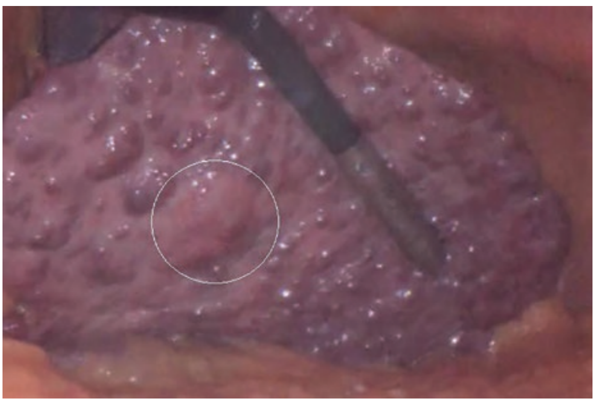

Fig. 14.2 Intraoperative view of the liver. The laparoscopic ultrasound probe is reflecting the left side of the liver anteriorly and the white circle demonstrates the hepatocellular carcinoma tumor

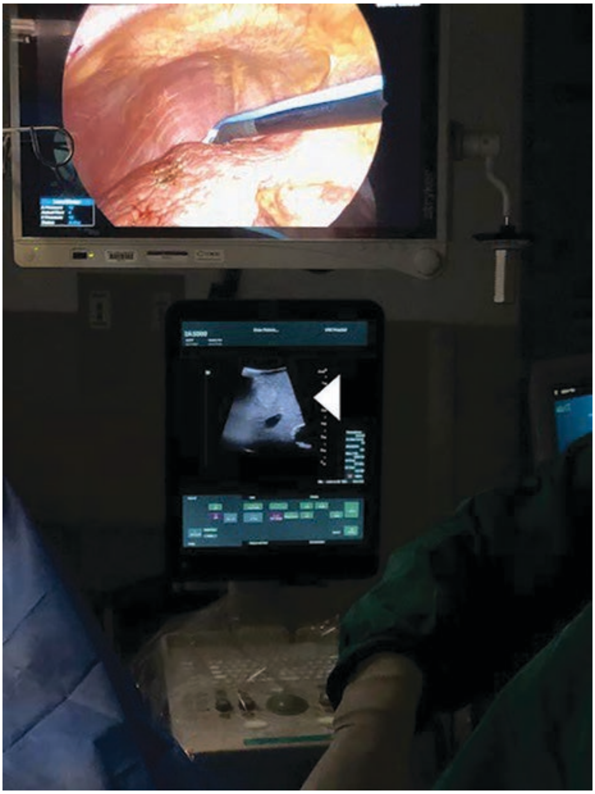

Fig. 14.3 Simultaneous view of the laparoscopic ultrasound probe scanning segment 8 of the liver. The ultrasound image demonstrates the tumor in segment 8 highlighted by the white arrowhead

enhanced acoustic imagery and minimizes distractors when you are studying the liver. The surgeon should be mindful to not over-magnify the image as this leads to a loss of physical spacing in the abdominal cavity. It is also important to be using an ultrasound system that is dedicated for operative performance. The probe selection and generator are designed to help enhance your imaging ability.

14.6.3 Microwave Ablation Procedure +/− Biopsy

In those cases where we are planning a biopsy of the tumor it is best to line up the ultrasound and biopsy in-plane as it will help with targeting. We prefer to use a spring-loaded needle biopsy system as it can be performed with one hand. Achieving hemostasis after the biopsy can typically be accomplished with electrocautery.

For the microwave ablation there are several microwave generators available and we currently use the 2.45 GHz, 14 G microwave antenna (Emprint, Medtronic, Boulder, CO). From a technical approach it is easiest to orient the antenna entry into the abdominal cavity so that it enters in-plane with the orientation of the ultrasound

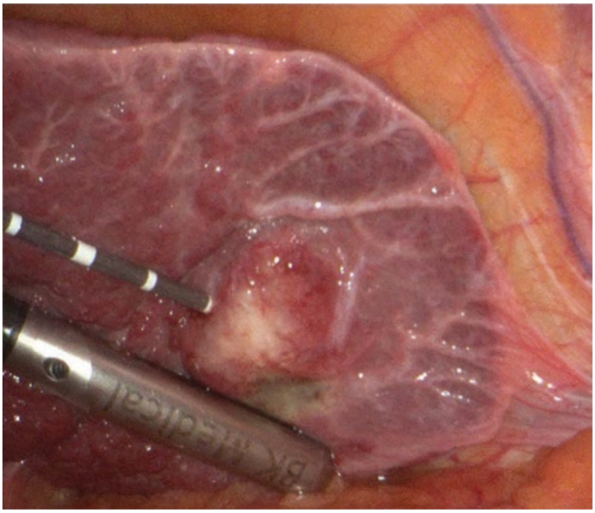

Fig. 14.4 The microwave ablation antenna is placed into the center of the tumor and the capsule demonstrates tissue change secondary to the microwave ablation. The laparoscopic ultrasound probe sits immediately adjacent to the tumor, reflecting the liver off the stomach

probe (Fig. 14.4). The antenna is inserted through a skin incision in the ipsilateral subcostal region. The generator is set between 75 and 100 watts (W) for 5–10 min based on the projected size of the ablation zone. Ideal ablations will create a 0.5–1.0 cm margin of treated tissue around the tumor. The targeting of the antenna and placement into the tumor and surrounding tissue is performed under real-time visual and ultrasonographic guidance (Fig. 14.5). To achieve a complete ablation the antenna may be repositioned in the liver to create overlapping treatment zones. For superficial or exophytic lesions, an initial 5 min ablation at 50 W is performed to minimize the risk of disruption of the liver capsule, followed by an ablation cycle at 75–100 W. When each treatment is completed and the antenna is ready to be removed from the liver we perform a technique called “track ablation” by setting the generator at 100 W while removing the antenna and ablating every centimeter of parenchyma for 2–3 sec along the path of the needle track.

After removal of the microwave antenna the ultrasound probe is removed and the abdomen is inspected for evidence of bleeding. The abdominal cavity is desufflated in a controlled fashion and the ports are removed. The fascia of the infraumbilical incision is closed with interrupted absorbable suture and the skin sites are subsequently closed with absorbable suture.

Troubleshooting

There are numerous pitfalls during the ablation procedure. It is important for the surgeon to map out the path and trajectory of the microwave antenna before they puncture the capsule of the liver with the antenna. The surgeon needs to avoid inadvertently placing the microwave antenna in a path that won’t allow them to get to the actual tumor. Ideally the surgeon is looking to place the antenna between one-half to two-thirds of the way across the diameter of the tumor as this will provide an optimal field of treatment. If the antenna is unintentionally placed in a plane that

Fig. 14.5 Ultrasound image of the microwave antenna within the tumor. The white arrow demonstrates the tumor and microwave antenna

won't allow the surgeon to get to the tumor, they can track ablate while withdrawing the antenna and reposition for a better trajectory. Other challenges are when the targeting places the antenna off-center of the intended target. In this event the surgeon can complete the ablation and perform a series of one or more overlapping ablations so that the entire tumor is treated. The challenge with performing overlapping ablations is that the energy field from the microwave obscures the surgeon's ability to perform real-time ultrasound. In that situation the surgeon must wait approximately 5–10 min at which time the ultrasound field will return to baseline and the surgeon can reposition the microwave antenna. Another critical area to troubleshoot involves avoiding the vasculature of the liver. This is best done in the pre-deployment phase of the microwave antenna. The surgeon should adjust the ultrasound image to provide a wider view of the liver and the intrahepatic vessels and slowly zoom in on the area of interest. In the event that the antenna does go through a small to medium sized vessel the microwave energy will coagulate vessels up to 5 mm in diameter. To successfully control for hemorrhage the surgeon can perform a longer track ablation at 100 watts thereby coagulating more of the parenchyma around the vessel. Another approach to achieving hemostasis involves repositioning the antenna in an adjacent area of the track and coagulating the parenchyma for short periods of time at 100 watts. These approaches do increase the risk of thrombosing a larger vessel and therefore it isn't a recommended first-line approach.

14.7 Post-Operative Management

Patients are typically discharged home several hours after completion of the procedure. We obtain a baseline surveillance imaging study approximately one month after the ablation to determine if the targeting and ablation energy adequately treated the tumor. This imaging can also be done earlier as an experienced abdominal radiologist will be able to verify placement of the antenna. Subsequent surveillance imaging is performed at 3 month intervals for the first year as there is a 10% risk of recurrent disease during the first year after diagnosis of hepatocellular carcinoma.

14.8 Conclusions

The introduction of laparoscopic-assisted ablation of hepatocellular carcinoma has been associated with overall improvements in patient survival after a diagnosis of HCC in the setting of cirrhosis. Over the last two decades more surgeons have begun to adopt this technology and the subsequent broader experience has provided an enhanced understanding of which patients will tolerate the procedure and how it can be used successfully. With the increased application of laparoscopic ablation we also have a better understanding of the safety risks associated with this procedure. Published complication rates have been reported as high as 20% [10, 21, 25, 26]. Our current experience with laparoscopic thermal ablation has allowed us to treat a broader pool of patients with lesions located in difficult anatomic regions of the liver. Our center's experience has also allowed us to use laparoscopic-assisted ablation as a curative treatment for select tumors. With increased experience we have seen the procedure time become quicker and the risk of major complications associated with the procedure have been lower than the published data. Nevertheless, the complication rates with microwave ablation will always be higher than other minimally invasive procedures as most of the morbidity risk is related to the patient's underlying liver disease, rather than the modality itself.

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Chapter 15
Laparoscopic Whipple

Filipe Kunzler and Horacio J. Asbun

Learning Objectives
- To get familiarized with:
  - Steps of a laparoscopic pancreatoduodenectomy
  - The importance of preoperative planning
  - The importance of following outcomes
- To better understand the commitment required to learn laparoscopic pancreatoduodenectomies

15.1 Introduction

The first pancreatic resections are credited to Trendelenburg in 1882 and Codivilla in 1898, who performed the first left pancreatectomy (LP) [1] and pancreatoduodenectomy (PD) [2], respectively. Whipple performed his first PDs in 1935, with 37 of such operations in his entire career and a mortality rate of 33%. Considered one of the most complex operations in the abdomen, the mortality rate was the greatest deterrent of this type of surgery throughout the twentieth century [3]. This scenario only changed in the mid 80s, when the first series reporting mortality rates under 5% made PD a viable therapeutic option [4].

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Laparoscopic Pancreatoduodenectomy (LPD) was first reported by Gagner and Pomp in 1994 [5]. The authors concluded that “although technically feasible, the laparoscopic Whipple procedure may not improve the postoperative outcome or shorten the postoperative recovery period”. This impression persisted in their first 12-patient case series, as they concluded that there was no associated benefit to the patient, but rather increased morbidity [6]. Cuschieri, another laparoscopic pioneer, considered the procedure to be inadvisable in 1996, after reporting 3 cases [7]. Only few surgeons thereafter persisted in attempting perfecting the technique as advances in technology and the experience gathered from other complex laparoscopic procedures culminated in improved results. In 2007 Palanivelu was the first to report good outcomes in a series of 42 patients undergoing LPD [8]. The procedure was, nevertheless, slow to be adopted until recent years, in which multiple manuscripts have been published [9, 10].

A systematic review of the literature was undertaken in the Miami International Guidelines on Minimally Invasive Pancreas Resection in 2019. Over 70 experts reviewed 694 manuscripts to produce evidence-based recommendations, which were endorsed by nine surgical societies. The evidence reiterated the need of high-volume centers and a long learning curve required for MIPD [11].

Minimally invasive PD was compared to open in three randomized controlled trials. Two of them favored the MIS group, showing decreased LOS with similar or better major complication profiles [12, 13]. Conversely, the third trial had to be prematurely stopped because of a higher 90-day mortality rate in the MIS group [14]. The authors state that there was concern with the learning curve of the participating surgeons. Indeed, low center volume is associated with higher 30 and 90-day mortality, especially in laparoscopic surgery [15]. All of these findings suggest that MIPD is safe and may have better outcomes, but remains being a complex procedure, requiring expertise and a high surgical volume for its benefits to be more evident.

The progresses in neoadjuvant treatment have significantly improved tumoral response and appear to be increasing the number of patients that finally reach a surgical stage. This poses a new challenge to the pancreatic surgeon. The progress made in pathological responses comes at the price of a more laborious surgery, greater operative times and potential for increased intraoperative blood loss [16]. The MIS approach may play a more important role in those difficult cases, in which the inherent magnification, better access, and a more meticulous dissection are of significant benefit. However, this type of operation does demand significant expertise in either the laparoscopic or robotic approaches to pancreatoduodenectomy.

15.2 Clinical Presentation

Surgical patients usually present in three clinical scenarios: symptoms related to the presence of the pancreatic mass, as an incidental finding, or through follow-up/screening of a pre-malignant lesion/high risk factors.

Table 15.1 Indications for pancreatic cancer screening based on genetic factors and family history

Criteria	Age to start screening
Peutz-Jeghers syndrome	40
Carrier of BRCA 1/BRCA 2 and 1 FDR	45–50 or 10 years younger the youngest relative
Carrier of PALB2 and 1 FDR	45–50 or 10 years younger the youngest relative
ATM and 1 FDR	45–50 or 10 years younger the youngest relative
Carrier of MLH1, MSH2, MSH6[a] and 1 FDR	45–50 or 10 years younger the youngest relative
Patient with a FDR that in turn also has one FDR	50–55[b] or 10 years younger the youngest relative

Note: FDR—First degree relative affected with pancreatic cancer
[a]Lynch Syndrome
[b]No consensus reached

The classic presentation of pancreatic head tumors is painless jaundice and weight loss. However, while the majority of patients have jaundice on presentation, only 50% of them are actually without any pain. Jaundice prompts the patient to seek medical attention and appears to lead to an earlier diagnosis [17]. The most common pathologies that present with jaundice are pancreatic adenocarcinomas, ampullary neoplasms, neuroendocrine tumors and distal cholangiocarcinomas [18]. It is also important to keep pancreatic cancer in the differential diagnosis of patients that present with new onset of diabetes or sudden worsening [19]. Similarly, cancer could present as acute pancreatitis, especially in the ones newly diagnosed and of unknown etiology [20]. Patients with chronic pancreatitis also have a higher incidence of pancreatic cancer.

Pancreatoduodenectomies are also performed for incidentally found lesions. The most common incidental findings are neuroendocrine tumors, cystic neoplasms of the pancreas, duodenal adenomas and choledochal cysts [21–23].

Screening of pancreatic cancer becomes more common as we better understand the genetic mutations associated with the disease. It is suggested that screening should be done on patients that have a life-time risk of developing cancer that is >5% (or five-fold increased relative risk). Screening should start with MRI/MRCP, EUS and fasting blood glucose/HbA1c at the corresponding ages depicted in Table 15.1 [24].

15.3 Preoperative Evaluation

Preoperative evaluation is focused mainly on assessing the malignant potential of the lesions, its relation with surrounding structures, and presence of metastatic deposits. Pancreatic lesions range from benign to premalignant and malignant. The relationship with surrounding structures basically entails defining resectability by assessing contact with adjacent vessels, particularly the celiac trunk, common hepatic artery, superior mesenteric artery, superior mesenteric vein and portal vein.

Metastasis might be an absolute contraindication for surgery for pancreatic adenocarcinomas, but only relative contraindication for duodenal adenocarcinomas or neuroendocrine tumors.

The preoperative evaluation before a pancreaticoduodenectomy requires a pancreas protocol image study, preferably magnetic resonance image (MRI). Other diagnostic modalities may include endoscopic retrograde cholangiopancreatography (ERCP), endoscopic ultrasonography (EUS) with core needle biopsies (CNB), depending on the clinical presentation.

15.3.1 Magnetic Resonance Image (MRI)

Pancreas protocol MRI consists of T2, T1 and diffusion weighted images. In summary, T2-weighted images are used to identify the transition points in the biliary and pancreatic ducts, to localize the lesion. Coronal T2 sequences are especially important for ampullary lesions as they allow for the assessment of extension of the lesion inside the biliary duct. T2 images also provide easy visualization of cystic lesions and allow for differentiation between main-duct and side-branch IPMNs. T1 images are acquired pre-contrast and in arterial (0 sec), portal (45 sec), venous (2 min) and delayed phases (5 min). The precontrast images provide optimal contrasting between the normal pancreas, which has high signal intensity (white), and the tumors, which have a moderate signal intensity (gray). Pancreatic adenocarcinomas tend to start enhancing in an heterogenous fashion between the venous and the delayed phases. Neuroendocrine tumors tend to enhance in the arterial phase and progressively washout. Enhancement is also an important clue to identify worrisome features in cystic neoplasms, namely nodularity and septal enhancement [25].

15.3.2 Endoscopic Ultrasonography (EUS)

The advent of EUS has greatly facilitated the biopsy of pancreatic lesions. Sampling the lesions is an essential step for confirming diagnosis in patients that have borderline resectable disease and will require neoadjuvant treatment. It also allows for differentiating mucinous cystic lesions from other types of cysts [23, 26]. Nevertheless, the combination of jaundice and double-duct sign, that is, dilatation of the biliary and pancreatic ducts, is highly associated with malignancy [24, 27]. In such scenarios, biopsies are usually avoided if the lesion is localized and amenable to upfront resection [26, 28].

15.3.3 Endoscopic Retrograde Cholangiopancreatography (ERCP) and Duodenoscopy

Endoscopic interventions serve two purposes: diagnosis and treatment. Duodenoscopy may provide direct visualization of duodenal and ampullary lesions while ERCP may provide fluoroscopic or direct visualization of biliary lesions through cholecochoscopy. Both modalities allow for tissue sampling. ERCP has the additional benefit of reestablishing the flow of bile through the placement of biliary stents. If the patient is borderline resectable and will likely benefit from neoadjuvant chemotherapy, an uncovered metallic stent firmly adheres to the biliary tree and has to be avoided in favor of fully covered or plastic stents. The stent should be placed as distal in the biliary tree as possible, not to harm the transection of the biliary tree during surgery.

15.4 Surgical Technique: Laparoscopic Pancreatoduodenectomy

15.4.1 Operative planning

Planning the operation will largely rely on the images. The authors prefered image modality is the MRI, done with an interval no greater than 4–6 weeks before the surgery. In brief, planning consists in assessing the location of the lesion and its relationship to the CHA/PV-GDA-SMA/SMV vascular network complex. Expect that lesions in the superior part of the complex will make the dissection of the GDA more difficult (Fig. 15.1a). Lesions in the proximity of the SMV and PV will also

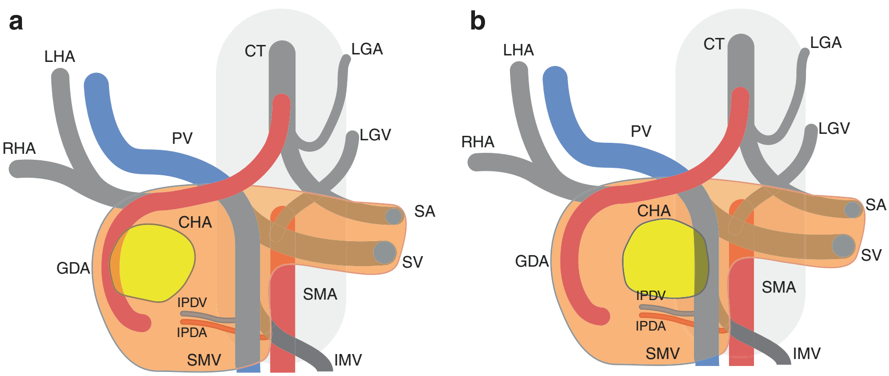

Fig. 15.1 Preoperative planning. (**a**) has the tumor more laterally, (**b**) has the tumor more medial

make the dissection of the uncinate process more complex, and may lead to portal vein resection and reconstruction (Fig. 15.1b). Also assess and take notes of anatomical variations while doing the preoperative planning.

Preoperative planning is based on the tumor location (represented in yellow) and the vessel network in the head of the pancreas. Tumors in the superior aspect of the head of the pancreas are closer to the gastroduodenal artery (GDA) and common hepatic artery (CHA) (Fig. 15.1a). Tumors in the medial aspect are closer to the superior mesenteric vein (SMV) and might require a venous resection (Fig. 15.1b). PV—portal vein, IMV—inferior mesenteric vein, RHA—right hepatic artery, LHA—left hepatic artery, CT—celiac trunk, SMA/V—superior mesenteric artery and vein, LGA/LVG—left gastric, SA/SV—splenic, IPDA/IPDV—inferior pancreatic.

1. Patient Position

After induction of general endotracheal anesthesia, an orogastric tube is inserted to keep the stomach decompressed. Two large-bore venous catheters are placed, and blood pressure is measured invasively by an intra-arterial catheter. Pneumatic compression stockings are used intraoperatively and postoperatively. The patient is placed in a supine, split-leg position, and carefully secured to the operative table. The surgeon stands between the patient's legs for the majority of the procedure, and the first and second assistants on the left and right side of the operating table, respectively. The surgeon will change to the right side of the table for the biliary reconstruction as noted below.

Tips:

- Throughout the procedure, most of the retraction is aided by gravity, which is achieved by tilting the bed and making use of the weight of the organs to facilitate exposure. Securing the patient to the bed is of utmost importance to safely perform these maneuvers.
- Throughout the procedure, when instrument retraction is required, this is most commonly achieved without grasping, to avoid injuries to the structures.

2. Trocar Placement

The procedure is performed with two 5 mm and four 12 mm ports. The first port is a 5 mm optical insufflating port placed below and to the left of the xiphoid area (P6). This trocar works as a Verres needle, as its bladeless tip is transparent and has a small opening that allows for air insufflation during the insertion. Continuous assessment with a 0° scope allows for precise identification of the abdominal wall layers prior to entering the peritoneal cavity. Only the tip of the port is introduced into the peritoneal cavity, it contains the orifice through which insufflation occurs. Additional ports are placed as shown in Fig. 15.2.

Tips: The triangulation between P1 and P3 is crucial for an adequate biliary reconstruction. Keeping track of their position throughout different procedures is an important step in troubleshooting the surgeon's ergonomics for this anastomosis. P1 is usually placed on the right side as high and as lateral as feasible.

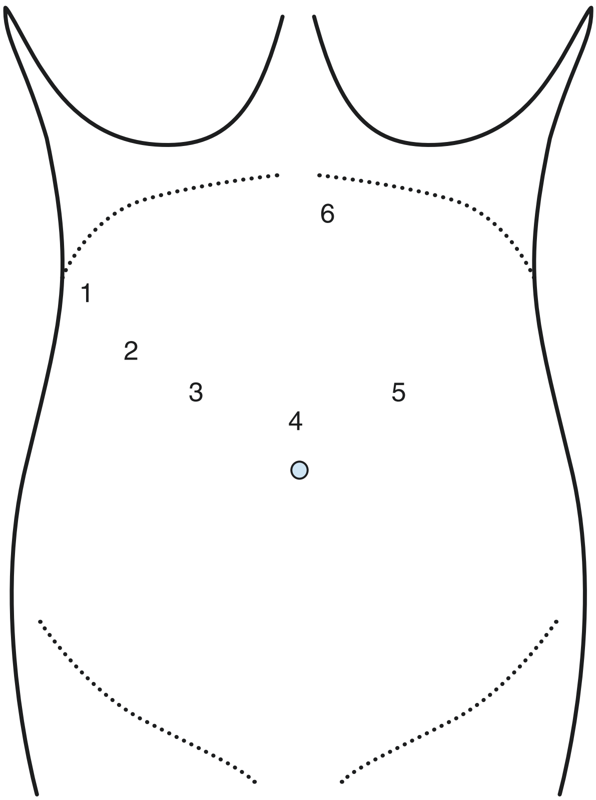

Fig. 15.2 Trocar placement. The trocars are placed in the following order: 6, 4, 3, 5, 1, 2. Trocar 6 acts as a Verres needle. Ports 1 and 6 are 5 mm, the others are 12 mm (Figure reproduced with permission from Horacio J Asbun)

3. Division of the Omentum and Colon Mobilization

The omentum is split longitudinally to facilitate gastrointestinal reconstruction (Fig. 15.3). Having two separate aprons of omentum at each site of where the post-pyloric duodenal jejunostomy would lay, decreases any potential tension and may help in keeping that anastomosis well aligned. Furthermore, it facilitates access to the ligament of Treitz. The landmark to define the point of transection of the omentum is the middle of segment 3 of the liver. Following this step, the lesser sac is entered and the colon is mobilized from left to right, avoiding injuring the right gastroepiploic vessel (Fig. 15.4). This dissection is carried up to the area of the tributaries of the trunk of Henle. Then, the hepatic flexure and the superior aspect of the right colon are mobilized, this will facilitate the exposure of the trunk of Henle tributaries and aid later in the exposure for the Kocher maneuver. (Fig. 15.5).

Tips:

- After division of the omentum, the patient is placed in a reverse Trendelenburg position.

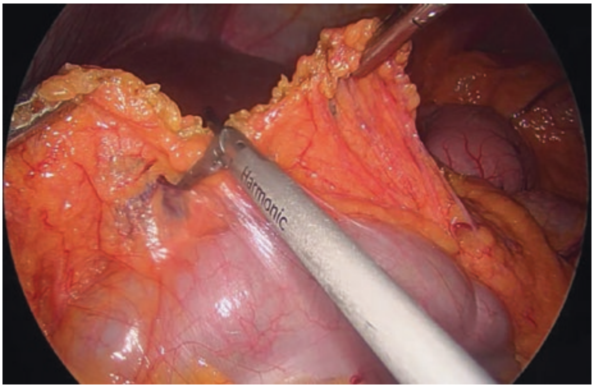

Fig. 15.3 Division of the omentum. Omental division is the first step of the procedure. The landmark line for transection is the middle of segments 2 and 3 (Figure reproduced with permission from Horacio J Asbun)

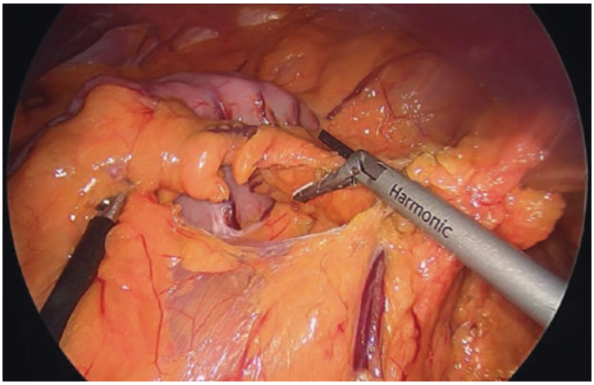

Fig. 15.4 Lesser Sac. Enter the lesser sac very laterally, just inferior to the gastroepiploic arcade (Figure reproduced with permission from Horacio J Asbun)

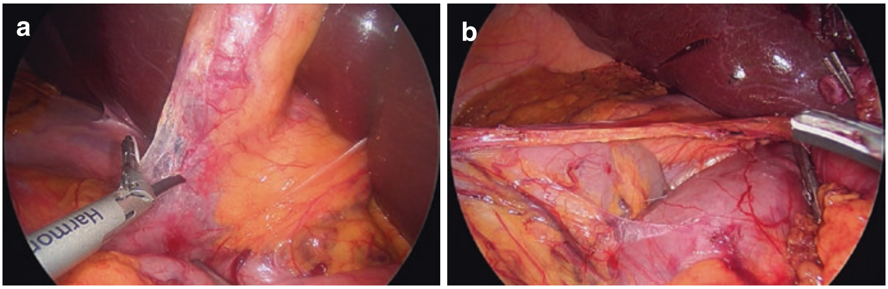

Fig. 15.5 Hepatic flexure of the colon. The dissection starts at the lateral border of the superior duodenal flexure (Fig. 15.5a) and extends laterally (Fig. 15.5b) (Figure reproduced with permission from Horacio J Asbun)

- To achieve best results entering the lesser sac, start transaction of the gastrocolic omentum very laterally, where the omentum is a single layer and thinner (Fig. 15.4).
- As the gastrocolic omentum is divided and the area of the lesser sac is exposed, a grasper (P1) retracts the stomach by pushing its posterior wall cephalad. As mentioned before, the retraction is done without grasping the stomach, but more by using a swiping maneuver superiorly and anteriorly. This facilitates identification and transaction of the gastrocolic ligament, identification of the right gastroepiploic vessels and allows for better understanding of the different layers of the ligament as the division reaches the more medial aspect.
- When mobilizing the right hepatic flexure of the colon, precise access to the avascular plane between right colon and Gerota's fascia markedly facilitates this dissection and expose this the anterior aspect of the duodenum (Fig. 15.5a) and continues laterally (Fig. 15.5b).

4. Division of the Tributaries of the Trunk of Henle and Duodenum

The tributaries of the trunk of Henle are encircled en bloc with the surrounding adipose tissue in 360 degrees using a finger type retractor (laparoscopic esophageal retractor), ligated and divided with a vascular stapler (Fig. 15.6). After the mobilization of the hepatic flexure and division of the trunk of Henle, the colon will drop because of gravity afforded by the reverse Trendelenburg position, giving adequate exposure to the area posterior to the antrum and pylorus. The GDA may already be visible in the anterior aspect of the pancreas. Small vessels in the posterior aspect of the pylorus and first portion of the duodenum are ligated and divided. The finger is also employed to create a tunnel posterior to the first portion of the duodenum,

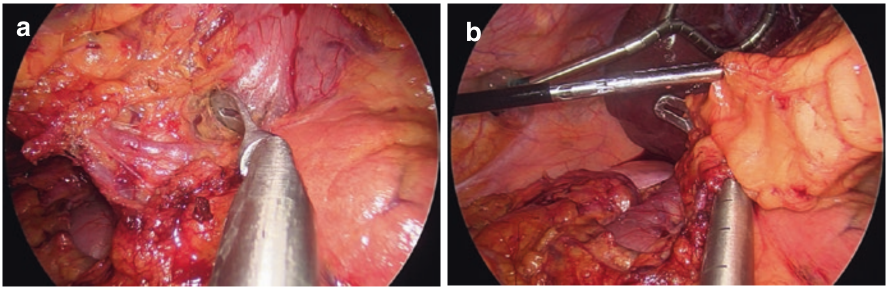

Fig. 15.6 Gastroepiploic artery and tributaries of the trunk of Henle. The finger is passed very close to the gastric wall (Fig. 15.6a). It is not necessary to individually isolate the artery and the vein (Fig. 15.6b), they are stapled-transected using the same vascular load (Figure reproduced with permission from Horacio J Asbun)

2–3 cm distally to the pylorus, where the proximal bowel will be staple-transected. (Fig. 15.7). Once the duodenum is transected, the right gastric branch is ligated and the distal third of the hepatogastric ligament is divided (Fig. 15.8). The pylorus and antrum are then moved cephalad and to the left for the rest of the procedure. This gives wide exposure to the area of the pancreas and duodenum.

Tips:

- When ligating and dividing the short vessels entering the posterior wall of the pylorus and duodenum, take very small bites with the ultrasonic shears.
- It is extremely important when going from caudad to cephalad behind the pylorus to always remember where the hepatic artery should be located. If the dissection does not readily open up a window to encircle the pylorus, consider looking superiorly and anteriorly to the stomach in the area of the hepatoduodenal ligament to assure there are no adhesions. One may also start the cholecystectomy dissection identifying the cystic structures at this time and to clear any potential adhesions. Extra attention to identify and spare the hepatic artery should be paid, in the presence of a difficult dissection of this area.

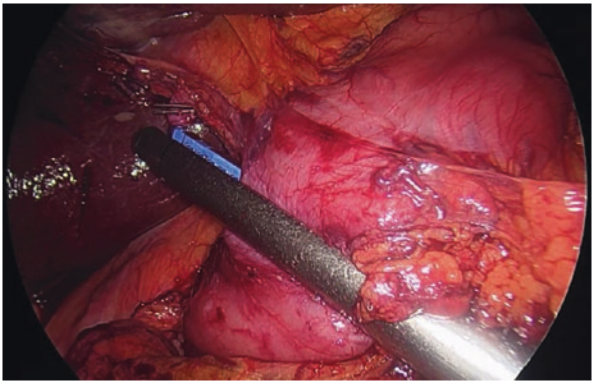

Fig. 15.7 Proximal bowel transection. The duodenum is staple-transected using a blue load, 2–3 cm distal to the pylorus (Figure reproduced with permission from Horacio J Asbun)

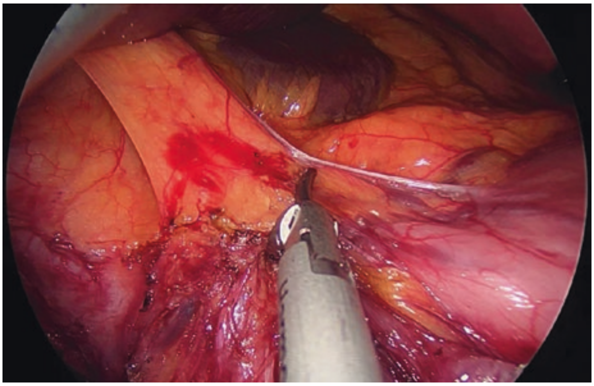

Fig. 15.8 Hepatogastric ligament. This ligament is transected to allow for mobilization of the stomach (Figure reproduced with permission from Horacio J Asbun)

- When developing the plane to encircle the tributaries of the trunk of Henle, the finger retractor should be passed in very close contact to the anterior aspect of the duodenal wall.
- After encircling the duodenum should be transected transversally as an oblique transection will prevent the creation of an adequate duodenojejunostomy.

5. Division of the Gastroduodenal Artery

Once the head of the pancreas is exposed, the hepatic artery lymph node serves as a landmark for the identification of the common hepatic artery (Fig. 15.9). The hepatic artery can be isolated with the aid of a right angle or finger retractor, followed by a vessel loop, if needed. The gastroduodenal (GDA) artery is isolated in 360 close to its origin, ligated and divided with a vascular stapler (Fig. 15.10).

Tips:

- The GDA transection is performed leaving a small stump. As pseudoaneurysms of the GDA may occur, the stump will facilitate endovascular intervention in case of bleeding (Fig. 15.10). The authors prefer to use a vascular stapler for

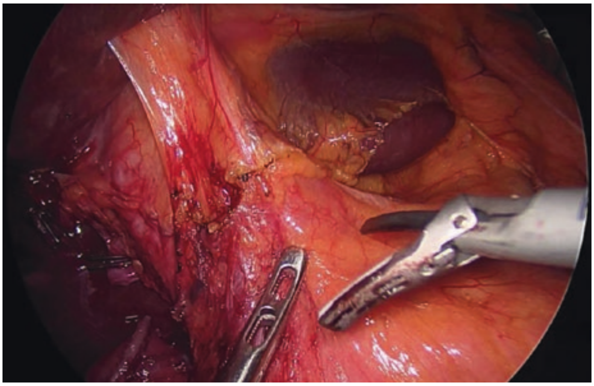

Fig. 15.9 Hepatic artery lymph node. This lymph node is a landmark for the gastroduodenal artery takeoff from the common hepatic artery (Figure reproduced with permission from Horacio J Asbun)

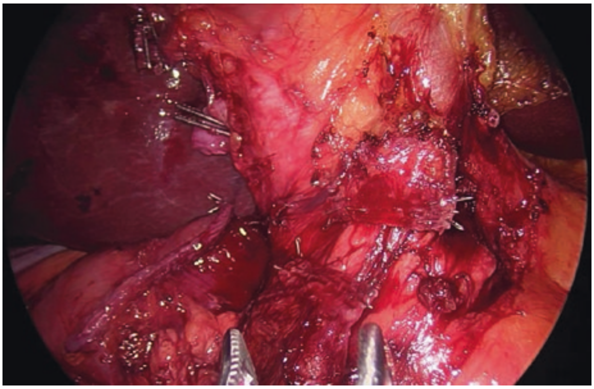

Fig. 15.10 Gastroduodenal artery. After the hepatic artery lymph node is dissected, the GDA is isolated and staple-transected with a vascular load, leaving a 5 mm stump (Figure reproduced with permission from Horacio J Asbun)

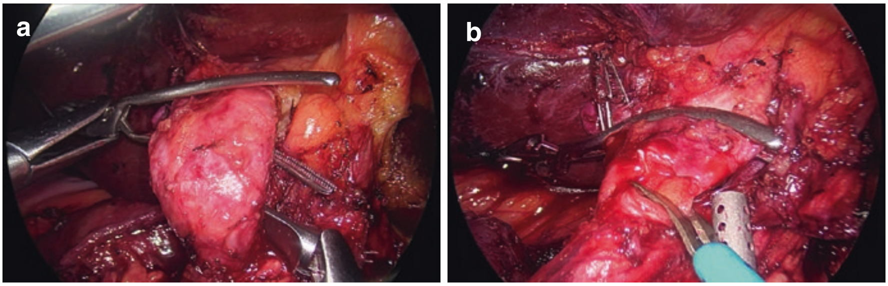

Fig. 15.11 Common bile duct transection. Isolation of the common bile-duct is done with the finger. A bulldog is placed to prevent bile spillage (Fig. 15.11a). The posterior wall of the duct is left longer than the anterior to facilitate reconstruction (Fig. 15.11b) (Figure reproduced with permission from Horacio J Asbun)

GDA ligation to assure a secure ligation without damaging the artery and its origin, but recognize this may not be a generalized preference.

6. Common Bile Duct Transection

With the GDA divided, the distal area of the hepatoduodenal ligament opens up and is further dissected to identify the common bile duct. The duct will be the first tubular structure coming lateral to medial from the right and once a plane is developed lateral to the hepatic artery, the common bile duct is isolated with a finger retractor. The finger retractor facilitates the encircling of the duct and its blunt edge decreases the chance of portal vein (PV) injury. The PV will be located immediately posterior and medial to the duct and the artery is usually visible during this dissection since the GDA has been divided. A bulldog clamp is then passed proximally around the bile duct (Fig. 15.11). The duct is opened by transecting its anterior wall first with scissors, then the posterior wall is divided leaving a longer posterior wall to facilitate the hepaticojejunostomy construction. Biliary cultures are taken at this point if a stent is present.

Tips:

- Preoperative review of the imaging for vascular evaluation is required for every case. A replaced right hepatic artery tends to run posteriorly and close to the common bile duct, (Fig. 15.12a). If not properly identified, it could be mistakenly isolated in conjunction with the common bile duct and injured.
- When reviewing pre-operative imaging, also check for stent type and position. Knowing how high the stent extends proximally will allow to know what to expect when dividing the duct. Uncovered metallic stents are particularly worrisome, as they are not amenable to removal.
- The authors do not feel transection of the bile duct above the cystic duct is necessary unless there are concerns for a clear margin. Transecting the distal CBD facilitates the angle of the anastomosis. When a parallel cystic duct opening is encountered at the level of division, the anastomosis is done to both, the cystic and the common duct openings together, using a single opening in the jejunum.

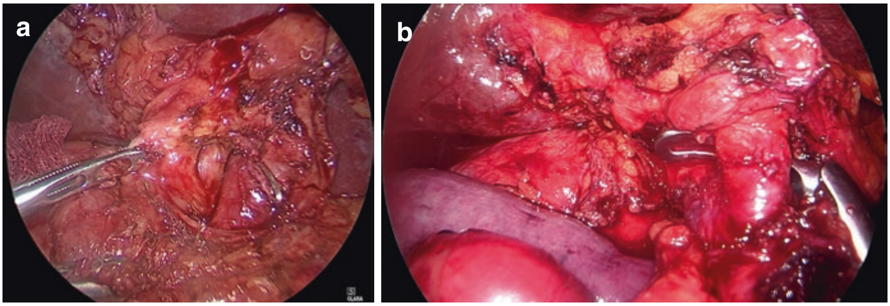

Fig. 15.12 Hepatic artery anatomical variations. Be aware of arterial variation as hepatic arteries might run laterally (Fig. 15.12a) or anteriorly to the common bile duct (Fig. 15.12b) (Figure reproduced with permission from Horacio J Asbun)

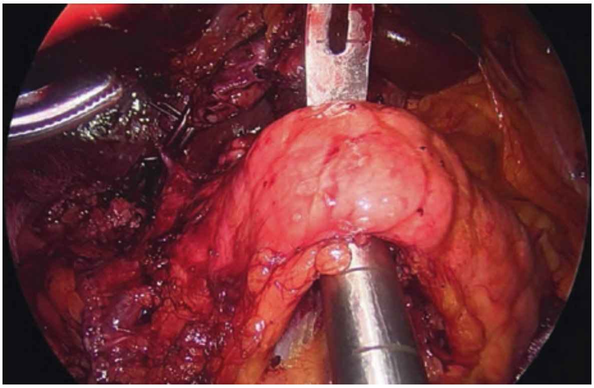

Fig. 15.13 Retropancreatic window. The pancreas is meticulously dissected from the anterior aspect of the SMV. The window is completed and the neck encircled with a penrose with the aid of a finger retractor (Figure reproduced with permission from Horacio J Asbun)

7. Retropancreatic Window and Mesenteric-Uncinate Groove Exposure
The retropancreatic window is made in a caudad-cephalad fashion. The transverse mesocolon is retracted downwards while the inferior edge of the pancreas is retracted upwards. This maneuver allows for the identification of the plane of dissection and facilitates exposure of the avascular space between the superior mesenteric vein (SMV) and the posterior aspect of the pancreatic neck. The location of the SMV can be assessed by identifying the PV above the pancreas and estimating where the SMV is likely to be located taking in account the PV-SMV transition, or, better, the SMV can be located directly with ultrasound. The dissection is performed meticulously and completed by the use of the finger retractor and placement of a penrose drain or similar around the neck of the pancreas. In a minority of patients, prior to this stage, the common hepatic artery needs to be dissected further, away from the superior edge of the pancreas at the level of the neck. (Fig. 15.13).

After the penrose drain has been passed, the neck is pulled anteriorly and dissection of the uncinate-mesenteric groove is performed to identify the plane between the two structures and to identify venous branches (usually one) going to the uncinate process. This step will facilitate the later mobilization of the duodenum and ligation of its mesentery once the Kocher maneuver is performed.

Tips:

- When making the pancreatic window, ultrasonic shears are used to ligate small veins tributary to the SMV under direct visualization. Short gentle blunt dissection strokes are very useful when developing the space during this tunneling.
- Review of the preoperative imaging should also include assessment of the PV/SMV angle to facilitate the identification of the were the SMV comes out behind the inferior edge of the pancreas. Following venous branches that drain into the SMV may also be helpful in some patients.

8. Pancreatic Neck Transection

The neck transection should be planned preoperatively. T2-weighted images allow for anticipation of the position of the pancreatic duct before the neck is transected. A sagittal series is of significant help on assessing the location of a small pancreatic duct (PD) within the pancreas. The parenchymal transection is started by taking a sizeable bite of the parenchyma at the inferior edge of the pancreas with ultrasonic shears and applying gradual compression. This will ligate the inferior arcade. Then the rest of the parenchyma is transected with the active blade of the ultrasonic shears, in a back and forth motion trying to individually identify the PD and not transect it. The duct is then sectioned with cold scissors, to the right of the prior transecting level, leaving a 2–3 mm protruding stump to facilitate reconstruction (Fig. 15.14). Then the rest of the pancreas parenchyma transection is resumed using a gradual compression technique with both blades of the ultrasonic shears. The superior arcade is ligated in similar manner.

9. Distal Bowel Mobilization

The mobilization of the remaining duodenum and proximal jejunum is performed with the bed tilted to the left and the camera on P4. The mobilized colon is swiped from right to left with a large instrument inserted through P6 and the divided distal

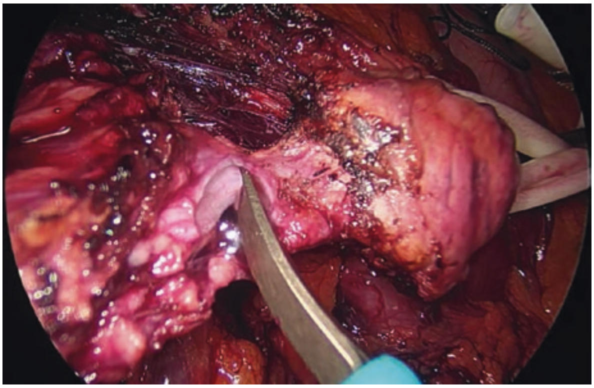

Fig. 15.14 Pancreatic neck transection. The parenchyma is transected with the active blade of the ultrasonic shears. The duct is sectioned with scissors, leaving a 2 mm stump (Figure reproduced with permission from Horacio J Asbun)

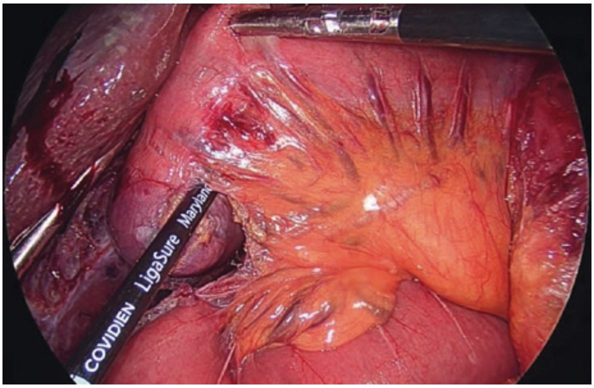

Fig. 15.15 Distal bowel mobilization. The distal bowel is pulled from the left to the right side of the abdomen. After staple-transection, the mesentery is vessel-sealed close to the bowel (Figure reproduced with permission from Horacio J Asbun)

stump of the duodenum is pulled cephalad, anterior and to the left with grasping forceps from P5. This gives adequate exposure to perform a Kocher maneuver, the mobilization of the third and fourth portion of the duodenum, and the opening of the ligament of Treitz from the right. Part of the jejunum is brought back behind the superior mesenteric vessels to the right abdomen. After the jejunum is transected with a stapler, the mesentery of the jejunum and duodenum is exposed, ligated and divided very distally with a vessel sealer (Fig. 15.15).

Tips:
- The exposure achieved with the swiping maneuver of the colon is important to access and release of the ligament of Treitz. The retraction initially appears counterintuitive.
- Careful hemostasis is essential in this step as the mesentery of the jejunum is another source of postpancreatectomy bleeding.
- During the ligation of the mesentery from right to left, the prior mobilization of the uncinate-mesenteric grove allows for visualization of the path of dissection towards the SMV.

10. Uncinate Process and Superior Mesenteric Artery Dissection
Once the distal bowel mesentery is ligated, the uncinate process is straddled with a large instrument and retracted to the right. The assistant uses an endoscopic Kittner and suction to retract the SMV to the left. This manner of retraction in association or not to indocyanine green (ICG) facilitates the identification of the plane of dissection (Fig. 15.16a). The uncinate is progressively separated from the SMV and SMA from caudad to cephalad under direct visualization. Small venous and arterial branches are ligated and divided with a bipolar vessel-sealer or clipped depending on their size (Fig. 15.16b, c). If there is concern that the lesion is tethered to the vessels, before the dissection is started, proceed with proximal and distal vascular control by placing vessel loops to control the inflow and outflow of the region of interest. Here, adequate employment of suction and suturing is essential for success.

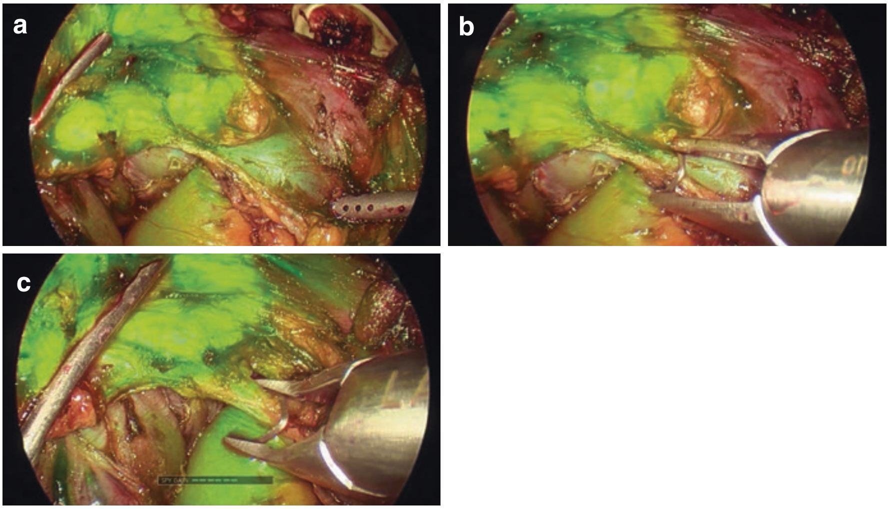

Fig. 15.16 Uncinate dissection. Identification of the plane of dissection is facilitated with indocyanine green (Fig. 15.16a). The head is retracted to the right with a long instrument while the SMV and SMA are retracted to the left with an endoscopic Kittner. Pancreatoduodenal veins (Fig. 15.16b) and arteries (Fig. 15.16c) are sealed or clipped according to their sizes (Figure reproduced with permission from Horacio J Asbun)

Troubleshooting:

- Advanced laparoscopic suturing skills are required, especially if bleeding occurs. One strategy to control bleeding is to gently press over the bleeding site with the side of the suction shaft. It seems intuitive to use the tip of the instrument, but this will increase the size of the hole in the vein. To assess the opening simply roll the shaft sideways and have the needle mounted to pass the suture. In these situations, it is important to be able to mount and pass the needle with one hand only, as the other hand will be on the suction device.
- During the dissection of the uncinate, the vessel sealer is activated with the foot pedal and its jaws continuously open and closed while active, to achieve an adequate hemostasis prior to division and helping in the dissection of the tissue.
- As the dissection progresses the straddling grasper opens the dissection line by retracting the uncinate process to the right. When further opening is being precluded, posterior attachments from the mesentery to the intestine are usually found, ligated, divided with the bipolar sealer. This will further open the plane of dissection.
- Preoperatively, plan for replaced hepatic arteries to the SMA, they will run close to the uncinate and might be inadvertently injured during the dissection. Identification of the origin of the replaced RHA on imaging, will significantly aid in knowing at what level of the dissection from caudad to cephalad one expects finding the replaced RHA origin. The SMV-PV and splenic vein junction is used as a reference.

11. Specimen Removal and Cholecystectomy

A laparoscopic bag is used to retrieve the specimen. The specimen is oriented inside the bag while closing it by grasping the distal bowel. The bag is pulled through P5 and the incision is opened to 3–4 cm. Margins are evaluated by frozen sections from the pancreatic neck, common bile duct and uncinate process. A cholecystectomy is performed while pathology is being processed.

Tips:

- Even though the cholecystectomy is usually performed at this stage, the identification, ligation and division of the cystic duct and artery using a critical view of safety technique, is done early in the procedure, prior to division of the CBD or at the mobilization of the hepatic flexure of the colon.

12. Hepaticojejunostomy

The proximal end of the transected jejunum is brought behind the mesenteric vessels into the right side of the abdomen to form an inverted "J" which will be used to reconnect the hepatic and pancreatic ducts. Care is taken not to create any kinks or acute torsions. For this part of the procedure the camera is placed in P2 and the surgeon works through ports P1 and P3. An antimesenteric opening is made in the jejunum, slightly smaller than the size of the hepatic duct. The assistant uses a grasper in P5 to hold the jejunum in place and the posterior wall is sutured in a running fashion, from left to right, with a 4-0 or 5-0 polydioxanone suture, mounted on a TF or RB-1 needle. PDS is an alternative when using 4-0. Having a longer posterior wall of the CBD facilitates the placement of the stitches in this layer. The anterior wall is constructed in the same fashion. Each stitch is passed under direct visualization (Fig. 15.17). The bulldog is released.

A 15Fr Blake drain is inserted in P1 and passed behind the anastomosis and left along the SMV. The jejunal loop is fixed to the Gerota's fascia.

Tips:

- The bulldog is preferentially released once the anastomosis is finished but occasionally, there is not enough room and it has to be released prior to the anastomosis. If so, one has to avoid bile contamination as much as feasible, particularly in patients with a prior stent. The assistant applies short bursts of suction throughout the anastomosis.
- A gauze is placed posterior to the jejunum at the area were the anastomosis will be performed. This helps aligning the jejunum, facilitates the anastomosis and catches bile spillage in the event the bulldog has been removed.

13. Pancreaticojejunostomy

The pancreaticojejunostomy is constructed in four layers. The camera is moved back to P4 and the working ports are P3 and P5. A first posterior layer is constructed with a running 4-0 or 5-0 polypropylene suture, starting superior and it is left untied inferiorly. The sutures are passed in the posterior surface of the pancreas and close

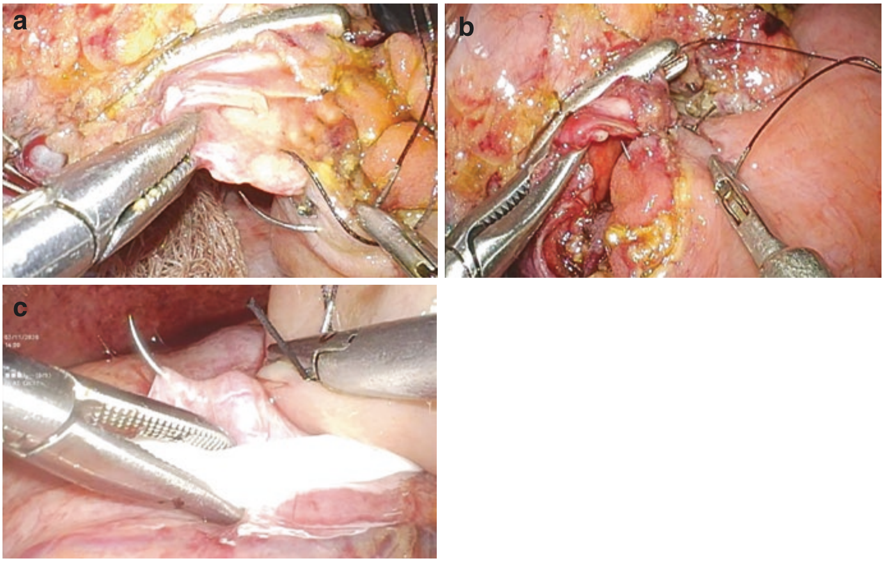

Fig. 15.17 Hepaticojejunostomy. With the bulldog in place, the walls of the bile duct are sutured in a running fashion with absorbable 4-0 or 5-0 polydioxanone. The posterior layer is constructed first. Notice how the longer posterior wall facilitates the placement of the stitches (Fig. 15.17a). The anterior layer is constructed afterwards (Fig. 15.17b). A 15Fr Blake drain is placed posterior to the anastomosis and the jejunum is sutured to the Gerota's fascia to decrease tension in the anastomosis (Fig. 15.17c) (Figure reproduced with permission from Horacio J Asbun)

to the mesenteric border of the jejunum, this will imbricate the stump anteriorly and improve the exposure of the pancreatic duct. The jejunum is opened and the duct-to-mucosa anastomosis is constructed with interrupted 5-0 or 6-0 polyglactin sutures, mounted on an RB2 or TF needle. A tube is inserted into the main pancreatic duct to facilitate placement of the stitches (Figs. 15.18 and 15.19).

The sutures in the posterior layer are passed inside-out in the pancreatic duct and except for the first stitch, are tied and cut immediately after being placed. The first suture is a stay suture at 6 o'clock (in relation to the PD) that includes both, the PD and the opening in the jejunum, this one is not tied and together with the tube will serve to expose the duct lumen. The next sutures are placed cephalad towards 9 o'clock first and then caudad towards 3 o'clock. Retraction with the tube and with the initial 6 o'clock stay suture is changed for each stitch to expose the different areas of the duct affording placement of all the stitches under direct visualization. Once all the posterior layer stitches are placed, the stay suture at 6 o'clock is tied. Then, the anterior layer is started by passing a stay suture at 12 o'clock, but only on the pancreatic duct. It is passed in the bowel at the end, when all other anterior layer stitches have been placed. The sutures on the anterior layer are placed outside-in in the pancreatic duct, and are left untied until all have been passed, this allows for continued visualization of the duct. The total number of sutures varies from 6 to 10 for small ducts, and increases in number as the size increases.

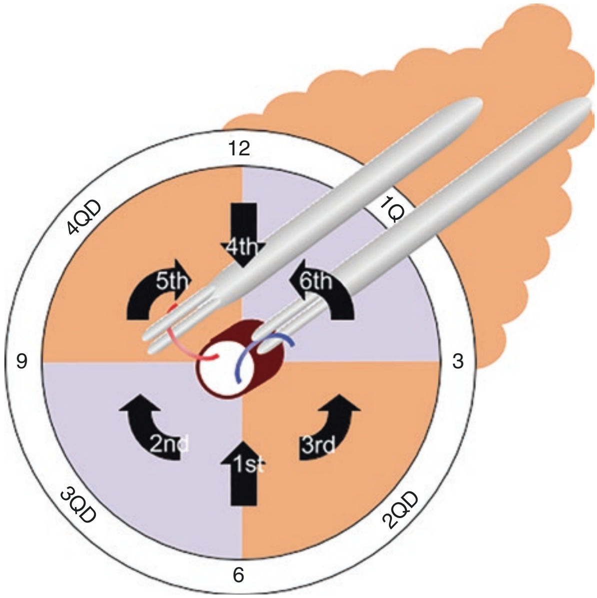

Fig. 15.18 Pancreaticojejunostomy suture schematic. Needle is mounted parallel to the shaft (blue) of the needle holder in quadrants 1 and 3, and perpendicular (red) in quadrants 2 and 4. Stay sutures are placed at 6 o'clock (first black arrow), to facilitate exposure of the posterior wall, and at 12 o'clock (fourth black arrow), for the anterior wall. Sutures follow in an interrupted sequential fashion (remaining black arrows), with 4-0 or 5-0 polydioxanone, from posterior to anterior (Figure reproduced with permission from Horacio J Asbun)

Tips:

- Mounting the needle in different angles is of crucial importance to place the sutures on the pancreatic duct. Despite being highly dependent on each surgeon's expertise, our group has noted that simulating the needle movement through the tissue, and paying special attention to its position helps to predict the best way to mount the needle. (Figs. 15.18 and 15.19).
- Care is taken not to cross the stitches. Careful orientation of the suture tail is done as the anterior stitches are placed to avoid crossing them.

14. Duodenojejunostomy

The duodenojejunostomy is also performed in four layers. The ligament of Treitz area is located and the jejunum is brought up, anterior to the colon, in the site of the previous omental split. The first posterior seromuscular layer is constructed incorporating the duodenum staple line, and attached close to the mesenteric border of the jejunum, in a running fashion with a 4-0 polydioxanone barbed-suture. A stay suture is placed in the beginning of the barbed-suture to facilitate mobilization of the structures. The mucosa is opened in both sides, the pylorus is mechanically dilated with a grasper. The posterior inner layer incorporates the staple line and is constructed in the same fashion. The posterior and anterior outer seromuscular layers are then done taking small bites (Fig 15.20).

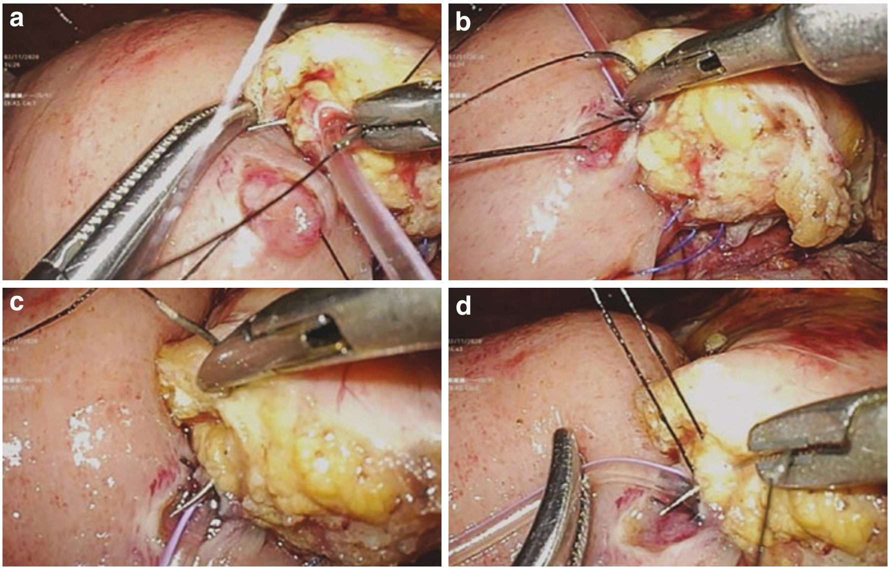

Fig. 15.19 Pancreaticojejunostomy by quadrants. The pancreatic duct exposure is achieved by moving the pancreatic duct stent and the stay suture in an ordered fashion depending on the quadrant. Starting in quadrant 3, suture is pulled inferiorly (Fig. 15.19a). Following In quadrant 2 (Fig. 15.19b), the suture is pulled laterally. In quadrant 4 it is pulled downwards (Fig. 15.19c), and in quadrant 1 upwards (Fig. 15.19d). The stent is manipulated in different directions exposing the edge of the duct to be stitched. Throughout the placement of the stitches the needle is mounted into the needle drive different angles for each stitch (Figure reproduced with permission from Horacio J Asbun)

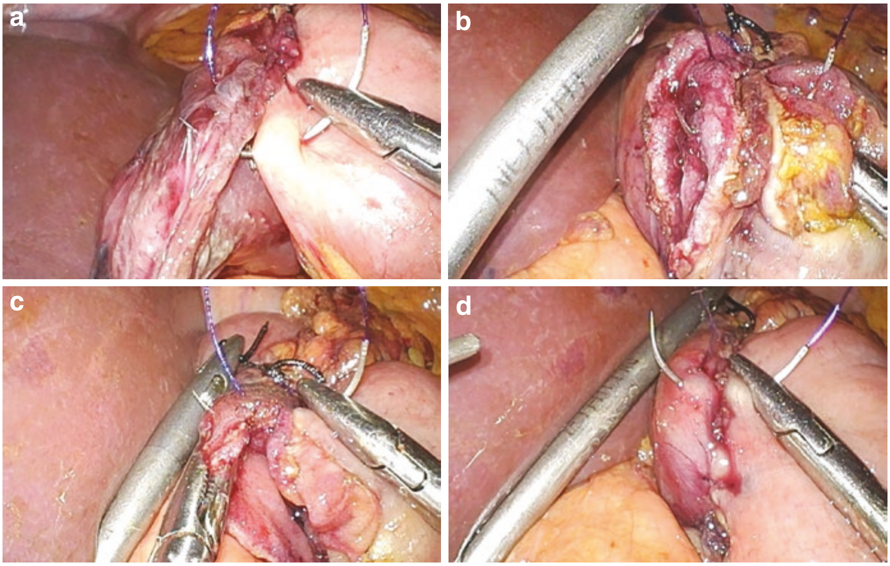

Fig. 15.20 Duodenojejunostomy. A loop of jejunum is brought anterior to the omental split to create an end-to-side duodenojejunostomy. The anastomosis is constructed in four layers (Fig. 15.20a–d), including the staple line (Figure reproduced with permission from Horacio J Asbun)

15.5 Postoperative Course

Patients are fed with sips of water the same day of surgery, clear liquids on postoperative day 1 and advanced according to how they feel. Most patients are discharged after a stay of 5–7 days. They are instructed to avoid eating fatty meals and roughage and ease back into a normal diet by the end of the first month. They are usually able to resume their normal activities by the end of the first month.

15.6 Conclusions

An adequate minimally invasive pancreatoduodenectomy can give the patient a chance for cure. The steps outlined in this chapter serve as a guide on the technical aspects of the operation, to minimize complications, and improve postoperative outcomes.

15.7 References

Conflict of Interest The authors have no conflict of interest to declare.

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Chapter 16
Robotic Pancreaticoduodenectomy

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16.1 Introduction

Pancreaticoduodenectomy (PD) is the standard surgical procedure for pancreatic head cancer and other peri-ampullary neoplasms [1]. Named after Allen Oldfather Whipple who first performed the operation as a one stage procedure, in 1935 [2], it was initially described by Alessandro Codivilla in Italy in 1898 and Walther Kausch in Germany in 1912. Over the course of the last three decades, improvements in surgical technique and perioperative care have led to markedly low mortality rates of under 2% at high-volume pancreatobiliary centers [3]. Despite this improvement in mortality rates, morbidity rates following open pancreaticoduodenectomy remained high, approaching 50% in some series [4].

The robotic platform offers a minimally-invasive alternative to open PD. When performed by experienced surgeons at high-volume centers on select patients, comparative studies demonstrate a decreased conversion rate for robotic PD (RPD) compared to its laparoscopic counterpart, and reductions in morbidity with non-inferior oncologic outcomes when compared to the open approach [5–10]. At the University of Pittsburgh, we implemented a robotic pancreas program in 2008 and have performed over 700 RPDs to date. Our initial studies focused on identifying the learning curve (nearly 80 cases for new adopters), with subsequent studies demonstrating superior outcomes to the open approach in highly selected patient cohorts. Over the last 5 years, we focused on safely disseminating our RPD technique to new adopters.

In this chapter, we describe a comprehensive step-by-step approach for robotic pancreaticoduodenectomy as it is performed at the University of Pittsburgh. We

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describe pitfalls and obstacles that may be faced by the operating surgeon along every step and offer practical solutions to avoid and handle the technical challenges associated with this complex operation.

16.2 Clinical Presentation

Pancreatic ductal adenocarcinomas (PDAC), and its variants, account for 90% of all pancreatic malignancies and tend to develop at a median age of 70 years with a slight predilection towards male gender [11, 12]. Only 15–20% of PDAC patients are amenable to curative-intent surgical resection as the majority (80–85%) have unresectable or metastatic disease at the time of diagnosis [13, 14]. The development of symptoms typically coincides with advanced stage disease at the time of presentation [14]. Common symptoms include abdominal or mid-back pain, anorexia, fatigue, weight loss, floating stools, dyspepsia, and obstructive jaundice. Furthermore, new onset diabetes mellitus in patients 50 years or older may be a warning sign for an underling pancreatic malignancy. Occasionally, the tumor can obstruct the pancreatic duct or duodenum and lead to pancreatitis or gastric-outlet obstruction respectively.

16.3 Preoperative Evaluation

A comprehensive clinical assessment is crucial in the evaluation of pancreatic cancer patients. A thorough assessment for commonly cited risk factors such as smoking, obesity, family history of malignancy, chronic pancreatitis, and alcohol consumption should be sought. Physical examination may reveal scleral icterus, malignant ascites or significant wasting and cachexia. Laboratory evaluation should include liver function tests, a complete metabolic profile and carbohydrate antigen level 19-9 (CA19-9) levels. Although non-specific at diagnosis, not secreted in upto 20% of PDACs and often falsely elevated in the presence of jaundice, CA19-9 is a useful biomarker in detecting recurrence and assessment of tumor response to systemic therapy [15, 16].

Cross-sectional imaging is critical in the initial evaluation, staging and preoperative planning for pancreatic head cancers. The anatomic location of the tumor with respect to the surrounding visceral structures and abdominal vessels dictates resectability status (resectable, borderline-resectable, locally-advanced disease/unresectable, metastatic) which in turn, dictates treatment algorithms [16]. The National Comprehensive Cancer Network (NCCN) recommends staging with a triphasic-pancreatic protocol-CT scan of the abdomen as the gold standard imaging modality to evaluate and stage pancreatic malignancies. The panel also recommends CT scan of the chest and pelvis for the detection of metastatic disease, magnetic resonance imaging for indeterminate liver lesions, and PET/CT in high-risk patients to detect extrapancreatic disease. Endoscopic ultrasound (EUS) is the preferred modality for obtaining a biopsy, while endoscopic retrograde cholangiopancreatography (ERCP) or percutaneous transhepatic cholangiography (PTC) can be utilized to place a stent for biliary decompression (if neoadjuvant therapy is needed) or as palliation for biliary obstruction secondary to unresectable disease [16, 17].

16.4 Technique

16.4.1 Patient Positioning

After induction of general endotracheal anesthesia, a nasogastric (NG) tube and a Foley catheter are inserted. Arterial line placement for intraoperative blood pressure monitoring is usually placed, however placement of a central venous line is at the discretion of the surgeon and the anesthesiologist. The patient is positioned on the split leg table, with both legs abducted to the "B" position. The right arm is tucked, and the left arm is extended to 60°. Appropriate padding of all pressure points is ensured to prevent neurovascular injury during the procedure. The patient should be anchored well to the table with circumferential straps placed over the chest and legs, as most of the operation is done in steep Trendelenburg position. Depending on the robotic platform available, the table is rotated 45° away from the anesthesia to dock the da Vinci SI robot (Intuitive Surgical, Sunnyvale, CA) over the head of the patient, or remains in its natural position for XI platform which is docked from the side (Fig. 16.1).

16.4.2 Trocar Placement and Explorative Laparoscopy

In total, 7 ports are placed for RPD (Fig. 16.2). Access to the abdomen is achieved under direct visualization using an optical separator trocar and a 5 mm 0° laparoscope in the left midclavicular line, 3–4 cm above the level of the umbilicus. Insufflation pressure should be set to 15 mmHg. A diagnostic laparoscopy to asses for gross peritoneal and/or liver disease is performed. If none is found, the remainder of the ports are placed in the following configuration under direct visualization: A 12 mm (for Si or 8 mm for XI) camera port is placed 3–4 cm above and to the right of the umbilicus in the same transverse line as the optical separator trocar. Next, three robotic 8 mm trocars are placed along the same transverse line: The original optical trocar is replaced with the first robotic trocar (R1), while the second (R2) and third (R3) robotic trocars are placed on the right side of the abdomen, at the mid-clavicular and anterior axillary lines, respectively.

Two bedside assistant trocars are then placed in the following configuration; a 5 mm trocar is placed in the right mid-clavicular line bisecting the camera trocar and

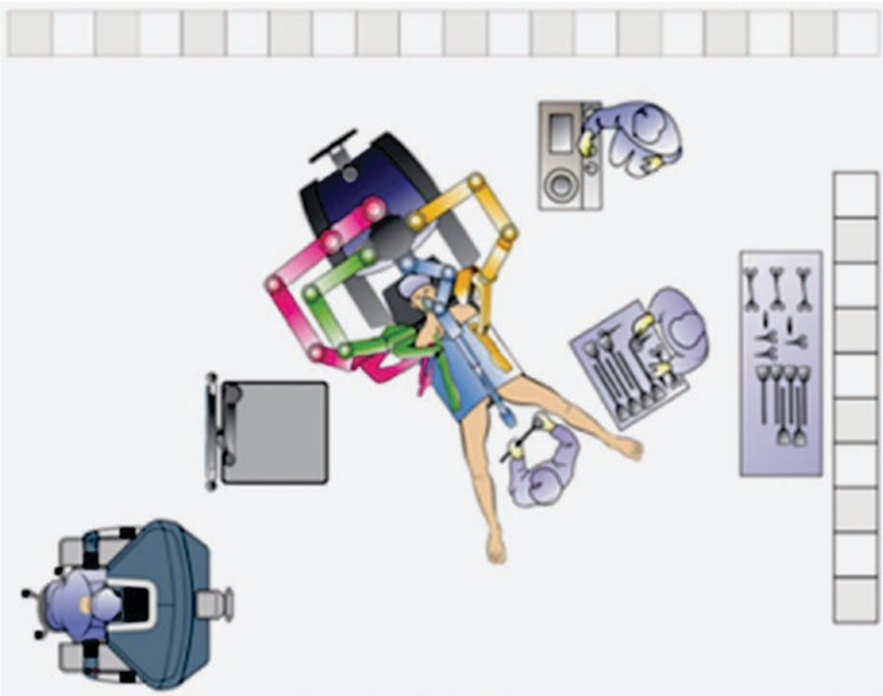

Fig. 16.1 Patient positioning for the SI robot © 2014 Intuitive Surgical, Inc.

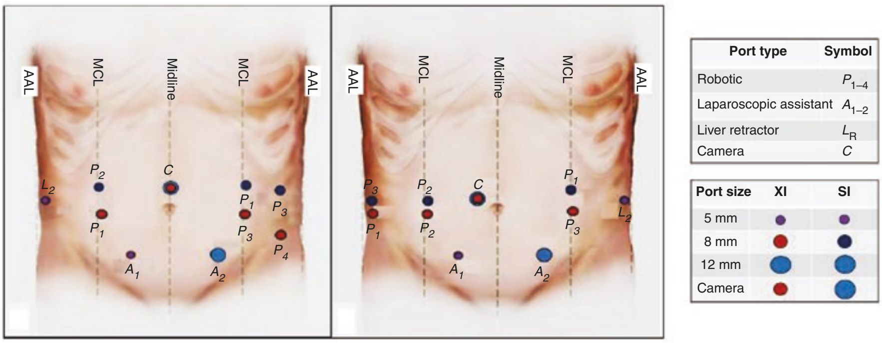

Fig. 16.2 Port placement A. XI B. SI

the R2 robotic trocar. The second assistant port is a 12-mm trocar placed in the left lower quadrant at the left mid-clavicular line bisecting the camera trocar and the robotic R1 trocar. Finally, a 5 mm trocar is placed along the left anterior axillary line to install the liver retractor. A Mediflex liver retractor (Mediflex ®Surgical Products, Islandia, NY) is then applied to provide cephalad retraction of the liver. Importantly, at least one-hand breadth between robotic trocars should be maintained to optimize the ergonomics of the robot (Fig. 16.2). Once all the trocars are correctly placed, the robot is docked over the patient's head (SI) or right side (XI) with two robotic arms on the right side (a cadiere in R3-lateral arm, fenestrated biopolar in R2—medial arm), one at the left side (hook unipolar in R1), and the robotic camera in the middle trocar.

Troubleshooting *In patients who have higher body mass index (BMI > 35), particularly those with central obesity, all trocars should be shifted superiorly. For patients with lower BMI (<25), all trocars should be shifted inferiorly. Care should be taken to avoid injury to the inferior/superior epigastric vessels, which could be in the direct line of trocar placement. The XI trocars should be placed slightly higher the SI robot. The robotic trocars should be placed at a 90-degree angle of entry with the skin, while the bedside assistant trocars should be placed at a 45 degree angle pointing cephalad to the resection field.*

16.4.3 Resection Phase

16.4.3.1 Mobilization of Right Colon, Kocherization of the Duodenum and Division of the Ligament of Treitz

Access to the lesser sac is first attained through the avascular plane of the gastrocolic ligament using a combination of monopolar cautery and the 10 mm LigaSure™ (Covidien, Mansfield, MA). During this step, the stomach is sequentially retracted cephalad and anteriorly using robotic arm R3. Dissection is carried all the way distally, carefully separating the transverse mesocolon from the gastroepiploic vein pedicle, until the hepatic flexure is completely mobilized. This step is crucial to allow full access to the duodenum and the head of the pancreas.

This is followed by Kocherization of the duodenum using a combination of blunt dissection and monopolar cautery. During this step, continuous sequential traction is applied on the duodenum, anteriorly and cephalad, by robotic arm R2. Furthermore, the bedside assistant maintains continuous counter-traction by pulling the transverse colon and hepatic flexure towards the left lower quadrant. After the conclusion of this step, the inferior vena cava, left renal vein and the ligament of Treitz should be clearly delineated.

The ligament of Treitz is then divided from the right-side using hook monopolar electrocautery. This step allows complete mobilization of the duodenum and creation of a tunnel for the proximal jejunum to eviscerate into the right upper quadrant (RUQ). 10 cm distal to the divided ligament of Treitz, a rent in the jejunal mesentery is created, and the jejunum is divided using an Endo-GIA (Covidien, Mansfield, MA) 60 mm stapler placed through the 12 mm assistant trocar. Finally, the mesentery of the proximal jejunum and the fourth and third portion of the duodenum is divided progressively using the energy sealing device up to the inferior border of the uncinate process. This step is crucial to create the plane needed for dissection of the

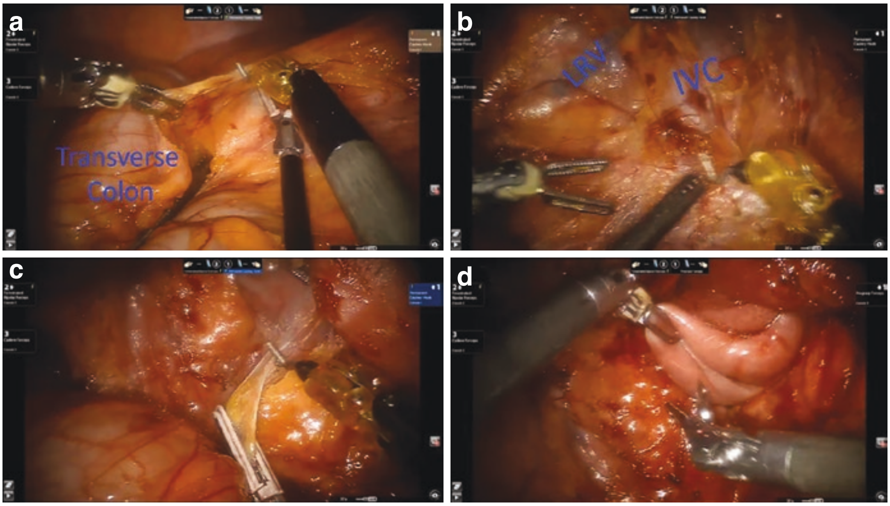

Fig. 16.3 Mobilization of the hepatic flexure by dividing the gastrocolic ligament and the white lines of Toldt (**a**). This allows complete Kocherization of the duodenum whilst it's being retracted "up & out" (**b**). Exposure of the left renal vein (LRV), inferior vena cava (IVC) and the suspensory ligament of the duodenum. The ligament of Treitz is divided from the right side (**c**), until a tunnel is created for the jejunum to be brought up toward the RUQ (**d**)

superior mesenteric vein (SMV) and Portal Vein (PV) junction that ensues later during the operation (Fig. 16.3).

Troubleshooting *This step requires considerable coordination between the console and bedside surgeons. In particular, the bedside assistant needs to be dynamic in retracting the hepatic flexure caudad to expose the third and fourth potion of the duodenum and dissect the ligament of Treitz. For this, a near total Catell-Braasch mobilization is performed to the point where the hepatic flexure can be retracted towards the left lower quadrant. Failure to rotate the hepatic flexure towards the left lower quadrant can lead to avulsion of the middle colic or gastrocolic veins causing significant hemorrhage. Performing this step can be challenging in obese patients and males in particular due to the larger mesocolon.*

16.4.3.2 Division of the Stomach and Dissection of the Porta Hepatis

The Pars flaccida is opened widely and dissection along the lesser curvature of the stomach is carried inferiorly, dividing the right gastric and right gastroepiploic close to the lesser and greater curvatures of the stomach respectively using a combination of bipolar electrocautery and LigaSure. The stomach is then divided just proximal to the pylorus using 2 loads of endo GIA 60 purple cartridge. Next, the distal transected portion of the stomach is grasped with a Cadiere in R3 and retracted laterally towards the RUQ. This traction facilitates optimal exposure for portal dissection.

Proceeding from right to left, the lymph nodes anterior to the common hepatic artery (CHA) (station 8A) are dissected using monopolar cautery and their feeding vessels, which usually emanate from the celiac trunk, are controlled with LigaSure by the bedside assistant. These lymph nodes are then sent to permanent pathology. The dissection is carried laterally until the right gastric artery is identified, which is doubly clipped with a 5-mm Endo clip (Covidien) by the bedside assistant and divided. This step allows clear delineation of the common and proper hepatic arteries (CHA and PHA) proximal and distal to the origin of the gastroduodenal artery (GDA) respectively. Next, regional lymphadenectomy along the portal vein (stations 8p & 12p) is completed while gentle traction is being applied to the CHA anteriorly using a closed bipolar grasper. The suprapancreatic portal vein is exposed. Once this step is complete, attention is turned to the GDA which is dissected circumferentially with a robotic hook (R1) and vessel looped. Arterial anatomy should be clearly delineated before dividing the GDA-either by preoperative high-quality CT (triphasic) imaging or intraoperative robotic ultrasound with Doppler color flow. In addition, pulsation in the RHA and LHA should be visualized after the GDA is 'test clamped'. If the above is achieved, the GDA can be safely divided using a 45-mm vascular load angled tip. A 10-mm robotic Hem-o-lok (Weck Closure Systems, Research Triangle Park, North Carolina) clip is placed on the GDA stump to mark its location.

Next, the CBD is dissected circumferentially using the hook monopolar cautery (R1) and the bipolar grasper (R2). The CBD is gently pulled to the right using the bipolar in R2, and the intervening lymphatic tissue (station 12b) is dissected and sent to pathology. The CBD is then transected using an Endo GIA 45-mm gold load with angled tip, to minimize biliary spillage during the rest of the procedure. After clear delineation of the portal triad, dissection is carried inferiorly along the anterior border of the PV until the pancreatic neck is reached, sweeping any remaining lymphoid tissue towards the specimen. This provides a "landing zone" for the pancreatic transection that follows creation of the retropancreatic neck tunnel (Fig. 16.4).

Troubleshooting *When opening the gastro-hepatic ligament, an accessory/replaced left hepatic artery from the left gastric artery should be protected. During portal dissection, a strict "no-touch" technique is advised when dissecting vascular structures. If during this process, the anterior wall of the PV is injured, repair is accomplished with 4-0 prolene stitches taken transversely, in an interrupted fashion. A precautionary minilap pad placed in the LUQ ready for use to tamponade bleeding and apply pressure is recommended. Care should be taken while dissecting the CBD, since small tributaries from the PV can be seldom encountered during this step and need to be controlled with LigaSure to prevent troublesome bleeding. Finally, preoperative triphasic CT scan is essential in delineating a replaced right hepatic artery (from the SMA); this vessel -if present- can be injured during division of the CBD if not recognized. Finally, the gallbladder should not resected at this stage, since it provides a 'handle' for the liver retractor; It can be resected when the PD dissection is done.*

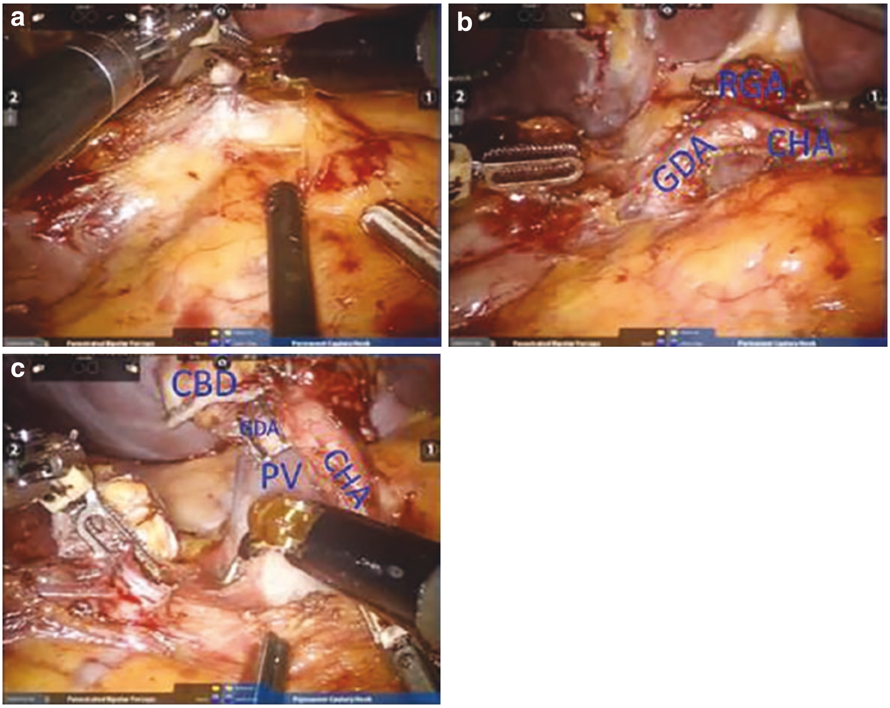

Fig. 16.4 Portal dissection: with the R3 arm retracting the transected stomach laterally towards the RUQ, dissection of the 8A lymph node proceeds from right to left (**a**). After the lymph node is removed, and the right gastric artery (RGA) is clipped and divided, the gastroduodenal artery (GDA) is skeletonized by clearing the adjoining lymphatic tissue. The common hepatic artery (CHA) both proximal and distal to the origin of the GDA is clearly delineated (**b**). Portal lymph-adenectomy is complete, the CBD is transected and dissection process caudally anterior to the portal vein (PV) until the "landing zone" is created (**c**)

16.4.3.3 SMV/PV Dissection and Transection of the Pancreatic Neck

This step begins at the inferior border of the pancreas. Using a cadiere or prograsp in R3 a continuous "up and out" traction force is applied to the duodenum/staple line. This allows clear demarcation of the SMV at the infra-pancreatic border and the entry point of the gastro-epiploic vein pedicle to the SMV. While the inferior pancreatic edge is being retracted anteriorly and superiorly using R2 (closed fenestrated Bipolar forceps), the bedside assistant retracts the mesolon inferiorly. This provides counter tension so dissection can be safely performed along the inferior border of the pancreas to identify the SMV using the hook monopolar in R1. Once located, dissection proceeds along the anterior surface of SMV in a cephalad direction, using hook monopolar cautery (R1) to divide small filamentous attachments along the pancreatic neck tunnel. This dissection is continued until the previously described supra-pancreatic dissection plane is reached. During this critical phase of

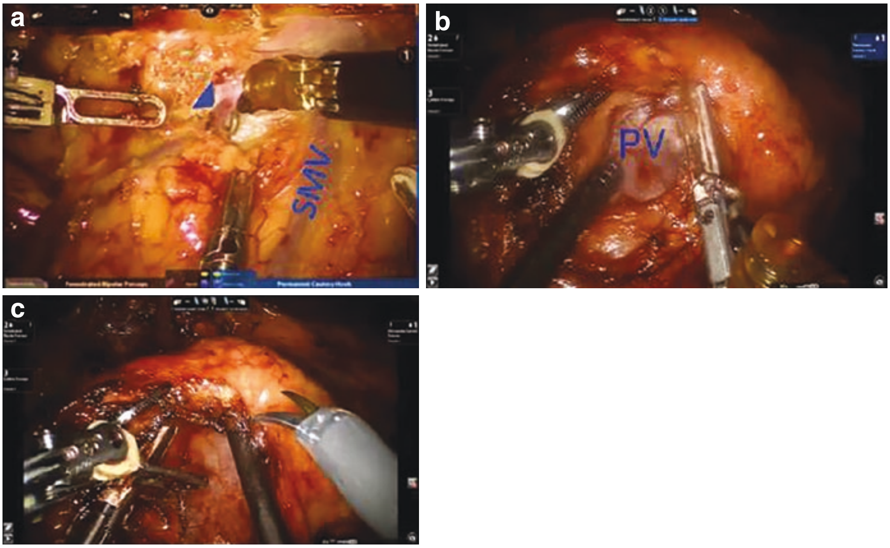

Fig. 16.5 Retro/infra-pancreatic dissection: with continuous "up & out" traction applied to the specimen with R3, the superior mesenteric vein (SMV) is identified at the inferior margin of the uncinate process. The dissection proceeds inferiorly until the trunk of Henle (blue arrowhead) is identified and controlled with LigaSure (**a**). Next, the retropancreatic tunnel is developed. With upward traction being applied to the pancreas with the bipolar forceps in R2, monopolar cautery in R1 is used to divide the flimsy attachments to the vein while a blunt instrument is used to protect the underlying PV/SMV by applying gentle downward traction (**b**). After the superior "landing zone" is reached, the pancreas is divided sharply with "hot" robotic shears (**c**)

the operation, the right gastroepiploic vein is identified and divided with sequential LigaSure burns. The middle colic vein can usually be preserved. It is crucial to identify the right venous branch of the middle colic vein (trunk of Henle); a common venous branch that joins the right gastroepiploic vein and the SMV. It should be controlled with multiple sequential burns using the LigaSure.

Finally, division of pancreatic neck is carried out using the hot monopolar shears in R1. To protect the SMV/PV during this step, the bedside assistant provides continuous gentle downward traction on the SMV in the retro-pancreatic tunnel using a blunt instrument (Suction/irrigation or grasper). This step is continued until the pancreatic duct is reached. It should be divided sharply without the use of heat to avoid thermal injury (Fig. 16.5).

Troubleshoot *The gastrocolic trunk can cause troublesome bleeding if not effectively controlled. The most effective modality is multiple consecutive burns using the LigaSure device right at its junction with the SMV; using metallic clips or ties are ineffective and can fall off during the course of the operation. Before pancreatic transection, care should be given to the superior and inferior transverse pancreatic arteries which are pre-coagulated with the fenestrated bipolar in R2 in lieu of the traditional figure of 8 transfection sutures used to control those vessels.*

16.4.3.4 Pancreatic Head and Uncinate Dissection (Fig. 16.6)

Using the Cadiere in R3, the specimen is retracted toward the right lateral abdominal wall. With this maneuver, the uncinate process is 'opened up' allowing safe dissection and margin clearance. Using hook monopolar cautery in R1 and fenestrated bipolar forceps in R2, filamentous attachments from the SMV/PV to the uncinate process are divided. During this process, the bedside assistant again protects the SMV/PV by providing gentle downward/leftward traction using a blunt instrument. The superior pancreaticoduodenal vein (of Belcher) and small venous tributaries from the first jejunal branch are identified during this process and controlled with multiple burns of the LigaSure. The first jejunal vein should be preserved (when possible if not involved by tumor) and reflected toward the left side. Once this is accomplished, the dissection of the superior mesenteric artery (SMA) layer ensues.

Dissection of the periadventitial SMA layer is performed using the hook monopolar electrocautery in R1 and the LigaSure. Care should be taken to stay at the lateral/anterior border of the SMA (along the plane of Leriche) to optimize the retroperitoneal margin. Exposure is enhanced by dynamically retracting the specimen toward the right lateral abdominal wall using the Cadiere or Prograsp forceps in R3. The inferior pancreaticoduodenal artery can be identified, is dissected at its base from the SMA, and ligated with metallic clips or the LigaSure. (Fig. 16.6). The specimen is then released and hemostasis is ensured.

Troubleshooting *In a majority of cases, the first jejunal vein arises from the right side of the SMV at the level of the inferior uncinate border and courses to the left posterior to the SMA. It has several uncinate branches. These can be easily avulsed causing significant bleeding. Gentle disseaction is necessary to identify them with the robotic hook. They should be divided with the LigaSure. Occasionally, the first jejunal vein needs to be transected. This is best done with a vascular stapler 45 mm load. Significant bleeding during this step of the operation can be managed by tamponade using the previously placed minilap. This allows for the surgical team to exchange the bipolar and hook in R1 and R2 to needle drivers for suture placement, or prepare for conversion to laparotomy.*

16.4.3.5 Cholecystectomy & Specimen Extraction

The gallbladder is now removed using a standard laparoscopic approach. R3 retracts the gallbladder cephalad towards the right shoulder, and dissection proceeds in the triangle of Calot using the robotic hook to establish the critical view of safety. The cystic duct and artery are doubly clipped and divided. The gallbladder is resected off its beds using the robotic hook cautery.

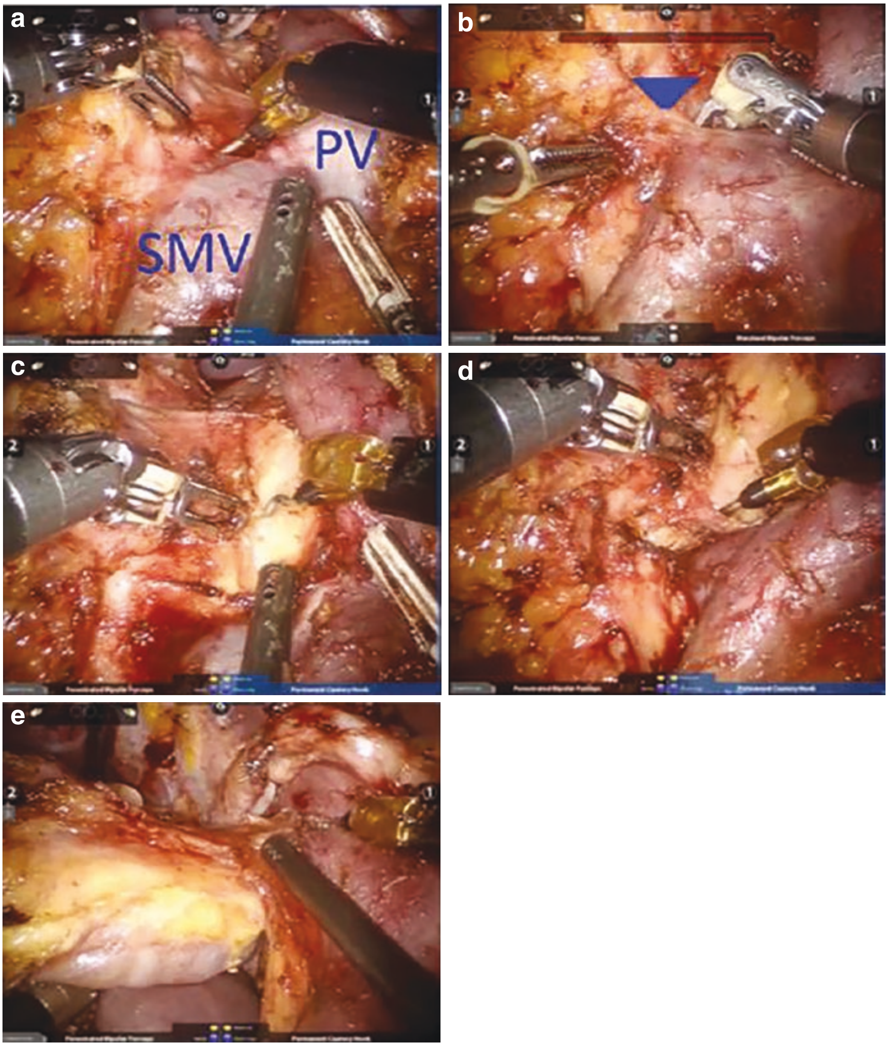

Fig. 16.6 Uncinate dissection and the superior mesenteric artery (SMA) layer: the entire uncinate process is removed with the specimen ensuring adequate retroperitoneal margin. A hook monopolar cautery in R1 divides these attachments and the small venous tributaries are controlled with LigaSure along the way (**a**). This step is carried through until the superior pancreaticoduodenal vein of Belcher (blue arrowhead) is reached (**b**) and controlled with LigaSure. During these steps, it's imperative to apply adequate traction on the specimen in the "up & out" direction. With the SMV and first jejunal vein retracted medially, the plane of Leriche is accessed (**c**). Dissection right along the SMA proceeds in systemic manner until the inferior pancreaticoduodenal artery is reach, dissected at its based and controlled with LigaSure and/or clips (**d**). The final attachments are divided with LigaSure

Both specimens (Whipple and gallbladder) are placed in a 15-mm endoscopic retrieval bag and removed from the 12-mm assistant trocar incision. This necessitates extending it slightly by 3–4 cm. Once the specimen is removed, a gel port (GelPoint Applied Medical, Rancho Santa Margarita, CA) is applied to maintain insufflation pressures. The 12-mm trocar is placed through the gelport. The specimen is sent for frozen margin assessment for the pancreatic and CBD/CHD margins, if deemed necessary by the surgeon.

Troubleshooting *Beware of bleeding from the left inferior epigastric as the LLQ is extended. We recommend placing the initial 12 mm port just lateral to the inferior epigastric artery and extending the incision laterally to avoid injuring this blood vessel.*

16.4.4 Reconstruction Phase

As mentioned previously in Sect. 16.4.3.1. a "neo-tunnel" is created after the division of the ligament of Treitz. The jejunal limb is brought up to the RUQ through this tunnel behind the root of mesentery and should lay comfortably with the antimesenteric border facing the transected pancreatic neck stump. The allows reconstruction of pancreatic and biliary anastomoses without undue tension.

16.4.4.1 Pancreaticojejunostomy

The pancreaticojejunostomy is performed in an end-to-side, duct-to-mucosa fashion using a modified Blumgart technique. First, the duct is cannulated with a size 4 or 5 French Hobbs ERCP stent (Hobbs Medical, Stafford Springs, CT) to prevent inadvertent narrowing. This is especially important if the duct is of narrow caliber (<3 mm). The pancreatic neck stump is mobilized from its retroperitoneal attachments for approximately 1–2 cm. This will allow the loop of jejunum to lay firmly under the pancreas and 'buttress' the posterior layer. Three interrupted 2-0 silk mattress sutures (each cut to 8 cm of length) are taken full-thickness through the pancreas (anterior surface to posterior surface), horizontally through the seromuscular layer of the jejunum, then back again through the pancreas from posterior to anterior, completing the U-stitch configuration. Two are taken at the superior and inferior edges, and a middle one straddles the duct. The sutures are then tied down to ensure complete opposition between the jejunal loop and the mobilized posterior surface of the pancreas. To facilitate this process, the most superior suture is kept under traction by the Prograsp R3. The needles are kept in situ after completing this step, since they are used to perform the anterior seromuscular layer later on. Hobbs stent mobility is checked to ascertain the duct is not narrowed by the middle straddle suture.

After the outer posterior layer of the anastomosis is constructed, the duct-to-mucosal inner layer is performed. An enterotomy is first made using a single jaw of the robotic endoshear on the antimesenteric border of the jejunal loop. Using 5-0 polydioxanone suture (Ethicon, Cincinnati, OH), 2 interrupted bites are taken posteriorly "in-out" through the duct, and then "out-in" full thickness through the bowel wall. These are tied (knots on the inside), and the stent is then placed into the jejunum. The anterior sutures (4–6 as needed) are now placed circumferentially in the same manner, but "out-in" full-thickness through the bowel then "in-out" through the duct (knots on outside) completing the inner layer. The anterior sutures are tied only after all of the sutures are placed under direct vision to ensure duct to mucosa sutures and inadvertent suturing of the indwelling stent.

After inner duct to mucosa layer is completed, the silk suture originally used to construct the posterior layer of the anastomosis, will now be used to complete the outermost layer in an interrupted Lembert fashion. At the end, the jejunum should completely encompass and cover the transected pancreatic stump (Fig. 16.7).

Troubleshoot *Caution is advised when taking the 2-0 U stitches through the pancreas, as this could inadvertently narrow the pancreatic duct, particularly with a soft gland and small caliber (<3 mm) duct. Placement of the Hobbs stent allows the surgeon to 'gauge' the direction of the duct and ensure that it is not violated. After tying these sutures firmly, easy mobility of the Hobbs stent should be interrogated.*

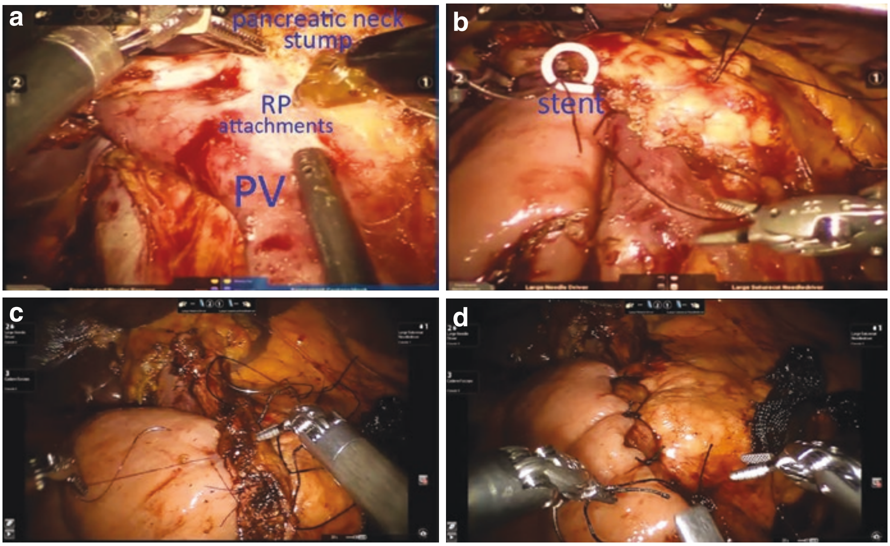

Fig. 16.7 Pancreaticojejunostomy. Mobilization of the pancreatic neck stump from its retroperitoneal attachments is first accomplished with hook monopolar cautery (**a**). After cannulating the pancreatic duct with a 4- or a 5- French ERCP stent, three modified Blumgart sutures are placed to create the posterior layer of the anastomosis (**b**). An enterotomy is then created, and the inner layer of the anastomosis is fashioned in a duct-to-mucosa fashion. The final layer of the anastomosis is complete using the originally placed silk sutures taken in a Lembert fashion (**c**, **d**)

16.4.4.2 Hepaticojejunostomy

The technique for construction of the hepatoeneteric anastomosis is also in an end-to-side fashion on the antimesenteric border of the jejunal loop that lies comfortably adjacent to the transected common bile/hepatic duct. It is prudent to always construct the hepaticojejunostomy about 10 cm distal to the Pancreaticojejunostomy. This extra distance has the theoretical advantage of minimizing biliary spillage from an adjacent pancreatic leak.

The mode of reconstruction depends on the size of the duct. If the duct is small (<8 mm) or has thin walls, the anastomosis is constructed using 5-0 PDS sutures in an interrupted fashion with a Hobbs stent placed across the anastomosis. In a large duct (>8 mm), the anastomosis can be performed using two running 4-0 V-Loc 180 green sutures (Covidien-Medtronic, Minneapolis, MN).

The staple line across the duct is cut sharply to ensure bleeding. The bile is suctioned, and spillage is avoided. Again, an enterotomy is made using a single jaw of the robotic shears, but care should be made to avoid enlarging the enterotomy beyond the size of the common hepatic or bile duct, since eventual manipulation almost always increases the size of the enterotomy.

Regardless of the technique of construction, the posterior layer is performed first, taking full thickness bites "in-out" through the duct, then "out-in" through the jejunal loop. The starting point is the most lateral edge on the right and proceeds medially. If continuous suturing is being performed, both V-Loc sutures are secured at the most lateral edge of the anastomosis and proceed in opposite directions. Gentle traction of the anterior sutures using cadiere or prograsp in R3 is again needed. Once the anterior and posterior layers overlap, they are tied completing the hepaticojejunostomy (Fig. 16.8).

Troubleshooting *If viability of the CHD is in question, then a more proximal transection margin could be selected. If a point where the right and left hepatic duct diverge is reached, a side-to-side ductoplasty can be performed, which is then anastomosed to a single jejunal enterotomy in an end-to-side fashion.*

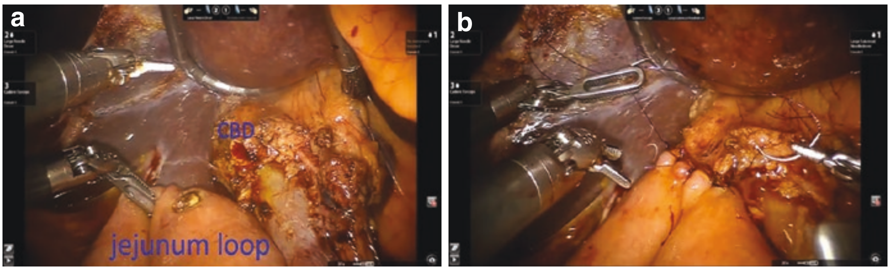

Fig. 16.8 Hepaticojejunostomy. If the CBD is adequate in caliber, the anastomosis can be constructed in a continuous running fashion using 4-0 V-Loc sutures. The first suture is taken at the lateral most aspect of the duct, and traction is applied on this suture using R3 until the posterior layer of the anastomosis is complete (**a**), the same is carried out for the anterior layer. If the duct is small in caliber, the anastomosis is complete in an interrupted fashion for the posterior and anterior layers (**b**)

16.4.4.3 Gastrojejunostomy

The distal end of the jejunal loop used as the "neo-duodenum" should be marked to differentiate the efferent and afferent limbs. We place a double long suture to denote proximal (afferent) and single long for distal (efferent). These markings should be made around 30–40 cm distal to the hepaticojejunostomy.

Next, the transverse colon and its mesentery are retracted cephalad, while the "excess" jejunum is reduced until the marking sutures are identified. This is a fundamental step for the proper orientation of the gastrojejunostomy and prevents twisting of the bowel. This is a difficult step to accomplish robotically and requires careful coordination between the console surgeon and the bedside assistant. The preselected loop of jejunum is brought up in an ante-colic fashion to construct an end-to-side, two-layered, isoperistaltic gastrojejunostomy. First, the posterior layer is completed using a series of interrupted 2-0 silk sutures in Lembert configuration. R3 grasps and retracts the corner stitch (at the lesser curve) for adequate exposure. Using the robotic "hot" scissors, around 6 cm of the gastric staple line is then removed, starting at the greater curvature proceeding towards the lesser curvature. An equivalent enterotomy is made. The interior layer of the anastomosis is completed using two 3-0 V-Loc 180 green sutures (Covidien-Medtronic, Minneapolis, MN) starting at each corner. The posterior aspect of the internal layer is completed in a continuous simple fashion, while the anterior layer is performed with a running Connell stitch. The sutures are tied when they overlap. Finally, the anterior layer of the anastomosis is completed using several interrupted 2-0 silk sutures taken in an interrupted Lembert fashion (Fig. 16.9).

Troubleshoot *The gastrojejunostomy can be performed in a side-to-side isoperistaltic stapled manner, but in a study from our institution comparing handsewn to stapled technique, our data demonstrated an increased risk of postoperative delayed gastric emptying using the stapled technique* [10].

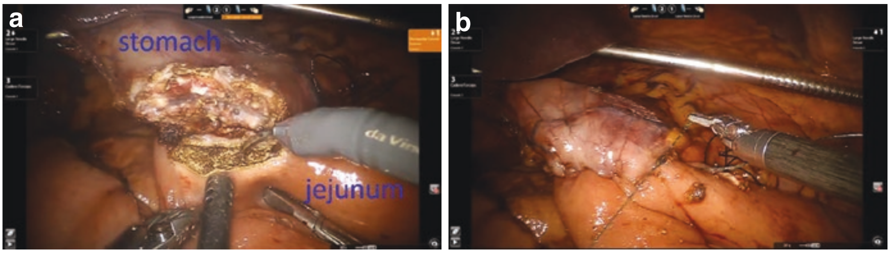

Fig. 16.9 Gastrojejunostomy: constructed in a two layered end-to-side fashion (**a**). The inner posterior layer is completed with a 3-0 V-Loc running stitch. When the last corner stitch is taken, transition to a running Connell stitch to complete the anterior layer of the anastomosis is performed (**b**)

16.4.5 Drain Placement, Closure

At the end of the procedure, a single 19F Blake drain is placed through the R3 trocar incision site. It is positioned posterior to the hepaticojejunostomy and anterior to pancreaticojejunostomy and attached to bulb suction. If the operating surgeon deems it necessary, the stump of the GDA can be covered with a vascularized tissue flap constructed from the round ligament. The SI or XI robot is undocked and the trocars are removed under vision. The fascia of the 12-mm trocar (SI) and the extraction site are closed with #1 polysorb sutures in an interrupted fashion.

16.5 Postoperative Management

Unless the patient's status requires intensive care monitoring, the majority of patients are transferred to a monitored surgical floor postoperatively and enrolled in an enhanced recovery pathway (ERAS). The nasogastric tube is removed shortly after the patient is transferred to the surgical ward or on postoperative day (POD) 1. Clear liquid diet can be started on the day of the operation or POD 1 and is advanced as tolerated to low residue diet by POD 5–6. The drain output and amylase levels are monitored daily and early drain removal is advocated. If the amylase level on POD 1 is <5000 IU/ml and continues to trend down, the drain can be removed on POD 3–5. Patients are generally discharged on POD6.

16.6 Conclusion

Robotic pancreaticoduodenectomy at the University of Pittsburgh is a complex procedure consisting of several well-defined steps. It requires a fundamental understanding of the principles of open pancreatic surgery, proper patient selection, and coordination between the console and bedside surgeon. Our methodological approach to this demanding operation has resulted in a safe and oncologically effective operation. In recent years, our team has shown the ability to disseminate our technique and approach to other adopters.

Conflict of Interest The authors have no conflict of interest to declare.

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Chapter 17
Laparoscopic RAMPS Distal Pancreatectomy for Pancreatic Cancer

Nina L. Eng and David A. Kooby

17.1 Introduction

Distal pancreatectomy (DP) is performed relatively infrequently, and the majority still are approached with an open technique [1]. Although the first laparoscopic DP was reported over 20 years ago by Cuschieri, the routine use of this approach was gradual and lacked longitudinal or randomized data [2]. Adaptation of LDP was slower for malignant disease given concerns regarding the adequacy of surgical margins and lymph node harvests when compared to the ODP approach [3]. A review of the National Inpatient Sample (NIS) database reports that the rate of laparoscopic DP increased from 4.3% to 7.3% from 1998 to 2009, respectively [4].

While surgical volume substantially influences outcomes in laparoscopy, recent observational analyses demonstrate no significant differences in morbidity, mortality, positive resection margins, or clinically significant fistula formation between laparoscopic and open approaches to DP [5, 6]. Laparoscopy also offers the potential benefits of reduced blood loss, improved cosmetic results, and faster postoperative recovery [7, 8].

DP is indicated for lesions to the left of the porto-mesenteric axis, the most common of which include pancreatic ductal adenocarcinoma, neuroendocrine tumors, and cystic neoplasms. A DP with splenectomy is typically performed for malignant indications to enhance lymph node retrieval and to optimize surgical margins. A Radical Antegrade Modular Pancreatico-Splenectomy (RAMPS) procedure may be employed to further optimize margin negative resection rates depending on tumor type and surgeon experience. Spleen preserving DP (SPDP) presents another option

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for benign and indolent pancreatic indications, although there remains no clear consensus on whether SPDP is superior to distal pancreatectomy with splenectomy (DPS).

Unlike minimally invasive pancreatoduodenectomy (MIPD), which requires complex organ reconstruction in addition to a challenging dissection, LDP is accessible to most competent pancreatic surgeons with appropriate laparoscopic abilities as it typically does not require a reconstructive phase. LDP can be performed safely with appropriate training, proper patient selection and sound operative technique. This chapter highlights the techniques of posterior RAMPS approach for pancreatic ductal adenocarcinoma (PDAC) with involvement of the left adrenal gland, as it is the most demanding form of LDP from the technical standpoint.

17.2 Preoperative Evaluation

All candidates for laparoscopic distal pancreatectomy (LDP) undergo the following preoperative evaluation: (1) comprehensive clinical evaluation; (2) radiologic evaluation; (3) histopathologic and serum diagnostic testing; (4) medical optimization.

17.2.1 Comprehensive Clinical Evaluation

Masses of the pancreatic body and tail constitute approximately one third of pancreatic neoplasms and are often discovered after significant growth and/or invasion into nearby structures has occurred [9]. The most commonly reported symptoms include weight loss, epigastric pain radiating to the back, and new onset diabetes mellitus. Different constellations of symptoms may also indicate certain classifications of pancreatic neoplasms. For example, weight loss, anemia, new onset diabetes mellitus and dermatitis necrolysis migrans may raise suspicion for a glucagonoma. Symptoms of pancreatic exocrine insufficiency and chronic abdominal pain may raise suspicion for an IPMN. Symptoms of peptic ulcer disease that do not resolve despite appropriate medical management may indicate the presence of a gastrinoma [9].

17.2.2 Radiologic Evaluation

Initial diagnosis of a pancreatic body or tail lesion begins with a computed tomography (CT) scan of the abdomen. CT scans of the chest and pelvis are often added once a lesion has been identified for the purpose of tumor staging and assessing for locoregional invasion, distant metastasis, and vascular invasion. Magnetic resonance imaging (MRI) is less frequently utilized but may be helpful in characterizing hepatic lesions. Ideal lesions for LDP resection are benign, less than 5 cm in diameter, and non-invasive to nearby organs and vasculature. However, numerous authors have reported LDP to be safe and effective for malignant lesions as well as larger and minimally extensive masses [10].

17.2.3 Histopathologic and Serum Diagnostic Testing

When an adequate transgastric window is identified on CT, endoscopic ultrasonography (EUS) is a useful tool for both assessing the primary lesion, as well as performing a fine needle aspiration (FNA) for cytology and histopathologic diagnosis. Regardless if an EUS-FNA is performed, if the lesion is suspicious for malignancy, the authors may perform a diagnostic laparoscopy to inspect the peritoneal cavity and obtain peritoneal, serosal, and hepatic tissue samples and washings for further pathologic evaluation.

Certain serum tests and tumor markers may be drawn to clarify or characterize particular diagnoses. CA 19-9 may assist with differentiating between inflammation and malignancy. Carcinoembryonic antigen (CEA) and CA 125 may assist with determining malignancy among mucinous cystic lesions of the pancreas [9, 11]. Functional endocrine tumors may be evaluated using levels of c-peptide proinsulin, gastrin, secretin, glucagon, and somatostatin.

17.2.4 Medical Optimization

For malignant lesions of the pancreatic body and tail, patients may proceed directly to surgery with subsequent adjuvant chemotherapy or they may undergo neoadjuvant chemotherapy (NAT) prior to surgical resection. Studies examining treatment of pancreatic ductal adenocarcinoma (PDAC) of the pancreatic head have reported improved survival and R0 resection among patients undergoing NAT [12–14]. Currently, there have not been high powered, randomized controlled trials comparing outcomes specifically for pancreatic body and tail lesions.

Regardless if the lesion is benign or malignant, patients are seen multiple times in clinic preoperatively to ensure cessation of tobacco use, optimization of diabetes management, adequate management of cardiopulmonary comorbidities, and organization of multi-disciplinary care (dieticians, medical oncology, gastroenterology, anesthesia, etc.).

17.3 Clinical Presentation

The case used as an example for the technique is that of a 62-year-old female who had hypertension, tobacco abuse, and new onset diabetes mellitus. She was a lean woman who noted a 10 lb weight loss with abdominal and back pain radiating to the

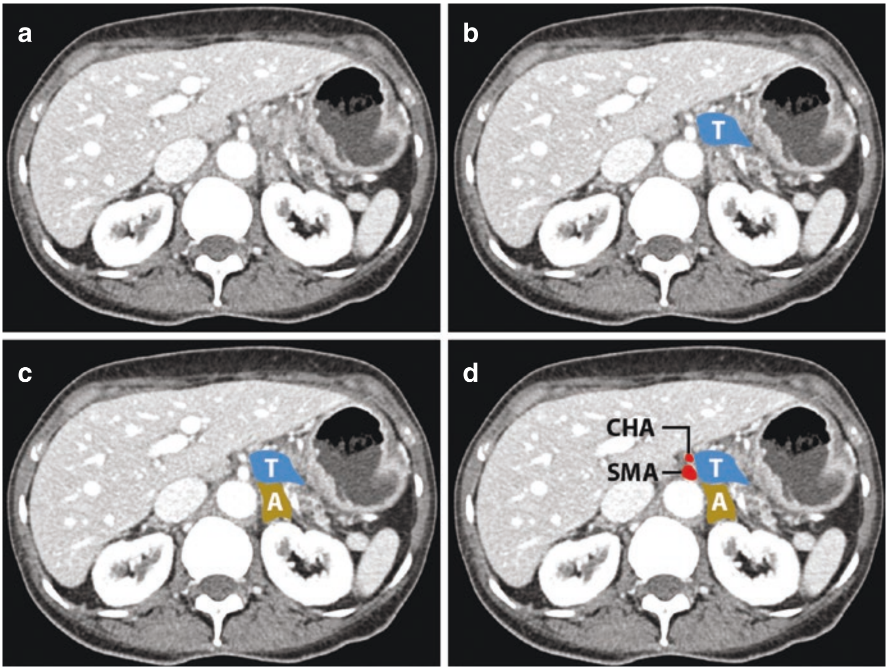

Fig. 17.1 Four panel axial CT image with contrast of a patient with a pancreatic body ductal adenocarcinoma. (**a**) Unlabeled image. (**b**) Image showing the center of the tumor (T). (**c**) the left adrenal gland (A). (**d**) the common hepatic artery (CHA) and the superior mesenteric artery (SMA)

left flank. She underwent cross-sectional imaging and was found to have a mass in the pancreatic body with loss of fat plane between the mass and the left adrenal gland (Fig. 17.1). An endoscopic ultrasound was performed with fine needle aspiration confirming a diagnosis of PDAC and she was started on preoperative chemotherapy, which she did not tolerate well. The decision was made to proceed with laparoscopic posterior RAMPS.

17.4 Operative Technique

17.4.1 Position of the Patient

There are two basic approaches for positioning patients for LDP: (1) supine with left flank bump and left arm tucked; and (2) lazy right lateral decubitus position on a beanbag with either a formal arm sling or pillows to support the arms. These are depicted in Fig. 17.2. The supine position provides better access to the porto-mesenteric axis and may be the preferred approach for lesions near the pancreatic neck and for PDAC in general. The lateral position provides the benefit of gravity to

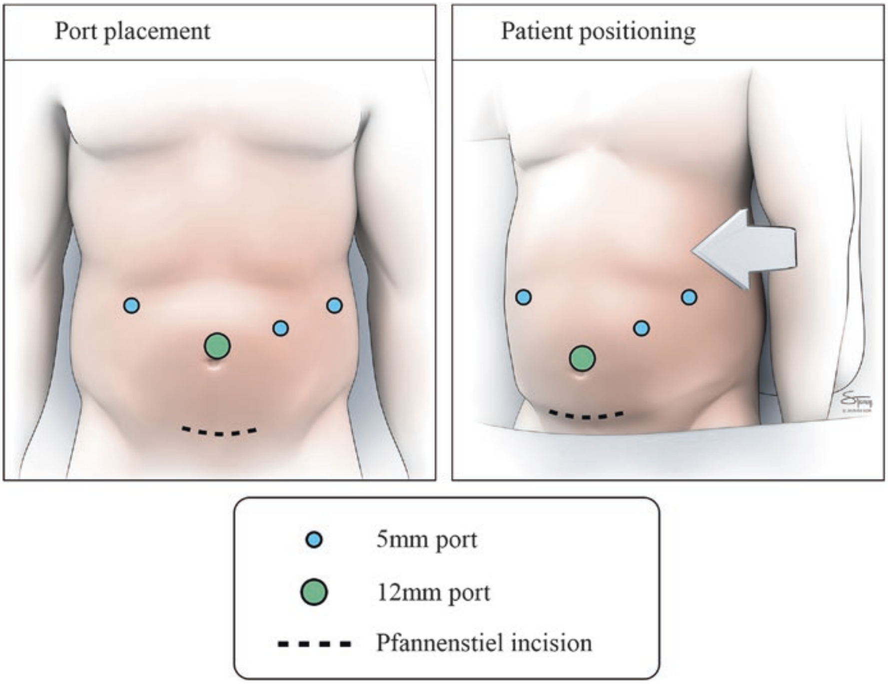

Fig. 17.2 Port placement and positioning. (1) Schematic port placement with three 5 mm ports, one 12 mm port at umbilicus for ultrasound and stapler use, and a Pfannenstiel incision for specimen extraction. (2) Patient positioning supine with left flank bumped with padding and patient secured to operating table to allow gravity retraction during the case

assist with splenic flexure mobilization and exposure to the pancreatic tail and spleen and may be preferred for lesions near the splenic hilum.

Bilateral sequential compression devices are activated prior to intubation to lessen the risk deep vein thrombosis. We prefer to provide heparin prophylaxis in the preoperative holding area prior to induction of anesthesia. Following general endotracheal intubation, a nasogastric or orogastric tube and sterile indwelling urinary catheter are placed, and standard antibiotic prophylaxis is provided. Once positioned, the patient should be secured soundly to the operating table, with proper protection for their extremities, to allow for table movement which can greatly enhance exposure during the case [8].

17.4.1.1 Tips and Troubleshooting

1. Inappropriate or inadequate patient positioning can complicate the procedure by making it difficult to retract the stomach and colon safely, especially in patients with central obesity. It may help to place trocars higher in these patients to avoid

having the colon and greater omentum interfere with visibility and access to the pancreas.
2. It is important to discuss venous and arterial access with your anesthesia colleagues prior to draping, especially when the patient is positioned in lateral decubitus positioning as bleeding and hypotension are inherent risks of these procedures.
3. Prep the patient down to the pubis to provide access for specimen retrieval through a Pfannenstiel incision. Our preference is to avoid upper abdominal extraction sites, as this can lead more postoperative pain and higher hernia rates.

17.4.2 Trocar Placement

We prefer to use a 4-port approach with three 5 mm ports and one 10/12 mm port, shown in Fig. 17.2. The abdomen can be insufflated using either a Veress needle technique in the left upper quadrant or a Hassan approach, at or slightly above the umbilicus. The primary surgeon stands to the patient's right and will use a grasper through a 5 mm port in right upper abdomen and a dissecting device, such as a bipolar cautery or ultrasonic shears, through a 10/12 mm port in or just above the umbilicus depending on body habitus. The assistant will stand to the patient's left and work through two 5 mm ports with a 5 mm 30-degree scope in the left abdomen, placed four finger breadths below the costal margin in the midclavicular line, and a grasper or suction-irrigator in the left flank. When using the supine position, addition of a subxiphoid liver retractor can be useful and sometimes necessary.

17.4.2.1 Tips and Troubleshooting

1. Consider swapping the left abdominal 5 mm port for a 10/12 port for challenging cases, as it allows for your assistant to place clips or sponges if necessary and also allows for use of a 10 mm scope for improved visualization when preferred. Having this additional 10/12 mm port also provides another angle for insertion of a linear cutting stapler for vascular and gland transection.
2. Remember to use table positioning and gravity to aid in retraction, after ensuring that your patient is properly secured to the table.

17.4.3 Diagnostic Laparoscopy and Division of the Gastrocolic Ligament

We begin with a diagnostic laparoscopy and assessment of the peritoneal cavity to evaluate for factors that may influence the surgical approach, including the extent of disease spread and involvement of intraabdominal organs, notably the liver and diaphragm. The lesser sac is then entered by dividing the gastrocolic ligament with a dissection device. The authors prefer using a curved tip bipolar dissector for enhanced hemostasis. Hemostasis is further maintained by dissecting along the avascular omental gastrocolic plane and ensuring adequate control of the short gastric vessels. The short gastric vessels are ligated and transected up to and including the connections to the upper pole of the spleen, as well as up to the angle of His at this time if a splenectomy will be performed. This permits mobilization of the stomach to expose the pancreas. For spleen preservation, the splenic vasculature may be preserved or solely the short gastric arteries, as delineated by the Warshaw and Kimura techniques, which will not be discussed further in this chapter [15, 16].

17.4.4 Tips and Troubleshooting

1. Hemorrhage from the short gastric vessels or the spleen can occur due to direct injury or overzealous traction. Prepare your assistant to stay calm and maintain appropriate exposure. Inexperienced assistants may in advertently move the grasper in response to hemorrhage and thereby compromise exposure to the area of hemorrhage. Strategic packing with a gauze sponge can help manage hemorrhage and provide time to regroup and allow anesthesia to catch up if necessary, prior to attempting repair or considering conversion.
2. Minor hemorrhage during the case can make dissection more difficult and interfere with progression of the operation. We suggest using a bipolar device for dissection with the ability to provide energy while the jaws of the device are slightly open to treat small bleeders that are away from bowel.

17.4.5 Mobilization of the Transverse Colon and Splenic Flexure and Stomach and Inferior Border of the Pancreas

Mobilization of the colon can vary in difficulty level depending on patient body habitus, degree of mesenteric fat, and amount of colon distention and peripancreatic inflammation. When the patient is positioned supine, we prefer to mobilize the transverse colon and splenic flexure from right to left, and for lateral decubitus, we prefer to mobilize the splenic flexure first from left to right (Fig. 17.3).

Once the colon is down and the lower pole of the spleen clear, we dissect along the inferior pancreatic border to begin the RAMPS dissection. By doing so, the operating surgeon can develop the retropancreatic plane to include the Gerota's perinephric fascia and expose the left renal vasculature and the left adrenal gland (Fig. 17.4). The left adrenal gland is taken en-bloc for a posterior RAMPS, as in this case, and preserved during an anterior RAMPS. We prefer to proceed with

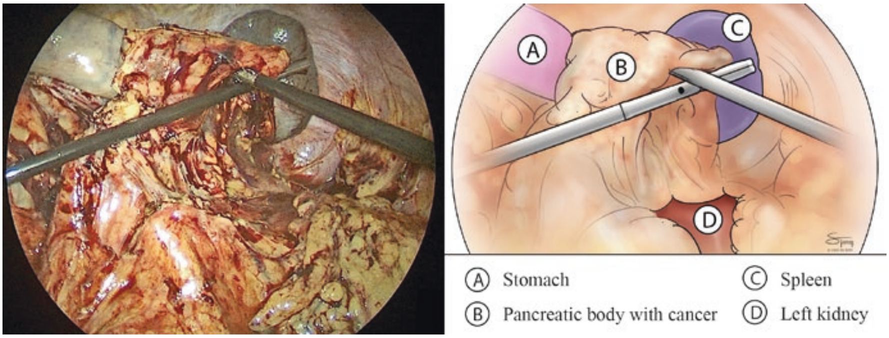

Fig. 17.3 Intraoperative photo showing the inferior dissection to include the left perinephric fat. Note, the splenic flexure of the left colon is dropped and the stomach is retracted cephalic following ligation and transection of the short gastric vessels. The spleen remains on its attachments to the diaphragm

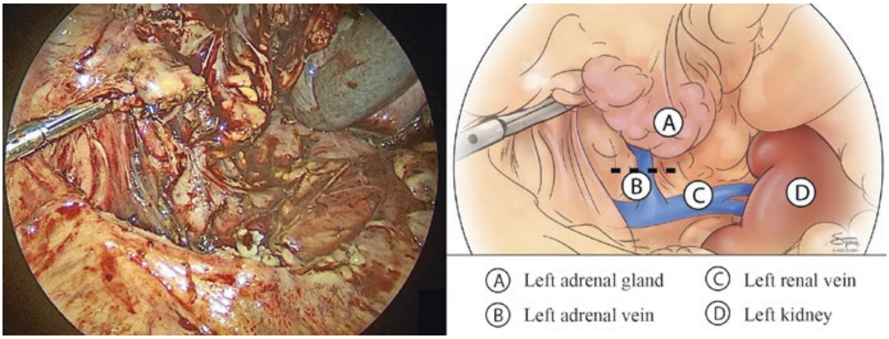

Fig. 17.4 Intraoperative photo showing dissection extending under the left adrenal gland to include it with the specimen. The broken line indicated the left adrenal vein, which will be ligated and divided. Note the exposure of the left renal vein

dissection to expose the porto-splenic confluence, the celiac axis and the superior mesenteric artery, as well as the left side of the aorta prior to transecting the pancreas or its vasculature, when possible (Fig. 17.5).

17.4.5.1 Tips and Troubleshooting

1. In patients with significant peripancreatic inflammation and retroperitoneal fat, it is possible to injure the left kidney or its vasculature if the plane of dissection is too deep.
2. Use of intraoperative ultrasonography can aid in accurately identifying the lesion and its margins and the relevant vasculature.

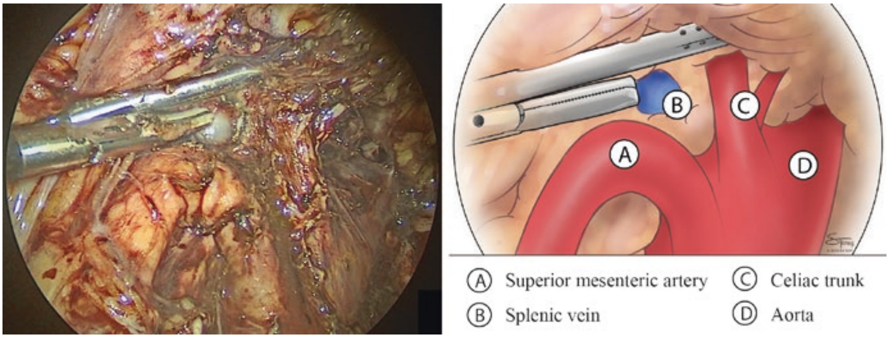

Fig. 17.5 Intraoperative photo showing dissection medially to expose the superior mesenteric artery (SMA) and celiac trunk, as well as the left side of the aorta. The splenic vein will come into view as well

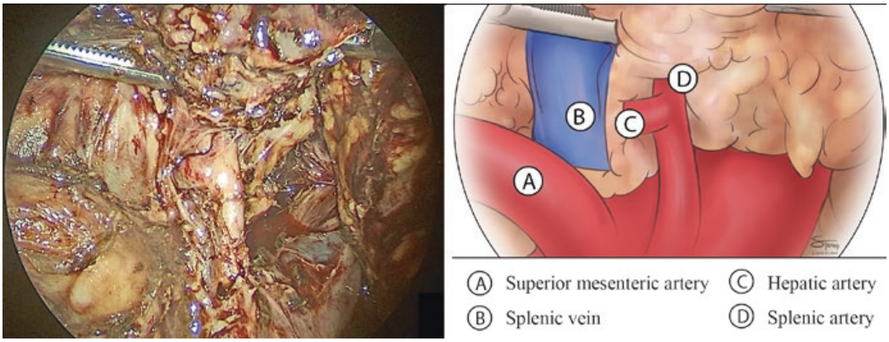

Fig. 17.6 Intraoperative photo showing dissection of the celiac axis under the pancreatic body. This is a unique view that is not visible during the open procedure. Labeled are the common hepatic artery (HA) and the splenic artery (SA). The superior mesenteric artery (SMA) and the splenic vein (SV) are also labeled

17.4.6 Division of the Splenic Vasculature

As we are describing a laparoscopic RAMPS procedure, a splenectomy is typically performed. Routinely we prefer to ligate and divide splenic artery at its origin (Fig. 17.6), followed by the splenic vein at its insertion (Fig. 17.7) in that order. The artery should be test-clamped prior to transection to confirm flow in the common hepatic artery. Transection may be completed with a vascular stapler or ties and locking clips.

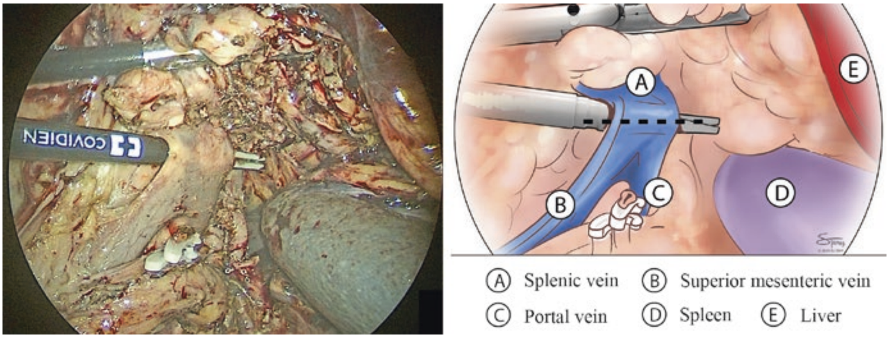

Fig. 17.7 Intraoperative photo showing bipolar dissecting shears behind the splenic vein (SV) prior to ligating and dividing it at its insertion into the portal vein with a linear vascular stapler. The broken line represents the planned line of transection

17.4.6.1 Tips and Troubleshooting

1. At risk during this dissection are the portal vein, superior mesenteric artery and vein, and the common hepatic artery during the RAMPS dissection whether performed open, laparoscopically, or robotically. The authors recommend thoughtful evaluation above and below the pancreas to confirm the anatomy prior to ligation and transection. Use of intraoperative ultrasound is suggested with simultaneous intraoperative review of patient imaging. While better with robotics, there are laparoscopic ultraviolet filter systems available for indocyanine green fluorescence. The authors have limited experience with these. Careful dissection with test clamping and flow ultrasonograpy are recommended.
2. We transect the splenic vasculature close to the celiac axis and the porto-superior mesenteric vein access to reduce the potential for thrombosis.
3. In more challenging cases due to tumor, radiation, and/or obesity, it is sometimes safer to divide the splenic vein before taking the splenic artery. While this approach increases splenic congestion, it is unlikely to cause significant problems and can be mitigated by preserving some of the short gastric vessels until after this step, at the sacrifice of less complete gastric mobilization.

17.4.7 Division of the Pancreas and Specimen Removal and Stump Management

The pancreatic gland may be transected utilizing a laparoscopic linear stapler, with or without staple line reinforcement, or with an energy device and suturing. Remaining retroperitoneal perinephric fat and splenic attachments are subsequently dissected to complete the posterior RAMPS dissection (Fig. 17.8). The pancreas

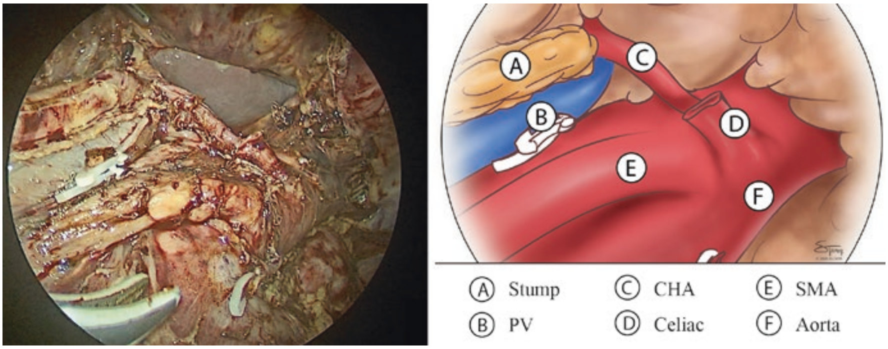

Fig. 17.8 Intraoperative photo showing the final medial dissection bed with the following structures labeled: the transected pancreatic neck stump (Stump) the portal vein (PV) with clips where the splenic vein was transected, the celiac trunk with common hepatic artery (CHA), the superior mesenteric artery (SMA) and the left side of the aorta

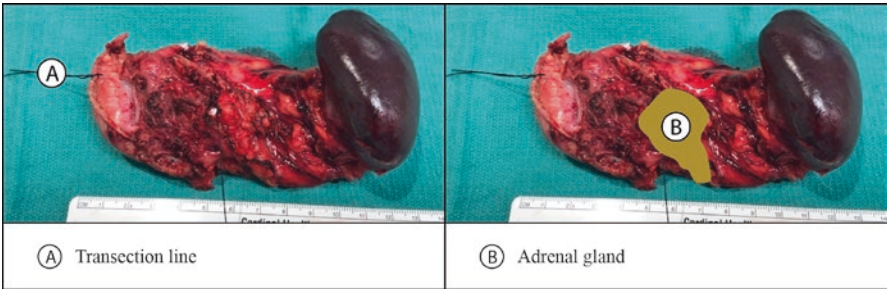

Fig. 17.9 Photograph of the under surface of the specimen. Panel 1 highlights the transection line. Panel 2 demonstrated the *en bloc* resection of the left adrenal gland

may be removed with or without the spleen utilizing one or two EndoCatch bag and examined for marking for pathologic examination (Fig. 17.9). The umbilical incision may be extended inferiorly for specimen delivery or a Pfannenstiel incision may be used to minimize hernia risk in the postoperative period.

The development of a pancreatic fistula at the distal transection margin occurs in approximately 20–30% of patients [17–19]. While this is not always avoidable, we recommend fortifying the pancreatic stump by utilizing clips or imbricating the transected edge over the staple line with interrupted sutures. The stump can also be fortified using an omental pedicle flap overlying the transected edge. The authors advocate leaving a fluted surgical drain at the distal end of the stump, though recent randomized data suggests that drain placement may not be necessary and depends largely on surgeon preference [20].

17.4.7.1 Tips and Troubleshooting

1. We prefer stapled transection of the gland over and sometimes to the right of the portal vein, when necessary to obtain clear surgical margins. We employ slow, compression closure of the stapler, as previously described.

17.4.8 Final Inspection and Closure

We irrigate and inspect the peritoneal cavity to confirm hemostasis and re-evaluate adjacent organs for pathologic lesions. The pancreas staple line is inspected for evidence of parenchyma fracture. The laparoscopic ultrasound may be utilized once more to confirm Doppler flow within the portal vein and hepatic artery. Upon completion, all instruments and sponges are removed from the abdomen under direct visualization, and the abdomen is desufflated. The fascia is closed with #1 non-looped PDS in a running fashion, and the skin is closed with 4–0 Monocryl. If a Hasson entry was utilized, we close with interrupted #1 Vicryl suture.

17.5 Postoperative Course

Patients are fed clear liquid diet the morning of the first postoperative day, advancing as tolerated to a low-fat, carbohydrate controlled general diet by the second postoperative day. Most patients are discharged within 3–7 days and are instructed to maintain a low-fat diet for the following four weeks. Patients are seen in clinic for a postoperative check within two weeks, and most are able to return to their normal, daily activities within this time. For post-splenectomy patients, vaccinations against encapsulated organisms may be administered 2–3 weeks prior to surgery or within 1–2 weeks after surgery. Using the RAMPS approach can augment peripancreatic margins and improve lymph node yield tremendously [21, 22].

17.6 Conclusions

Laparoscopic posterior RAMPS distal pancreatectomy can be safely and feasibly performed utilizing the laparoscopic approach for both pancreatic cancers of the body and tail. Careful attention to each technical aspect of the procedure can maximize success and optimize perioperative outcomes.

Conflict of Interest The authors have no conflict of interest to declare.

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Chapter 18
Robot-Assisted Distal Pancreatectomy

Sarwat B. Ahmad, Samer Al Masri, Alessandro Paniccia, and Amer H. Zureikat

18.1 Introduction

Minimally invasive distal pancreatectomy is most commonly done laparoscopically, but a growing number of surgeons are utilizing the robotic platform either alone or in conjunction with laparoscopy [1, 2]. RDP may be performed for either benign or malignant disease, although we have previously reported superior R0 resection rates and lymph node yield with the robotic approach [3]. Offering enhanced visualization and dexterity, RDP has been associated with lower conversion to open compared to LDP [3]. With lower conversion rates, RDP may be a cost-effective option in select cases [4, 5]. The learning curve for RDP is around 40 cases, although this may be shorter in the presence of appropriate training, mentorship and guidance [6].

Both robotic and laparoscopic DP have been shown to be safe and feasible. The technical advantages of robotic surgery may be especially relevant for pancreatic body and neck tumors that require enhanced vascular dissection, splenic preserving DP, or those that require intracorporal recontsruction [4, 7]. The disadvantages of robotic DP compared to pure laparoscopy are primarily related to limited resources and trained staff, access to the console, and lack of formal training to ensure safety. Selection of surgical technique and platform should be based on surgeon preference and availability of resources.

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18.2 Clinical Presentation

Most distal pancreatectomies are performed for malignant indications (pancreatic cancer, neuroendocrine tumors, or metastatic disease from renal cell cancer for example) or premalignant cystic neoplasms. Pancreatic cancer develops at a median age of 70, and only 15–20% of cases are surgically resectable. Since obstructive jaundice is not a feature of pancreatic body and tail cancers, these lesions often present late with advanced disease. Most patients present with vague abdominal or mid back pain, weight loss, fatigue, steatorrhea and abdominal distention due to ascites. Nearly a third of patients will have new onset diabetes, and those with pancreatic cysts can present with acute pancreatitis secondary to duct pancreatic duct obstruction. Occasionally these tumors may invade adjacent organs causing obstruction of the duodenum, colon or stomach.

18.3 Preoperative Evaluation

Following a thorough history and physical examination, a pancreas protocol triphasic CT scan is our preferred modality for identifying a pancreatic mass and delineating vascular involvement and metastatic disease. A noncontrast CT of the chest is obtained to rule out lung metastases. On CT, involvement of the celiac trunk, hepatic artery, aorta, superior mesenteric artery and porto-mesenteric venous confluence should be assessed. We routinely perform endoscopic ultrasound to biopsy the lesion for diagnosis which is needed for the administration of neoadjuvant therapy. We generally do not perform MRI or PET scans for pancreatic cancer, unless there are questionable liver lesions on CT that need further characterization. Although the tumor marker CA19-9 is not used to diagnose pancreatic cancer, high levels at diagnosis may indicate occult systemic disease and is an indication for neoadjuvant therapy at our institution.

18.4 Technique

18.4.1 Positioning and Set-up

The patient is placed supine on a split leg table or in low lithotomy to allow the camera-holder (laparoscopic portion) or bedside assistant (robotic portion) to stand between the legs. Foley catheter and orogastric tube are placed. A chest strap is secured. The left arm is tucked. All pressure points are padded according to protocol. During the laparoscopic portion, the surgeon stands on the patient's left and the assistant on the right side. A second assistant drives the camera between the legs for the laparoscopic portion of the operation.

18.4.1.1 Trouble shooting

The patient should be positioned in steep Trendelenburg to allow the left mesocolon to retract inferiorly, facilitating mobilization f the splenic flexure. This is particularly important in an obese patient.

18.4.2 Trocar Placement

A 5 mm optical view trocar is used to enter the abdomen in the left upper quadrant along the mid-clavicular line. The abdomen is explored for metastatic disease. Additional robotic trocars are placed in the supraumbilical level (12 mm for SI, 8 mm for XI), right paramedian (mid-clavicular line), left anterior axillary line, and right anterior axillary line (liver retractor), about 7–10 cm apart. The entry trocar is replaced with a robotic trocar in the left mid-clavicular line (Fig. 18.1). A figure-of-eight (0-vicryl) fascial stitch is placed trans abdominally and secured externally around the 12 mm port (camera site). This is held under tension by a surgical clamp on the patient drape to add stability to the camera port and will ultimately be used to close the fascial defect at the end of the procedure. The camera is repositioned to the supraumbilical trocar. A self-retaining retractor (Mediflex liver retractor, Mediflex ®Surgical Products, Islandia, NY) is placed through the 5 mm RUQ port to facilitate stomach exposure by retracting the left lateral sector of the liver. Once complete access to the lesser sac is obtained—after ligation of all short gastric vessels—the self-retaining retractor is repositioned to elevate the stomach and the left lateral sector of the liver anteriorly. This simple maneuver provides excellent

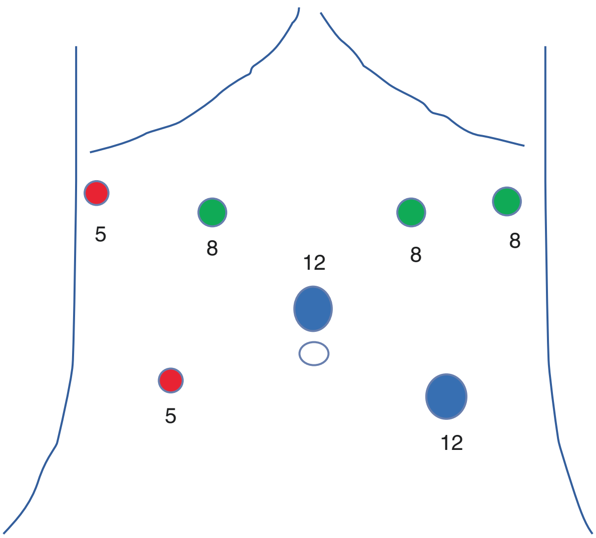


Fig. 18.1 Trocar placement for robotic distal pancreatectomy: camera port (supraumbilical *blue* for SI or 8 mm *green* for XI), robotic arms (*green*), liver retractor (RUQ *red*), and bedside assistant (RLQ *red* and LLQ *blue*)

exposure to the anterior surface of the pancreas. Two laparoscopic assistant ports, a 5 mm port in the RLQ and a 12 mm port in the LLQ (future specimen extraction site) are placed for the bedside assistant to use for Ligasure™, laparoscopic graspers, linear staplers and suction. The robot is then docked over the head of the patient. An atraumatic grasper such as the Cadiere forceps is inserted into Arm 3 (left anterior axillary line), hook cautery in Arm 2 (left mid-clavicular), and an energy sealing device (fenestrated bipolar, ultrasonic dissector) in Arm 1 (right mid-clavicular). Opening the lesser sac and mobilization of the splenic flexure may be performed laparoscopically prior to docking the robot, depending on surgeon preference.

18.4.2.1 Troubleshooting

Care must be taken not to place the ports too low. In an average patient, the robotic ports are one hand's breadth above the level of the umbilicus, but in an obese patient, these may need to be 5 cm higher to allow for dissection of the pancreatic tail and short gastric vessels. It is paramount to ensure that the LLQ 12 mm port is not positioned in line with any of the left upper quadrant ports to avoid collisions between the assistant instruments and the robotic arms.

18.4.3 Division of the Gastrocolic Ligament and Entry into the Lesser Sac

Using laparoscopic graspers, the stomach is initially retracted anteriorly (i.e. toward the anterior abdominal wall) and toward the liver while the omentum is retracted caudally. An attempt should be made to identify a thin area in the gastrocolic ligament, commonly along the mid to distal third of the greater curvature. After access to the lesser sac is secured, the dissection proceeds laterally and the stomach is retracted to the right, while the greater omentum is retracted caudally. A 10 mm Maryland tip laparoscopic Ligasure™ (Covidien-Medtronic, Minneapolis, MN, USA) is used to divide the gastrocolic ligament, preserving the left gastroepiploic vessels (Fig. 18.2a). The stomach is re-grasped posteriorly and rotated up as the dissection is carried leftward to include the short gastric vessels until the left phreno-oesophageal ligament (angle of His) (Fig. 18.2b).

18.4.3.1 Troubleshooting

While opening the lesser sac, care must be taken not to violate the mesentery of the transverse colon (unless it needs to be resected with the specimen). This occurs especially in patients at the extreme ends of BMI or after severe pancreatitis. When

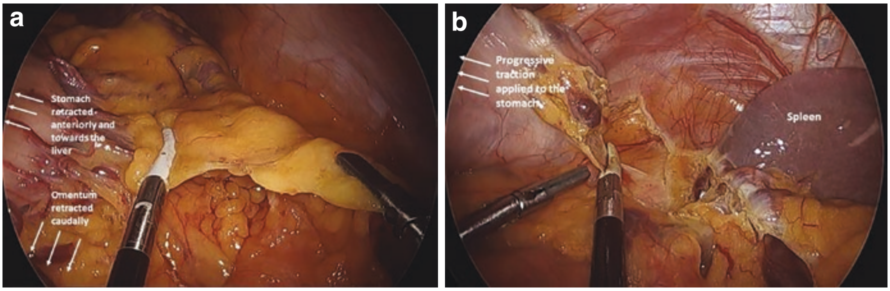
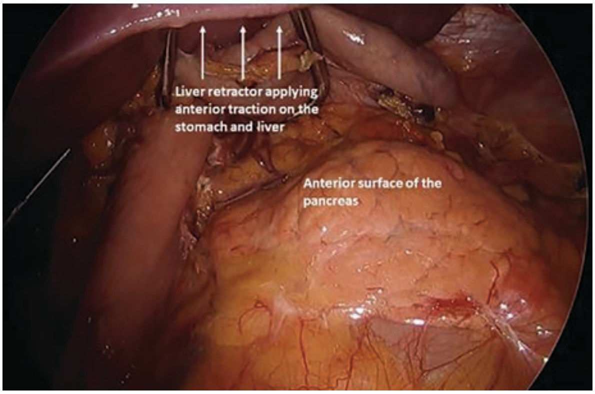


Fig. 18.2 (**a**) Use of ligasure™ by the bedside assistant to widely open the lesser sac. (**b**) Dissection is carried all the way towards the angle of his dividing the short gastric vessels along the way using the Ligasure and exposing the left crus

Fig. 18.3 Liver retractor applied on the stomach and liver anteriorly to expose the lesser sac widely



the plane of dissection is elusive, the posterior wall of the stomach can be used as a safe guide into the lesser sac, which can be reached by dissecting the areolar tissue along its surface.

18.4.4 Medial to Lateral Pancreatic Exposure

Medially, the lesser sac is opened to the level of the gastroduodenal artery (GDA) and the pancreatic neck. This will facilitate subsequent exposure of the pancreatic neck (Note: if the lesion is in the pancreatic tail, there is no need to expose the pancreatic neck). The liver retractor is now re-positioned to retract the stomach and left lateral sector of liver anteriorly to expose the pancreas (Fig. 18.3). The splenic flexure is mobilized with the Ligasure™.

18.4.4.1 Troubleshooting

Ideally, the self-retaining Mediflex retractor is positioned to place the left gastric pedicle on stretch, thereby exposing the pancreatic neck, body and tail. Failure to do so will require retraction using the third robotic arm, which is not an efficient utilization of this arm.

18.4.5 Division of the Pancreas

At this time, the robot is docked over the patients head if not done already. The peritoneum overlying the inferior and superior border of the pancreas is opened at the pancreatic neck exposing the portal vein and SMV respectively, and dissection is performed to establish a retropancreatic tunnel. An ultrasound can be used to identify relationship of pathology to planned transection point. An umbilical tape is placed around the gland (Fig. 18.4a) and retracted anteriorly with the third robotic arm to facilitate placement of the stapling device along the retropancreatic tunnel without injuring the portal vein. The pancreatic gland is typically divided using an Endo-GIA™ 60 mm cartridge staple load directly over the portal vein at the neck of the pancreas (Fig. 18.4b), to the left of the GDA. When possible, the umbilical tape should be incorporated within the stapled line on the specimen side. The umbilical tape can then be manipulated with the robotic third arm to provide lateral and anterior retraction during subsequent pancreatic mobilization.

18.4.5.1 Troubleshooting

We prefer using a vascular load for division of the pancreas neck for improved hemostasis. This is performed slowly over 2–3 minutes. However, if the pancreatic gland texture is thick, it may require either a 3–4 mm stapler load (purple) or

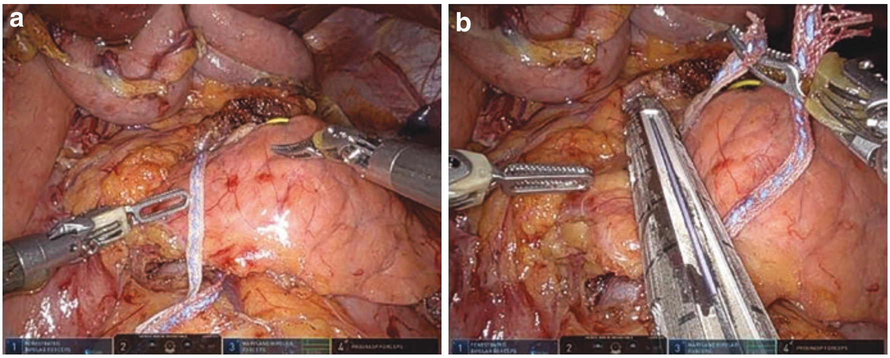


Fig. 18.4 Division of the pancreas. (**a**) Umbilical tape placed around the anticipated pancreatic transection line. (**b**) Division of the pancreas using an EndoGIA stapler

4–5 mm (black) load depending on the thickness. The latter stapler will require upsizing of the LLQ port to a 15 mm port.

18.4.6 Division of the Splenic Vessels

The splenic artery (Fig. 18.5) and vein (Fig. 18.6) are now dissected out individually and encircled with vessel loops. The robotic hook and Maryland are well suited for this dissection. We recommend isolating each vessel with a vessel loop to ease transection with the stapler. In a non-spleen preserving case, the vessels are divided

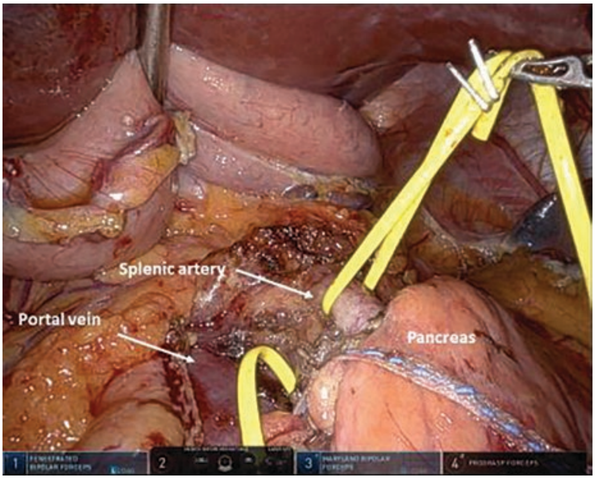


Fig. 18.5 Isolation of the splenic artery at its origin found at the superior border of the pancreas

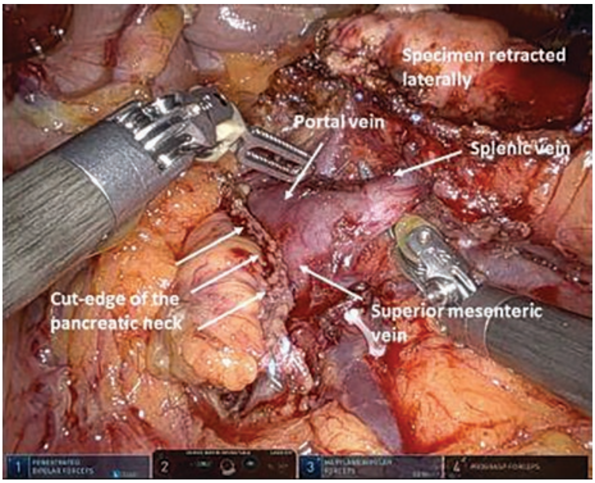


Fig. 18.6 Identification of the splenic vein confluence with the portal vein, posterior and inferior to the pancreas after division of the pancreatic neck

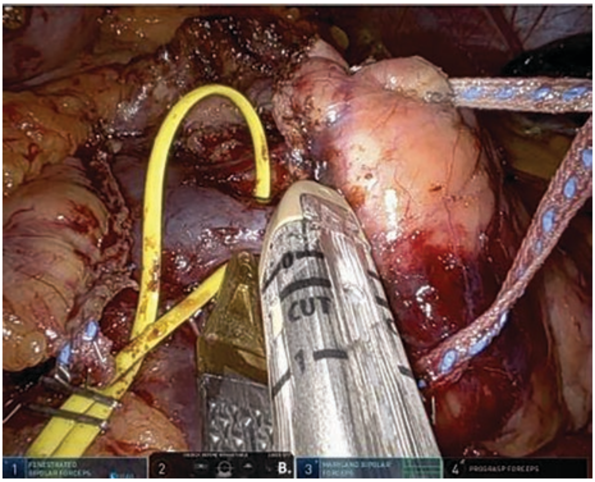


Fig. 18.7 Division of the splenic vein

separately (artery first then vein, Fig. 18.7) using a curved tip Endo-GIA™ vascular 45 stapler (Covidien, Mansfield, MA, USA).

18.4.6.1 Troubleshooting

We recommend dividing the pancreatic neck, splenic artery then splenic vein in that sequence. This allows decompression of the spleen and reduces venous congestion. Occasionally, the splenic artery dives deep to the pancreatic neck, and may not be accessible at the superior/anterior surface of the pancreas. In this scenario, complete mobilization of the pancreas off of the retroperitoneum is performed early and the splenic artery is dissected and divided from below the pancreas.

18.4.7 Resection of the Pancreato-Splenic Complex Off of the Retroperitoneum

The dissection is continued in the retropancreatic plane towards the spleen (Fig. 18.8a). The inferior mesenteric vein may be encountered and taken with the Ligasure™ device or clips. The splenocolic, splenophrenic, and splenorenal ligaments are released with the Ligasure™ to completely release the specimen from the retroperitoneum (Fig. 18.8b). If performed for pancreatic adenocarcinoma, resection of the posterior retroperitoneal fascia (Gerota's fascia) en-bloc is performed. We do not resect the left adrenal gland unless it is involved with tumor. This can be accomplished with the Ligasure™ if needed.

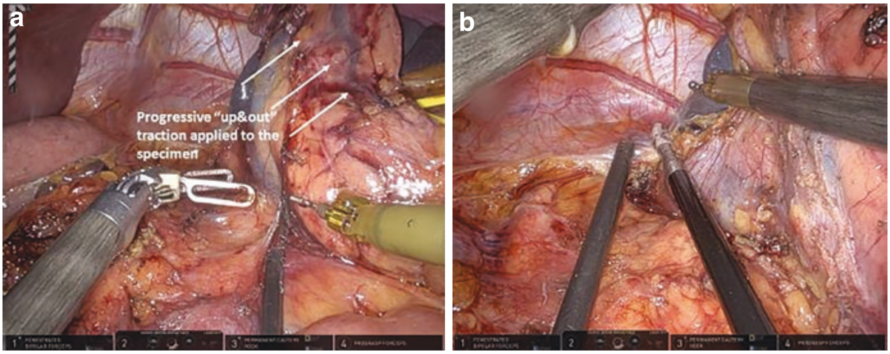


Fig. 18.8 (**a**) Division of small retroperitoneal attachments to the specimen using the Ligasure™ while the specimen is being retracted upward and outward towards the left upper quadrant. (**b**) Division of the splenophrenic ligament using the Ligasure™

18.4.7.1 Troubleshooting

This portion of the operation requires dynamic assistance by the bedside surgeon, especially in an obese patient. The robotic surgeon needs to reposition arm 3 several times to ensure anterior retraction of the specimen to allow for division of retroperitoneal tissue. The previously placed umbilical tape allows for easy manipulation of the pancreatic gland.

18.4.8 Specimen Removal and Closure

The specimen consisting of the resected pancreas with spleen are placed in a 15 mm retrieval bag. The LLQ port site is extended and a wound protector placed to facilitate safe extraction of the specimen en bloc. It is sent for frozen section or permanent analysis. A 19-Blake drain is brought into the abdomen through the left anterior axillary line coursing along the splenic fossa—creating a deep loop at the diaphragmatic recess—before continuing underneath the stomach to reach the transected pancreatic margin. Hemostasis is ensured. All ports are pulled under direct visualization and the 0-vicryl stitch placed at the beginning of the case (around the camera fascial site) is tied down. The fascia of the extended port site is closed with interrupted #1 Vicryl® suture. Skin is closed using subcuticular 4–0 absorbable suture and skin glue.

18.4.8.1 Troubleshooting

Beware of bleeding from the left inferior epigastric as the LLQ is extended. We recommend placing the initial 12 mm port just lateral to the inferior epigastric and extending the incision laterally to avoid transecting this blood vessel.

18.5 Postoperative Management

The patient is admitted to a monitored floor for recovery. The nasogastric tube is removed intraoperatively or on postoperative day (POD) 1. Clear liquid diet is started on POD 1 and advanced as tolerated. The foley catheter is removed on POD 1 and the patient should ambulate every shift. The drain fluid character and volume are monitored closely. Drain fluid amylase levels are checked on postoperative day 1 and 3. Depending on surgeon discretion, if the drain amylase remains elevated, a somatostatin analogue may be started. If the drain amylase trends down from a starting level of below 5000 U/L and the effluent is not concerning, the drain is pulled on day 3 or prior to discharge. Hospital length of stay is typically 3–5 days.

18.6 Conclusions

RDP can be performed safely with similar outcomes to laparoscopic PD with regard to length of stay, rate of pancreatic fistula formation, and readmission. The steps of the operation are essentially unchanged from the laparoscopic approach. The lower rate of conversion to open (compared to laparoscopy), presumably due to better visualization, dexterity and enhanced dissection abilities around vasculature, may offset the increased costs of resources associated with the robotic approach. Such factors will likely continue to drive increased use of the robotic approach for complex pancreatic resections.

Conflict of Interest The authors have no conflict of interest to declare.

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Part IV
Abdominal Wall

Chapter 19
Laparoscopic TAPP Inguinal Hernia Repair

Emmanuel E. Sadava and María E. Peña

19.1 Introduction

Inguinal hernia repair is one of the most common procedures in general surgery, with approximately 20 million inguinal herniorrhaphies performed every year around the world [1]. Since its introduction in the '90s, laparoscopic approach has been widely accepted by the surgical community. In comparison with open hernioplasty, the laparoscopic inguinal hernia repair has shown a reduction in postoperative pain, surgical site infection rate, and hospital stay. As a result, faster recovery and earlier return to daily activities can be observed [2–5].

There are two main approaches for laparoscopic inguinal hernia repair: transabdominal preperitoneal (TAPP) and totally extra peritoneal (TEP). Both techniques are considered effective. It is assumed that learning curve is longer than open repair, since at least 30–75 cases in TAPP [6] and up to 250 cases in TEP [7] are needed to obtain a low recurrence rate. Surgeon's expertise as well as patient's preference play a key role when deciding which type of repair to perform. TAPP repair is used more frequently since most general surgeons have experience in the laparoscopic view of the abdominal cavity. Knowledge of the anatomical landmarks for the posterior approach of the inguinal region as well as the key steps of this technique are crucial to achieve an optimal repair.

We describe a systematic approach of laparoscopic TAPP repair which could help to avoid troublesome side effects and be useful for educational purposes.

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The main goals of the laparoscopic inguinal hernia repair are to reduce symptoms and improve quality of life with an adequate durability. In addition, the inguinal repair should be decided to prevent complications such as incarceration or bowel obstruction which may require emergency surgery.

19.2 Clinical Presentation

Inguinal hernia usually presents in primary care as a bulge in the groin area that becomes more evident when standing, coughing or doing exercise. It may also be associated with mild to moderate inguinal pain, which might affect daily's activities in up to 30% of the cases [6, 8]. As the hernia increases in size, other symptoms such as tenderness in the inguinal zone, pain irradiated to the testicle and/or bowel sounds in the bulge area can also be referred by the patients.

Potentially life-threatening complications such as incarceration or strangulation are also possible in acute presentations. Although complicated inguinal hernias are infrequent, they should be suspected in patients with symptoms of intestinal occlusion and no history of abdominal operations.

19.3 Preoperative Evaluation

Most hernias can be diagnosed on physical examination. Both inguinal regions should always be examined, since a contralateral hernia could be detected in up to 30% of patients [9]. In cases of in conclusive findings, an ultrasound can help to diagnose an occult hernia or to rule out other differential diagnosis such as pubic bone syndrome, adenopathy, urologic diseases or hip pain, among others.

Preoperative optimization of patients´ comorbidities/habits (obesity, diabetes, smoking) is encouraged in all patients. Thromboprophylaxis is indicated only in patients with history of thrombotic events. Preoperative antibiotics are given systematically in order to prevent surgical site infections.

19.4 Technique

19.4.1 Laparoscopic TAPP Repair

19.4.1.1 Position of the Patient and Surgical Team

After induction of general endotracheal anesthesia, the patient is positioned with both arms tucked. In order improve exposure of the working area during the operation, the patient is shifted in 20–30° of Trendelenburg position and tilted 15–20° to the contralateral side of the hernia.

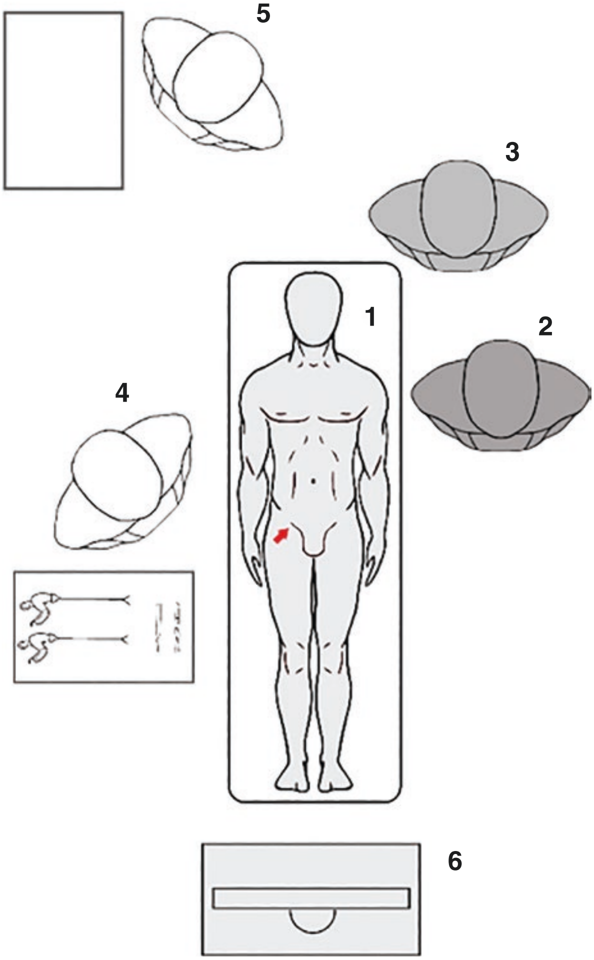

Fig. 19.1 Positioning of the patient (*1*), surgeon (*2*), assistant (*3*), nurse (*4*), anesthesiologist (*5*) and monitor (*6*) for a right hernia repair (*red arrow*)

The surgeon stands on the opposite side of the defect to be repaired (Fig. 19.1). The assistant stands behind the surgeon, next to the patient's head. The monitor is placed at the foot of the operating table.

Note: The bladder should be emptied before surgery to reduce the risk of injury. A urinary catheter should be considered in difficult cases.

19.4.1.2 Trocar Placement

Access to the abdominal cavity is achieved by standard techniques. We perform pneumoperitoneum with a Veress needle at the umbilicus. In cases of previous surgery at the umbilical zone, an open approach (Hassan's technique) is preferred.

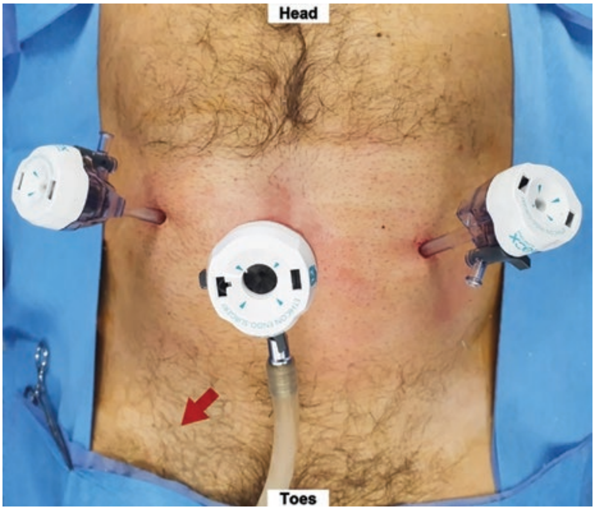

Fig. 19.2 Trocar placement with a three-port technique in a right hernia repair (*red arrow*)

A three-port technique is used (Fig. 19.2). One 12-mm port is placed at the umbilicus for the camera and for passing the sutures and mesh. Two accessory 5-mm ports are placed in each flank in a horizontal line with the umbilical port. They should be at least "1-hand" distance from the umbilical port to achieve an adequate ergonomic position.

Troubleshooting: Additional care must be taken when accessory ports are placed. Superficial epigastric vessels should be recognized by transabdominal illumination so as to avoid injury. Also, inferior epigastric vessels running along the rectus muscle (beneath the posterior rectus fascia) should be identified by direct vision before placing ports.

19.4.1.3 Laparoscopic View of the Inguinal Region

One of the major advantages of the laparoscopic TAPP approach is that all potential types of hernia (indirect, direct and femoral) can be simultaneously identified. In addition, the contralateral groin can be explored to find occult hernias.

Using a 30° angled scope, most of the anatomical landmarks of the groin arevisualized through the peritoneum transparency (Fig. 19.3). The internal inguinal ring, the inferior epigastric vessels, the spermatic vessels, and the vas deferens should be recognized. These elements form an inverted "Y" that divides the groin into three zones [10]:

- Zone 1: Lateral to the internal inguinal ring and the spermatic vessels
- Zone 2: Medial to the inferior epigastric vessels and the vas deferens
- Zone 3: Between zone 1 and 2, and includes the deep inguinal ring and the external iliac artery and vein in the so-called "doom triangle"

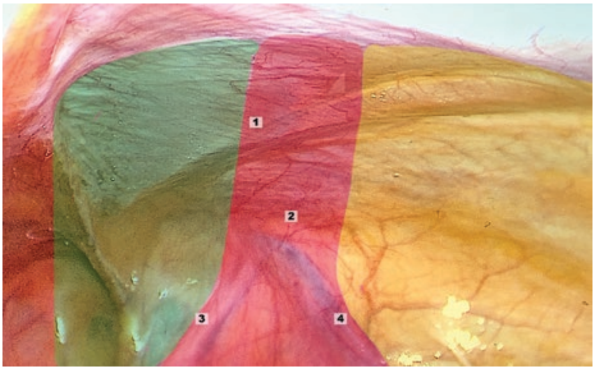

Fig. 19.3 Division of the groin into three zones: zone 1 (*yellow area*), zone 2 (*green area*) and zone 3 (*red area*). Inferior epigastric vessels (1), internal inguinal ring (2), vas deferens (3) and spermatic vessels (4) are visualized

The surgeon should identify these three zones in order to perform a proper and safe TAPP repair.

Troubleshooting: Each zone can be addressed at surgeon's preference. However, the zone 3 requires more attention to minimize the risk of major vascular injury and should only be approached if the of the other two zones have been completely dissected previously.

19.4.1.4 Division of the Peritoneum

A peritoneal incision is performed at least 4–5 cm above the internal inguinal ring. The extension should be planned as an imaginary line from the lateral aspect of the medial umbilical ligament to the anterior superior iliac spine. First, the medial umbilical ligament is softly grasped and pulled down; with this maneuver the peritoneum will separate from transversalis fascia and the surgeon may begin the peritoneal incision with either scissors or cautery. Secondly, the inferior aspect of the peritoneum is grasped and pulled down in order to reach the avascular preperitoneal space. Peritoneum incision continues laterally until reaching the anterior superior iliac spine.

Troubleshooting: Peritoneal incision length must be adequate when a large prosthesis is placed. Otherwise, the operation will be more demanding and will have higher risk of recurrence due to mesh misplacement.

19.4.1.5 Making the Peritoneal Flap—From Zone to Zone

At this point, the surgeon should enter the preperitoneal space and make a wide dissection to allow a sufficient mesh overlap. We prefer to begin with zone 2 (medial to the inferior epigastric vessels); here, the fatty-areolar plane makes the blunt dissection easier (Fig. 19.4). The bladder is dissected down and the Cooper's ligament and pubic bone are visualized. Afterwards, zone 1 (lateral to spermatic vessels)

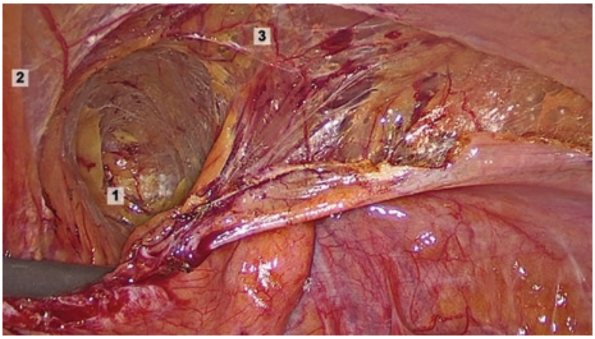

Fig. 19.4 Approach to zone 2. Cooper's ligament (*1*), medial umbilical ligament (*2*) and inferior epigastric vessels (*3*) are visualized

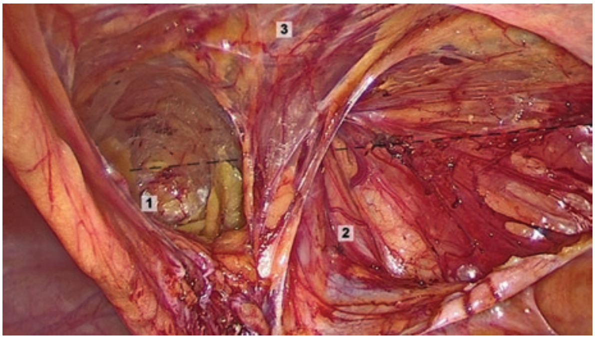

Fig. 19.5 Approach to zone 1. Cooper's ligament (*1*), spermatic vessels (*2*), inferior epigastric vessels (*3*) and the inguinal ligament (*dashed line*)

is approached (Fig. 19.5). This area is also called the "triangle of pain" and contains the lateral cutaneous nerve of the thigh, femoral branch of the genitofemoral nerve and femoral nerve. In this zone, the fat tissue should be carefully dissected from the peritoneum and kept attached to the inguinal floor in order to avoid nerve damage.

Finally, zone 3 is addressed and the spermatic cord must be identified. Indirect sac should be dissected from other structures paying special attention to spermatic vessels and vas deferens. Large indirect sacs are usually more challenging. In these cases, the surgeon should focus on recognizing the anatomic landmarks (inferior epigastric vessels, vas deferens, and spermatic vessels) and keep traction on the peritoneum (the hernia sac itself). A lipoma of the cord can also be identified, most often laterally to the spermatic cord. This is an independent structure that runs into the inguinal canal next to the spermatic cord and must not be mistaken with the fat tissue surrounding the cord. We usually perform a full reduction of the lipoma with gentle traction and blunt dissection followed by resection.

Once the vas deferens and inferior epigastric vessels are separated from the preperitoneal fat, all three zones converge (Fig. 19.6). Dissection is completed when a critical view of the myopectineal orifice [11, 12] is achieved, and the surgeon should be able to identify the hernia defects, the pubic symphysis, Cooper's ligament, bladder, inferior epigastric vessels, vas deferens, spermatic cord, iliac vessels, psoas muscle, and nerves location.

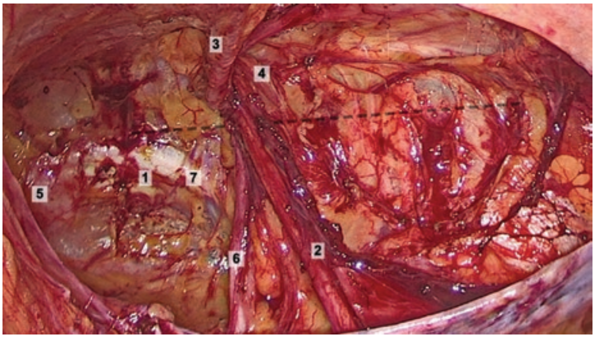

Fig. 19.6 Approach to zone 3. Copper's ligament (*1*), spermatic vessels (*2*), inferior epigastric vessels (*3*), internal inguinal ring (*4*), pubic bone (*5*), vas deferens (*6*) corona mortis (*7*) and inguinal ligament (*dashed line*) are visualized

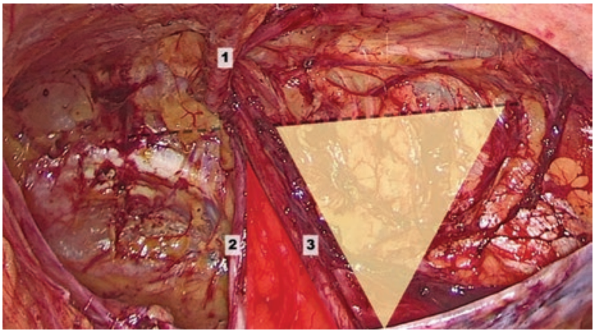

Fig. 19.7 Critical view of the myopectineal orifice with the triangles of pain (*yellow*) and Doom (*red*). Inferior epigastric vessels (*1*), vas deferens (*2*), spermatic vessels (*3*) and inguinal ligament (*dashed line*) are visualized

Troubleshooting: Cautery, as any another energy instruments, should be avoided in zone 1 (triangle of pain), especially next to the superior anterior iliac spine where there is a more dense tissue (Fig. 19.7). Here, we section the fat tissue immediately next to the edge of the peritoneal flap to enter in the preperitoneal space and then continue with blunt dissection towards the inguinal floor. Direct hernias will be found in zone 2. In order to reduce hernia recurrence, the direct sac must be completely dissected from the transversalis fascia ("the pearly pseudo-sac") as well as the fat tissue surrounding the edges of the defect. In zone 3, the vas deferens and the spermatic vessels must not be detached from their back side (Doom triangle, Fig. 19.7). The pulling maneuver in this zone is essential; the surgeon should always grab the peritoneum and pull it back towards the trocar (mimic taking out the grasper of the abdomen) to minimize major vascular and nerve injury.

19.4.1.6 Mesh Placement

Although several mesh types with a wide variety of properties are currently available, there is robust evidence regarding the optimal size of the mesh in order to reduce recurrence rates [6, 12–14]. The mesh has to reinforce the entire inguinal

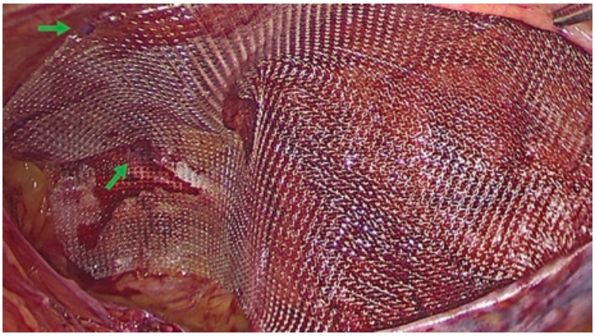

Fig. 19.8 Mesh positioning with a 4 cm overlap for all hernia sites and fixation with tackers (*green arrows*)

region and should be sized at least 10 × 15 cm. We prefer to place large meshes, with a minimum of 12 × 15 cm. The prosthesis is introduced into the abdominal cavity through the umbilical port and is unrolled in the preperitoneal space. The surgeon should check that the mesh covers all potential spaces for hernia (indirect, direct, and femoral) considering at least a 3–4 cm mesh overlap for each space (Fig. 19.8). Direct hernias are potential risk factor for recurrence [14, 15]. In these cases, special attention should be payed to the medial edge of the mesh, which must reach the pubic symphysis or even extend to the opposite side.

Mesh positioning finishes when the whole prosthesis is fully adapted to the inguinal floor. These technical tips may be easier when anatomical or self-fixating meshes are placed, but since flat meshes are the most commonly used, the surgeon must not forget the three-dimensional shape of the inguinal floor.

Troubleshooting: To reduce recurrence rate in indirect hernias, the inferior aspect of the mesh should be checked in the lateral zone. There should be at least 2 cm between the edge of the mesh and the limit of the peritoneal dissection to minimize the risk of mesh folding after closing the peritoneum. It is also preferable to round the corners of the prosthesis in order to avoid wrinkles if a flat mesh is used.

19.4.1.7 Mesh Fixation

Although several devices have proven to be effective for mesh fixation, such assutures, tacks, fibrin glue or cyanoacrylate [13–16], there is lack of consensus about the best fixation method. They are chosen according to surgeon's preference, and mechanical fixation with tacks are the most employed. We prefer to use 4 to 6 absorbable tacks to fix the mesh (Fig. 19.8) at the Cooper's ligament, anterior rectus muscle, and transversus muscle (both covered by transversalis fascia). Firing angle is critical to achieve an adequate mesh fixation [15]. The surgeon should use the opposite hand from the outside to feel the device and push it against the tissue in a 90° firing angle.

The mesh should be slightly loose, since a tight mesh could cause postoperative pain. Mechanical fixation must not be used below the inguinal ligament to avoid vascular and nerve damage.

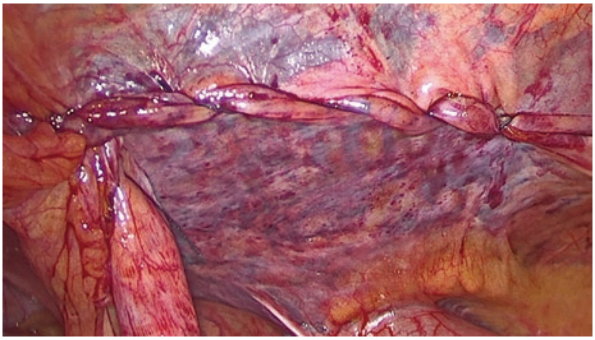

Fig. 19.9 Complete peritoneum closure without gaps

Troubleshooting: When fixing the mesh on the lateral side, fires should be placed at least 2 cm above of the inguinal ligament to reduce potential nerve injury. Using the opposite hand from the outside makes this maneuver easier and safer.

19.4.1.8 Closing Peritoneum and Trocar Site

Running sutures or tacks are used to close the peritoneum. It is important to achieve a complete peritoneum closure without leaving gaps to avoid mesh exposure to the viscera and to reduce the risk of bowel incarceration (Fig. 19.9). We routinely use barbed sutures since they simplify this step.

Accessory trocars are removed under direct vision and pneumoperitoneum is evacuated. The umbilical port fascia is closed with a figure-of-eight stitch of an absorbable suture.

19.4.1.9 Postoperative Course

Day-case surgery is suitable for most patients undergoing TAPP repair. Postoperative pain is managed with non-steroidal anti-inflammatory agents for 2–3 days. Follow-up at clinics is usually scheduled at 7 and 30 postoperative day. Patients are encouraged to start their daily activities within the first week, and full activities, including routine heavy-lifting, after 3–4 weeks.

19.5 Conclusions

A properly executed technique for laparoscopic TAPP repair improves patients' quality of life and reduces the risk of hernia recurrence. Acknowledgement of crucial anatomical landmarks of the inguinal floor and key points of each step of the procedure helps to avoid troublesome side effects and obtain optimal postoperative outcomes.Conflict of InterestThe authors have no conflict of interest to declare.

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Chapter 20
Laparoscopic and Robotic Transabdominal Preperitoneal Inguinal Hernia Repair

Ivy N. Haskins and Arielle J. Perez

20.1 Introduction

More than 700,000 groin hernias, including inguinal and femoral hernias, are repaired annually in the United States [1–5]. In fact, inguinal hernia repair (IHR) is one of the most commonly performed general surgery operations [1–5]. There are currently several available surgical approaches to the repair of a groin hernia, including open, laparoscopic, and robotic-assisted techniques. All of these techniques have been shown to be safe and effective [6–9]. Nevertheless, open IHR remains the gold standard [6, 7]. In the 2004 VA Cooperative Study, patients undergoing open IHR experienced better outcomes with respect to postoperative morbidity and inguinal hernia recurrence compared to patients undergoing laparoscopic IHR [6]. These differences in outcomes between the open and laparoscopic IHR groups, however, became insignificant as surgeon volume increased [6]. In the recently published RIVAL randomized controlled clinical trial, robotic-assisted IHR showed no advantage over laparoscopic IHR in the short-term for unilateral, primary inguinal hernias [10]. These findings reinforce the ideas that surgeons performing minimally-invasive IHR should do so on a regular basis and that perhaps a minimally-invasive approach to IHR is most advantageous for bilateral and/or recurrent groin hernias [2]. Therefore, it is important that general surgeons understand the key steps to a minimally invasive IHR so patients who may benefit from a laparoscopic or robotic-assisted approach can be offered these surgical approaches. Herein, we detail our approach to the evaluation of patients with a groin hernia, the important technical steps to minimally invasive transabdominal preperitoneal (TAPP) IHR, as well as the postoperative care and follow-up of patients undergoing laparoscopic or robotic-assisted IHR.

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20.2 Clinical Presentation, Preoperative Evaluation, and Patient Selection

There are surgeon, patient, and hernia factors that need to be considered when evaluating and deciding the surgical approach to an IHR. For all patients referred to a general surgeon for evaluation of a groin hernia, a focused history of inguinal hernia-related symptoms should be performed, focusing on groin pain, presence of a groin bulge, bowel obstructive symptoms, and any overlying skin changes. A physical exam of the groin should also be performed. In order to do this, the patient should be standing. Visual evaluation comparing both groins can often times reveal a visible groin bulge and confirm the presence of an inguinal hernia. If not, external pressure over the inguinal canal while asking the patient to cough and/or perform a Valsalva maneuver should facilitate diagnosis of a groin hernia. Often times a patient with a groin hernia will be referred to a general surgeon after imaging confirmation, such as with an abdominal or scrotal ultrasound or computed tomography (CT) scan of the pelvis. In these cases, the physical examination should reinforce and be consistent with the findings on imaging. If a groin hernia diagnosis is still allusive following physical examination but the patient's history and symptoms are consistent with a possible inguinal hernia, or if the physical examination is not consistent with the findings seen on imaging, imaging or reimaging of the patient's groin should be performed.

Once a groin hernia has been diagnosed by exam and/or imaging, the surgeon must decide if the patient requires surgical intervention. In the early 2000s, most patients with groin hernias were undergoing IHR despite small hernia defects and only mild to moderate discomfort due to the presumed risk of hernia incarceration and strangulation [2, 9, 11, 12]. However, in two studies published in 2006, one by Fitzgibbons et al. and one by O'Dwyer et al., they found that the annual risk for inguinal hernia incarceration or strangulation was less than 1% [11, 12]. Following these studies, it has been recognized that a "watchful waiting" approach to inguinal hernia management is an acceptable option.

Additional studies since 2006 have subsequently found that upwards of 30% of patients with asymptomatic or mildly symptomatic inguinal hernias crossover to surgical repair within one year of the diagnosis of an inguinal hernia and that the rate of crossover after the first year following diagnosis of an inguinal hernia is close to 5% annually [2, 11, 13–15]. Furthermore, in the 2013 follow-up study by Fitzgibbons et al., they found that up to 79% of patients crossed over to surgical repair ten years after initial inguinal hernia diagnosis while still maintaining a low incidence of emergency operations [16]. For these reasons, a thorough discussion between the patient and the surgeon should be had, counseling on optimal timing of surgical repair. Patients who are more likely to benefit from a more urgent surgical repair of their groin hernia include those patients with a known femoral hernia, patients with an inguinal hernia who experience groin pain with activity, patients whose daily activities are limited by their inguinal hernia, and those patients with a chronically incarcerated inguinal hernia [5, 15–17].

While the above-listed risk factors should automatically qualify a patient for elective groin hernia repair, patients without these risk factors should still be considered for IHR following a thorough discussion with their surgeon regarding the risks and benefits of operative versus nonoperative management of their groin hernia. Following this discussion, if the decision is made to proceed with IHR, the surgeon must decide if a minimally invasive approach is beneficial and feasible. Prior pelvic surgery and/or radiation are often relative contraindications to a minimally invasive IHR due to the potential difficulties in dissection of the preperitoneal space posed by scar tissue [18]. On the other hand, patients with an inguinal hernia recurrence following an open or anterior IHR, patients suspected of having bilateral inguinal hernias, and female patients (due to the higher incidence of a femoral hernia and the ease of evaluation of the femoral space with a minimally invasive approach) are more likely to benefit from a laparoscopic or robotic-assisted IHR [5, 17, 18].

Once a patient has been identified as a potential candidate for a minimally invasive IHR based on their specific groin hernia risk factors, a thorough review of their medical history must be performed. Most commonly, laparoscopic and robotic-assisted groin hernia repairs are performed under general anesthesia [5]. Therefore, patients who cannot tolerate general anesthesia due to their associated medical comorbidities are not candidates for a minimally invasive IHR. In terms of patient-specific risk factors that may contribute to increased morbidity and mortality following minimally invasive IHR, we use the risk factors previously identified by the Ventral Hernia Working Group to aid in our preoperative discussions [19].

While the associated morbidity and mortality following IHR is much less than that following ventral hernia repair, we do feel that optimization of patient-specific risk factors can further improve postoperative outcomes and hernia repair durability. Furthermore, the natural history of groin hernias affords a period of time with minimal associated symptoms, in most cases [11, 12]. Therefore, preoperative optimization of patients with a groin hernia is often easily facilitated without a significant increase in the rate of groin hernia events, such as inguinal hernia incarceration with associated bowel obstruction or strangulation. The specific patient factors that we address prior to laparoscopic IHR include patient's weight, smoking status, nutritional status, and severity of any disease that may lead to a chronic or prolonged increase in intra-abdominal pressure (i.e. chronic obstructive pulmonary disease) as well as have a negative effect on postoperative wound healing (i.e. diabetes mellitus). Additional details regarding our approach to preoperative weight loss, smoking cessation, and management of diabetes mellitus are detailed below:

1. Weight Loss—It has been shown in several studies that overweight and obese patients are at an increased risk for postoperative wound events and ventral hernia recurrence following open ventral hernia repair [20–22]. We extrapolate this information to our inguinal hernia patients. While overweight and obese patients may be better candidates for minimally invasive (laparoscopic or robotic-assisted) surgery due to smaller incisions which may offset some wound healing issues, the negative effects of increasing weight on outcomes following inguinal hernia repair surgery must still be considered. Therefore, we recommend that

any minimally symptomatic patient with a body mass index (BMI) ≥ 34 kg/m^2 lose weight prior to IHR.

2. Smoking Cessation—The detrimental effect of nicotine on the wound healing process has been extensively studied by Sorensen [23]. For any patient actively using nicotine products, they are required to abstain from nicotine use for six weeks preoperatively. In addition to patient reported abstinence, we may sometimes require a negative urine nicotine test prior to repair of their ventral hernia, especially for patients who have a history of unsuccessful attempts at smoking cessation.
3. Control of Diabetes Mellitus—There are currently no studies that have investigated the effect of elevated glycosylated hemoglobin (HgA_1c) levels on postoperative wound events and hernia recurrence following IHR. Nevertheless, the association of elevated HgA_1c levels with adverse events has been studied in other areas of surgery, including cardiac and orthopedic surgery [24]. Therefore, for minimally symptomatic patients with diabetes mellitus, we require a preoperative HgA_1c level within the three months leading up to IHR and attempt to achieve a HgA_1c level as close to 6.5% as possible.

The approach to preoperative optimization is similarly discussed in our minimally invasive ventral hernia repair chapter. While we recognize that improvement in medical comorbidities is quite vague, we are borrowing many of our recommendations from studies performed either in general surgery patients with the inclusion of hernia patients or in specialty services such as cardiac or orthopedic surgery. Furthermore, similar to enhanced recovery after surgery (ERAS) pathways, it is currently unknown which patient comorbidity (and subsequent modification of that comorbidity) has the greatest impact on postoperative outcomes following minimally invasive IHR [25]. Therefore, when counseling patients on the above comorbidities, we emphasize each factor equally.

20.3 Surgical Technique

This section will highlight the key steps to performing a minimally invasive, laparoscopic or robotic-assisted inguinal hernia repair, as performed at our institution. While both transabdominal preperitoneal repair (TAPP) and total extraperitoneal repair (TEP) are considered minimally invasive forms of IHR, we will focus on the TAPP repair only. Furthermore, at our institution, we use the da Vinci Xi® System (Intuitive Surgical, Sunnyvale, CA, USA) and will discuss the ports and instruments used with this robotic platform only.

Before discussing the key steps to a minimally invasive TAPP IHR, we would like to caution that the learning curve for a minimally invasive IHR is longer compared to the learning curve for open IHR [3]. In fact, in a recent study by Merola et al., they noted that proficiency in open IHR was achieved after approximately 40 open IHRs, which is in stark contrast to the 250 repairs referenced in the VA Cooperative Study for laparoscopic IHR [6, 26]. We recognize that there may be variation in the technical aspects of this procedure and we recommend that variations to the steps below be adopted by surgeons as needed in an effort to maximize both patient safety and surgeon comfort [26].

1. Routine preoperative interventions are performed, including the administration of preoperative antibiotics and the placement of sequential compression devices as recommended by the Surgical Care Improvement Project (SCIP) guidelines.
   (a) It is important to note if patients have a history of methicillin-resistant *Staph aureus* (MRSA) wound infection. In these cases, we recommend the use of preoperative antibiotics that cover MRSA.
   (b) The administration of chemical deep venous thrombosis (DVT) prophylaxis should be determined based on patient-specific risk factors for DVT formation. We do not routinely administer chemical DVT prophylaxis due to the proximity of the surgical dissection to the iliac, femoral, and epigastric vessels. However, if chemical DVT prophylaxis is not administered, it is important that pneumatic compression devices are placed on the patient's legs prior to induction of general anesthesia.
2. Patients are placed supine on the operating room table.
3. General anesthesia is induced and all groin hair is removed with surgical clippers. We selectively perform Foley catheterization of the bladder in patients in whom we anticipate a difficult dissection (i.e. previous pelvic history) and in patients who are unable to successfully void prior to being brought back to the operating room.
4. Both arms are tucked, taking care to adequately pad the elbow and other pressure points.
5. Access to the abdominal cavity is achieved. For a laparoscopic TAPP IHR, this is performed in an open fashion at the umbilicus through a Hasson technique. For a robotic-assisted TAPP IHR, a distance 20 centimeters (cm) superior to the pubic tubercle is identified. This distance is typically superior to the umbilicus and therefore access to the abdominal cavity is performed using an optical entry technique following placement of a Veress needle in the left upper quadrant of the abdomen.
6. We place three ports total.
   (a) For laparoscopic TAPP IHR we place one 12 millimeter (mm) Hasson port at the umbilicus, one 5 mm port along the lateral aspect of the ipsilateral rectus abdominis muscle at least 10 cm lateral and 2–3 cm above the umbilical port, and one 5 mm port along the lateral aspect of the contralateral rectus abdominis muscle at least 10 cm lateral and in line with the umbilical port (Figure 20.1a). If a bilateral inguinal hernia is planned for repair, both 5 mm ports are placed in line with the umbilical port (Figure 20.1b).
   (b) For robotic-assisted TAPP IHR, we place three 8 mm ports. The first port is placed 20 cm superior and caudad to the pubic tubercle. Two additional 8 mm ports are placed, each 8 cm lateral to, and on either side of, the peri-umbilical 8 mm port (Fig. 20.2).

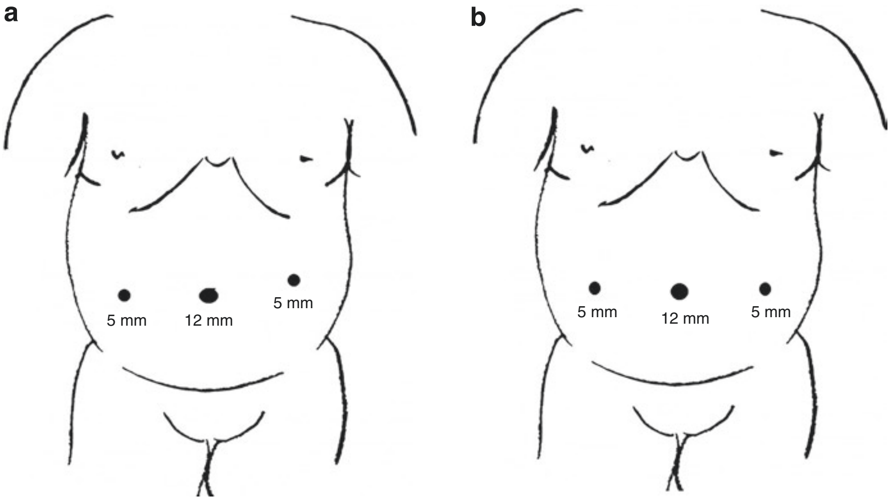

Fig. 20.1 Location and sizes of ports used for a laparoscopic transabdominal preperationeal (TAPP) inguinal hernia repair (IHR). (**a**) This image demonstrates a unilateral, left TAPP IHR. A 12 mm port and two 5 mm ports are used. The 5 mm port that is placed on the side of the inguinal hernia is placed 2–3 cm above the umbilical port while the contralateral 5 mm port is placed in line with the umbilical port. All of the ports can serve as working ports. The periumbilical port can also be used for camera placement if a 10 mm camera is used and is the site where the mesh is introduced into the abdominal cavity. (**b**) This image demonstrates a bilateral TAPP IHR. A 12 mm port and two 5 mm ports are used. The 5 mm ports are placed in line with the umbilical port. All of the ports can serve as working ports. The periumbilical port can also be used for camera placement if a 10 mm camera is used and is the site where the mesh is introduced into the abdominal cavity

7. A 30-degree 5 mm laparoscope (laparoscopic TAPP) or a zero-degree camera (robotic-assisted TAPP) is used. The camera for a laparoscopic TAPP IHR is placed at the 5 mm port on the ipsilateral side of the inguinal hernia. The role of the assistant during laparoscopic TAPP IHR is vital in helping to create a proper view of the pelvis. The camera for a robotic-assisted TAPP IHR is placed at the midline 8 mm port.
8. The working ports for a laparoscopic TAPP IHR are the periumbilical 12 mm port and the 5 mm port on the contralateral side of the inguinal hernia. Typically, we use “hot” scissors and a Maryland grasper for the dissection. The working ports for a robotic-assisted TAPP IHR are the lateral 8 mm ports. We typically use “hot” scissors and a ProGrasp™ forceps or a BiPolar grasper.
9. The ipsilateral anterior superior iliac spine (ASIS) is palpated externally and visualized on the screen. A mental note or a peritoneal cautery mark can be placed to a site superior and lateral to the ASIS as this will ultimately serve as the superior and lateral extent of the dissection. A high peritoneal flap is then created by grabbing the peritoneum with the grasper just lateral to the ipsilateral medial umbilical ligament. The peritoneum is scored transversely from medial to lateral to the previously noted or marked site just superior and lateral to the ASIS. For a unilateral IHR, the peritoneal flap is created on the side of the her-

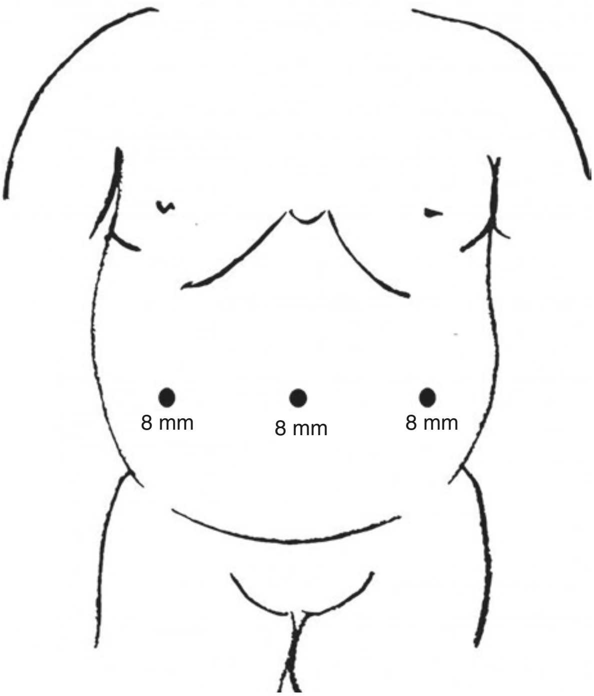

Fig. 20.2 Location and sizes of ports used for robotic-assisted transabdominal preperationeal (TAPP) inguinal hernia repair (IHR). An 8 mm port is placed 20 cm above the pubic tubercle. Two additional 8 mm ports are placed 8 cm lateral to and in line with the umbilical port. All of the ports can serve as working ports and for mesh entry

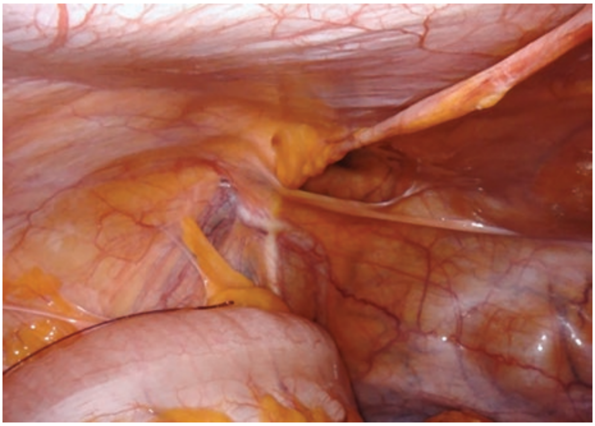

Fig. 20.3 Thorough inspection of the groin reveals a left direct inguinal hernia

nia defect only. For bilateral IHRs, the peritoneal flap is created on both the left and right side (Fig. 20.3).

10. Once the high peritoneal flap is opened, a combination of blunt dissection and electrocautery are used to open the peritoneal flap in the midline from the umbilicus distally to Cooper's ligament (Figs. 20.4 and 20.5). The white of bilateral Cooper's ligament should be visualized and serves as the landmark for the most distal extent of the preperitoneal dissection.

Fig. 20.4 Development of the peritoneal flap from the periumbilical port site at the median umbilical ligament. This is performed with bipolar cautery attached to laparoscopic scissors through the contralateral 5 mm port with downward traction on the peritoneum and a by Maryland Grasper through the periumbilical 12 mm port. For the purposes of this picture, a left inguinal hernia repair is being performed

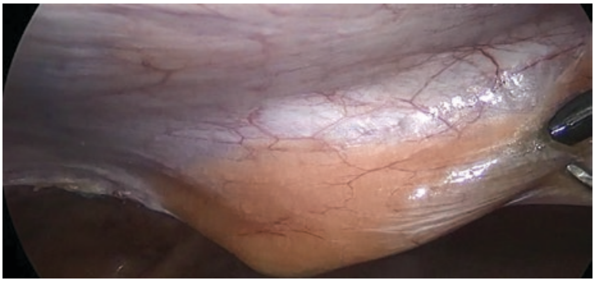

Fig. 20.5 Once the peritoneal flap is started, it must be further opened. In order to do this, the laparoscopic scissors are placed within the flap and gentle downward pressure towards the patient's spine is applied. Care must be taken to ensure that the epigastric vessels are not incorporated into this blunt move in order to avoid injury to them. For the purposes of this picture, a left inguinal hernia is being repaired

11. The peritoneal flap is opened up medially, at least 2 cm below Cooper's ligament into the Space of Retzius (Fig. 20.6).
12. Next, the remainder of the peritoneal flap is created laterally. It is important that the epigastric vessels are not taken down with the peritoneal flap but rather remain superior along the anterior abdominal wall (Fig. 20.7). Avoidance of dissection of the epigastric vessels helps to minimize the risk of damaging these vessels or causing hemorrhage.
13. It may occur that the flap dissection is initially started in the retrorectus plane medially and then carried out laterally into the preperitoneal plane. If this occurs, the two planes must be connected by dividing the lateral extent of the posterior rectus sheath until it disappears at the arcuate line. (Fig. 20.8).
14. The peritoneum is grasped and pulled to the lower contralateral corner while the fat and tissue fibers are cleared from the peritoneum, working from the most

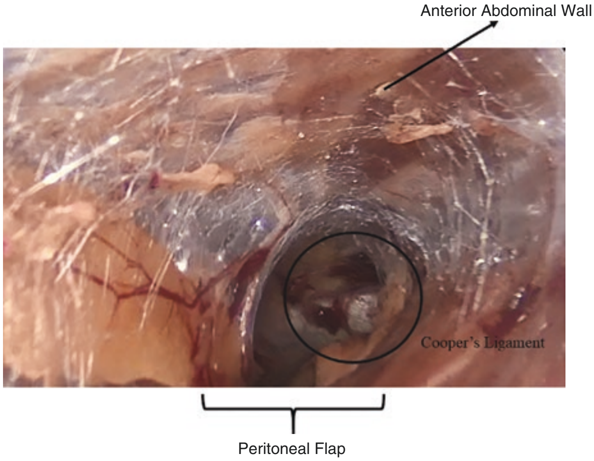

Fig. 20.6 Dissection of the peritoneal flap is carried down medially until Cooper's ligament is identified

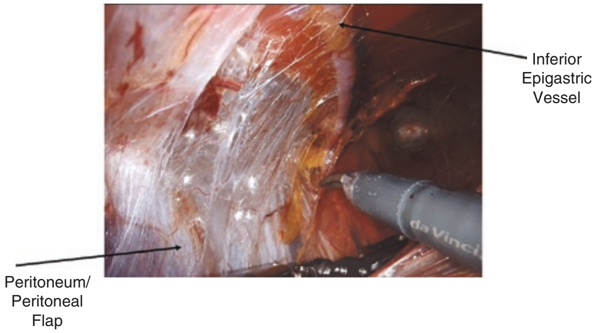

Fig. 20.7 When performing the peritoneal dissection, it is important to ensure that the inferior epigastric vessels remain up on the anterior abdominal wall in order to minimize the risk of damage to these vessels and serious hemorrhage

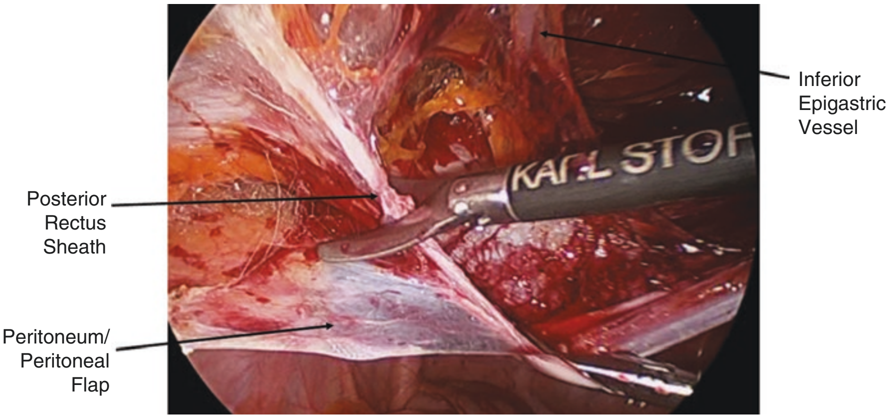

Fig. 20.8 Creation of the peritoneal flap medially can sometimes occur in the retrorectus space rather than in the preperitoneal space. When this occurs, the two spaces must be connected near the semilunar line

cephalad part of the peritoneal flap towards the internal ring, to reduce the hernia sac and isolate the cord structures. During this portion of the dissection, it is essential to monitor for and use caution around the gonadal vessels and vas deferens. Additionally, care is taken to avoid extensive dissection along the Psoas muscle in order to avoid injury to the nerves.

15. As the internal ring is approached, the spermatic cord (male patient) or round ligament (female patient) is identified. The peritoneum is carefully dissected away from these structures and any cord lipoma is reduced.
16. Additional dissection of the peritoneal flap is performed inferior to the internal ring to ensure adequate mesh overlap and to reduce any future clam-shelling of the mesh. In females, the round ligament is routinely ligated with an energy device at this time, close to the peritoneum, to avoid injury to the overlying nerves. It has been our experience that ligation of the round ligament helps to facilitate future mesh placement. However, there are many surgeons who do not ligate the round ligament and this is not a mandatory step to a minimally invasive TAPP IHR.
17. The direct, indirect, femoral, and obturator hernia spaces are identified and inspected. Any hernia is reduced (Fig. 20.9).
18. The preperitoneal space is re-inspected to ensure hemostasis and that the flap is large enough to accommodate an approximately 10 × 15 cm piece of medium weight, uncoated, synthetic mesh. The peritoneal flap is inspected from the abdomen to ensure that there is no tethering of the peritoneal flap to intra-abdominal adhesions or structures, such as the sigmoid colon.
19. At this point, a pause should be taken to ensure the critical view of the myopectineal orifice has been obtained, per the recommendations put forth by Daes and Felix in 2017 (Fig. 20.10) [27].
20. For a laparoscopic TAPP IHR, the mesh is introduced through the periumbilical 12 mm port. For a robotic-assisted TAPP IHR, the mesh is placed through any of the 8 mm ports prior to docking of the robot. The sutures used to secure the

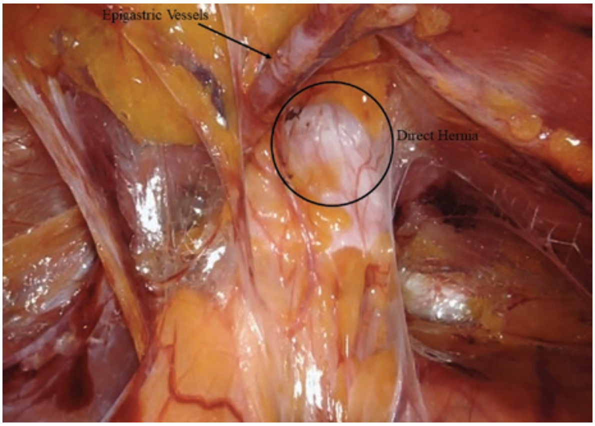

Fig. 20.9 Demonstration of the direct hernia sac, medial to the inferior epigastric vessels

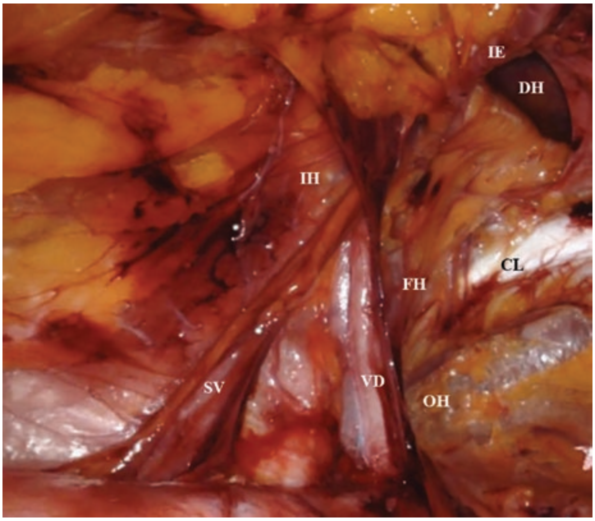

Fig. 20.10 Following reduction of the direct hernia defect, the remainder of the potential groin hernia spaces are evaluated. Here, you can see the direct hernia (DH) along the anterior abdominal wall medial to inferior epigastric (IE) vessels. Also demonstrated in this picture is Cooper's ligament (CL), the spermatic vessels (SV), and the vas deferens (VS). While not present, the sites of indirect (IH), femoral (FH), and obturator (OH) hernias are also noted. Appropriate dissection and evaluation of these potential spaces and important landmarks facilitates the critical view of the myopectineal orifice

mesh and to close the peritoneal defect (in our case a 0 Vicryl suture and a 2–0 barbed suture) are also introduced into the pelvis prior to docking of the robot.

21. The mesh is placed over all hernia spaces with at least 3 cm of overlap superior to the direct hernia space and 2 cm inferior to Cooper's ligament (Fig. 20.11). It should be noted that while we use a flat piece of medium weight, uncoated, synthetic mesh, there are several other mesh options that can be used for a minimally invasive IHR based on surgeon preference and institution availability.
22. For a laparoscopic TAPP IHR, the mesh is secured with a permanent tacking device. Two tacks are placed on Cooper's ligament medially, one tack is placed medially and superior on the anterior abdominal wall, taking care not to injure the inferior epigastric vessels, and one tack is placed lateral and superior on the anterior abdominal wall, taking care not to injure any of the groin or cutaneous nerves that run in this area (Fig. 20.12). For a robotic-assisted TAPP IHR, the mesh is secured with a 0 Vicryl suture in the same places as the mesh is secured in a laparoscopic TAPP IHR (Fig. 20.13).
23. For a laparoscopic TAPP IHR, the peritoneal flap is closed over the mesh, using the same permanent tacking device as was used to secure the mesh, once again being mindful of not injuring the inferior epigastric vessels (Fig. 20.14). For a robotic-assisted TAPP IHR, the peritoneal flap is covered over the mesh using a slowly absorbable barbed suture (Fig. 20.15).

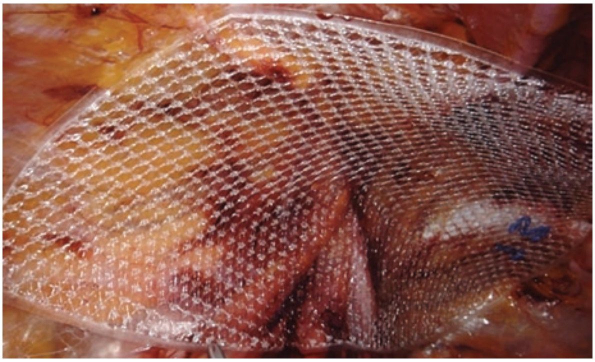

Fig. 20.11 A 10 × 15 cm piece of medium weight, synthetic mesh has been placed within the preperitoneal space, ensuring adequate coverage of all groin hernia spaces. Demonstrated here is securement of the mesh medially to Cooper's ligament

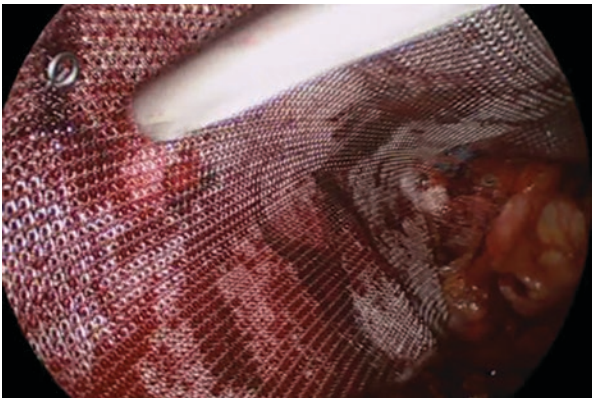

Fig. 20.12 Fixation of the mesh at the superior and lateral site of the preperitoneal flap. Care must be taken not to perform fixation too laterally on the anterior abdominal wall in order to avoid injury to the nerves

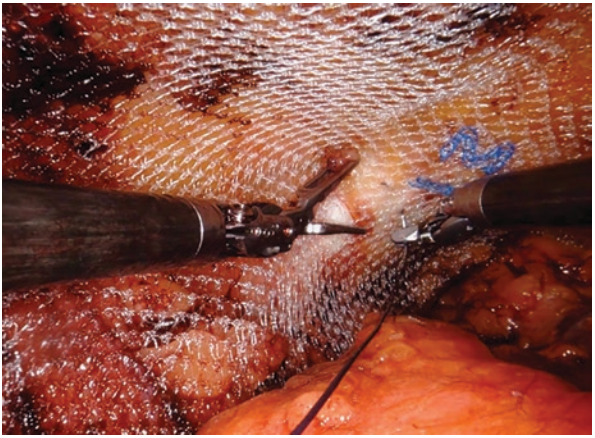

Fig. 20.13 Fixation of the mesh to Cooper's ligament during robotic-assisted inguinal hernia repair

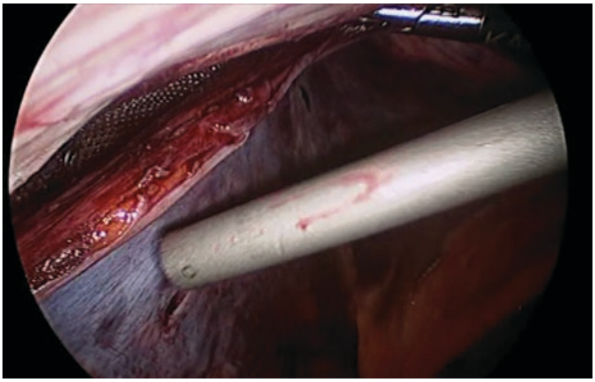

Fig. 20.14 Laparoscopic closure of the peritoneal flap over the mesh using the same permanent tacking device that was used for mesh fixation

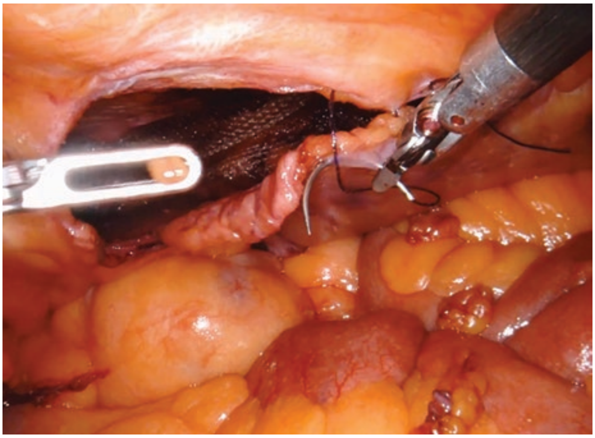

Fig. 20.15 Robotic-assisted closure of the peritoneal flap over the mesh, which is performed in a running fashion using a slowly absorbable barbed suture

24. Any holes in the peritoneum should be closed after closing the peritoneal flap to prevent a preperitoneal hernia. We use a 2–0 Vicryl suture and place either interrupted or figure-of-eight sutures to close the openings in the peritoneum, depending on the size of the defect.
25. Gentle pressure to push the peritoneum against the abdominal wall and desuflate the preperitoneal space is performed to evaluate and ensure that the underlying mesh will not clam-shell after dessuflation of the abdomen.
26. Once it is confirmed that the mesh is in the appropriate position within the peritoneum, the robot is undocked.
27. For a laparoscopic IHR, the 12 mm port site is closed. None of the 8-mm ports for a robotic-assisted IHR or the 5 mm ports for laparoscopic IHR are closed.
28. Any needles are removed from the abdomen, the lateral ports are removed, and the abdomen is desufflated under direct visualization. During desufflation of the abdomen, it is critical to watch how the peritoneum lays over the mesh. If the peritoneum is not flat, this should raise your suspicion for clam-shelling of the mesh, which requires re-insufflation of the abdomen and evaluation.

29. The remaining midline trocar with the camera is then removed.
30. An ilioinguinal nerve block is performed on the ipsilateral side of the inguinal hernia and all incision sites are closed with subcutaneous sutures and skin glue is placed.

20.4 Postoperative Management and Follow-Up

Postoperatively, the Foley catheter, if present, is removed prior to the patient emerging from general anesthesia. We often times will perform a "fill and pull" by inserting 150–200 milliliters (mL) of sterile water into the patient's bladder prior to removing the Foley catheter to aid with postoperative voiding. Patients are transferred to the post-anesthesia care unit (PACU) and are routinely discharged to home, assuming they are able to successfully void postoperatively and that they have met all other PACU discharge criteria. Additional details regarding the postoperative management of our patients are as follows:

1. Postoperative Pain Management. We follow the recommendations provided by the Abdominal Core Health Quality Collaborative (ACHQC) regarding the management of postoperative pain following IHR [27]. Specifically, patients are instructed to place a cold compress at the groin site/site of previous inguinal hernia intermittently (i.e. 30 minutes on, 30 minutes off) for the first 24 hours postoperatively. Patients are also instructed to take acetaminophen and ibuprofen around the clock for the first three days postoperatively. Patients are typically provided with six narcotic tablets with instructions to take every four to six hours if they have persistent pain that is not relieved by the other interventions described above. With the exceptions of patients with chronic pain, none of our patients have had issues with the above postoperative pain management regimen. We believe that the key to successful postoperative pain management with minimization of narcotic pain management is based on thorough patient counseling as to pain expectations and management postoperatively during the preoperative visit and prior to surgery in the preoperative area. We also provide patients with printed information on what to expect postoperatively during their preoperative clinic visit and similar discharge instructions in the PACU to help reinforce the discussions that we have had with them regarding pain control modalities following minimally invasive IHR.
2. Postoperative Follow-Up. Patients are instructed to return to clinic for a routine postoperative appointment within two to four weeks of their inguinal hernia surgery. At that time, if patients are without evidence of wound healing issues or other concerns, such as a large/symptomatic hematoma or seroma or concern for an inguinal hernia recurrence, patients are instructed to follow-up on an as-needed basis. For patients that have either a large/symptomatic hematoma or seroma, patients are instructed to return to clinic on a weekly basis until the hematoma/seroma is almost fully resolved. We prefer not to perform percutaneous aspiration or drain placement into a postoperative hematoma or seroma in

order to minimize the risk for mesh infection. For patients in whom an inguinal hernia recurrence is suspected, either a groin ultrasound or pelvic CT scan is obtained for further evaluation.

3. Postoperative Physical Activity. Patients are instructed to perform activities of daily living and to limit lifting to less than 10 pounds until their postoperative clinic appointment. At that time, if a patient is without postoperative issues, they are cleared for light activity, including walking on the treadmill and lifting twenty pounds. Patients are asked to refrain from heavy lifting (i.e. >20 pounds) or heavy aerobic exercise until six weeks postoperatively.

At our institution, we participate in the ACHQC and our postoperative follow-up is consistent with the timeline outlined by the ACHQC. We encourage patients to return at six months postoperatively, at one year postoperatively, and annually thereafter but this rarely occurs for asymptomatic patients. Postoperative wound events are defined as recommended by Haskins et al. and ventral hernia recurrence is determined either by physical examination or by the ventral hernia recurrence inventory, which has shown to be applicable to patients who have undergone groin hernia repair [28, 29]. We evaluate our outcomes within the ACHQC on a bi-annual basis and have found that the patient selection, operative technique, and postoperative management of these patients, as detailed above, has improved our overall minimally invasive TAPP IHR outcomes.

20.5 Conclusions

Inguinal hernia repair is one of the most commonly performed general surgery operations. There are many surgical approaches to the repair of a groin hernia, including a minimally invasive, laparoscopic or robotic-assisted TAPP IHR, as described in this chapter. It is our intention that this article serves as a guide to the perioperative management of patients undergoing a minimally invasive TAPP IHR. While we recognize that there will be some variation in surgical technique, the key steps described in this article are essential to producing long-term and durable outcomes following a minimally invasive, laparoscopic or robotic-assisted TAPP IHR.

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Chapter 21
Laparoscopic and Robotic Ventral Hernia Repair

Ivy N. Haskins and Arielle J. Perez

21.1 Introduction

Despite being one of the most commonly performed general surgery operations, ventral hernia repair (VHR) lacks standardization in all phases of perioperative care [1–4]. A minimally invasive approach to ventral hernia repair (VHR) using laparoscopy was first introduced in 1993 [5]. Since that time, laparoscopic VHR has been shown to be both a safe and effective approach to the management of ventral hernias [1, 6–10]. Additionally, laparoscopic VHR has been shown to have a decreased rate of postoperative wound events and hospital length of stay (LOS) compared to open VHR through the elimination of large midline incisions [11–14]. Currently, laparoscopy is the accepted gold standard minimally invasive approach to VHR [15]. Nevertheless, robotic-assisted approaches to VHR, which were first introduced in 2003, have also been shown to offer similar advantages with respect to decreased wound events and hospital LOS compared to open VHR [15]. With the currently available approaches to VHR and the knowledge that VHR lacks standardization, it is critical that a tailored approach to VHR be employed in order to optimize patient and hernia outcomes. Herein, we detail our approach to patient selection, surgical technique, and postoperative management of patients undergoing minimally invasive VHR.

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21.2 Clinical Presentation, Preoperative Evaluation, and Patient Selection

There are several different factors, including surgeon, patient, and hernia-specific factors, that must be considered when deciding the type of VHR technique that is most appropriate for a specific patient. First, we will discuss surgeon factors that must be considered prior to performing VHR. In a recent article by Kockerling et al., it is suggested that additional training in hernia surgery may be beneficial to young surgeons due to the increased complexity of ventral hernias as a disease process [16]. In other words, the authors argue that a tailored approach to VHR is more easily facilitated by 'hernia specialists' similar to the management of vascular diseases by vascular surgeons or any other specialty surgeon [16]. The recommendations put forth by these authors are consistent with the current value-based healthcare market landscape in the United States [16–18]. Unfortunately, while the learning curve for proficiency with laparoscopic inguinal hernia repair (IHR) has been well studied, there are currently no studies that have investigated the learning curve for laparoscopic VHR or robotic-assisted IHR or VHR [16]. Therefore, our recommendation is that surgeons who choose to perform minimally invasive VHR (either laparoscopic or robotic-assisted) have received training in this surgical technique and that they feel as confident in producing a durable hernia repair using either laparoscopy or the robotic platform as they do performing an open VHR.

Next, we will discuss patient factors that contribute to the decision as to the surgical approach to VHR. During the preoperative patient visit, it is important that patient comorbidities, social history, and previous surgeries be thoroughly reviewed. First and foremost, minimally invasive VHR is performed under general anesthesia. Therefore, patients who cannot tolerate general anesthesia due to their associated medical comorbidities are not candidates for either laparoscopic or robotic-assisted VHR. In terms of additional patient factors that may contribute to increased morbidity and mortality following minimally invasive VHR, we use the risk factors previously identified by the Ventral Hernia Working Group to aid in our preoperative discussions [19]. In order to facilitate this discussion and to encourage preoperative patient optimization, we use the Outcomes Reporting App for Clinician and Patient Engagement (ORACLE) tool, which has been previously described by Haskins et al. [20] The modification of patient factors preoperatively is part of our prehabilitation process for patients undergoing elective minimally invasive VHR and includes:

1. Weight Loss—It has been shown in several studies that overweight and obese patients are at an increased risk for postoperative wound events and ventral hernia recurrence following open ventral hernia repair [21–23]. While overweight and obese patients may be better candidates for laparoscopic or robotic-assisted VHR due to smaller incisions that may offset some of the wound healing issues, the negative effects of increasing weight on outcomes following minimally

invasive VHR must still be considered. Therefore, we recommend that any patient with a body mass index (BMI) ≥ 34 kg/m^2 lose weight prior to VHR.

2. Smoking Cessation—The detrimental effect of nicotine on the wound healing process has been extensively studied by Sorensen [24]. For any patient actively using nicotine products, they are required to abstain from nicotine use for six weeks preoperatively. In addition to patient reported abstinence, we may sometimes require a negative urine nicotine test prior to repair of their ventral hernia, especially for patients who have a history of unsuccessful attempts at smoking cessation.
3. Control of Diabetes Mellitus—There are currently no studies that have investigated the effect of elevated glycosylated hemoglobin (HgA$_1$c) levels on postoperative wound events and ventral hernia recurrence following VHR. Nevertheless, the association of elevated HgA$_1$c levels with adverse events has been studied in other areas of surgery, including cardiac surgery and orthopedic surgery [25]. Applying these studies to VHR, we require a preoperative HgA$_1$c level within the three months leading up to VHR and attempt to achieve a HgA$_1$c level as close to 6.5% as possible.
4. Other—Other patient comorbidities that are addressed are those that may lead to increased intra-abdominal pressure, such as chronic obstructive pulmonary disease, and factors that may adversely affect wound healing, such a malnutrition.

While we recognize that improvement in medical comorbidities is quite vague, we are borrowing many of our recommendations from studies performed either in general surgery patients with the inclusion of hernia patients or in specialty services such as cardiac surgery or orthopedic surgery. Furthermore, similar to enhanced recovery after surgery (ERAS) pathways, it is currently unknown which patient comorbidity (and subsequent modification of that comorbidity) has the greatest impact on postoperative outcomes following minimally invasive VHR [26]. Therefore, when counseling patients on the above comorbidities, we emphasize each factor equally.

Finally, we will discuss hernia-specific factors that are considered prior to minimally invasive VHR. These factors include the timing of the surgery (i.e. urgent or emergent versus elective repair), size and location of the hernia, and number and type of previous VHRs. In order to understand any previous prior abdominal wall surgeries, it is important to obtain previous operative reports in order to determine if a patient has undergone prior components separations or abdominal wall tissue debridements, the type and location of previous mesh placement, and number of previous abdominal surgeries. For these hernia-specific factors, we consider patients appropriate for minimally invasive VHR if:

1. Size of the hernia defect is <7 centimeters (cm) on physical examination and cross- sectional imaging [27, 28].
2. Location of the hernia along the anterior abdominal wall such that at least 3 cm of mesh overlap can be achieved on all sides of the hernia defect [27]. To allow for suture fixation, ventral hernias that are in unique locations, for example in the

subxiphoid and suprapubic region, mesh fixation and overlap may not be easily achieved without a preperitoneal approach.
3. If mesh was used during previous VHR, it was either an absorbable mesh or can be easily removed using minimally invasive techniques such that it will not affect the ensuing repair.
4. Prior surgical history does not suggest difficulty accessing the abdominal cavity, such as the need for extensive adhesiolysis. Caution should be taken for patients with multiple previous abdominal operations, a history of an open abdomen, or a history of an intra-abdominal catastrophe. In such cases, access to the abdominal cavity and freeing of the abdominal wall may be challenging and consideration of an open approach to VHR is warranted.

21.3 Surgical Technique

This section will highlight the key steps to performing a minimally invasive VHR. We will discuss minimally invasive VHR using intraperitoneal mesh placement, also known as the IPOM technique. While there are other minimally invasive VHR techniques, such as the preperitoneal and extended total extraperitoneal techniques, these are outside the scope of this chapter. Please note that the steps described below are specific to our institution and have been adopted to facilitate both patient safety and surgeon comfort.

1. All patients receive universal decolonization against methicillin-resistant *Staph aureus* (MRSA) with five days of nasal mupirocin preoperatively. Patients are not routinely instructed to perform preoperative chlorhexidine scrub or to undergo mechanical bowel preparation, as both of these interventions have been associated with an increased risk of postoperative wound events [29, 30].
2. Routine preoperative interventions are performed, including the administration of preoperative antibiotics and the administration of chemical deep venous thrombosis (DVT) prophylaxis, as recommended by the Surgical Care Improvement Project Guidelines. It is important to note if patients have a known history of MRSA wound infection. In these cases, we recommend the use of preoperative antibiotics that cover MRSA.
3. Patients are placed supine on the operating room table.
4. General anesthesia is induced and all hair from xiphoid to pubis is removed with surgical clippers. For patients with a hernia at or below the umbilicus, a Foley catheter is placed to decompress the bladder and to minimize the risk of bladder injury during dissection and mesh fixation.
5. Both arms are tucked, taking care to adequately pad the elbow and other pressure points.
6. The patient is slightly flexed to maximize the space between the subcostal margin and the anterior superior iliac spine.

7. Access to the abdominal cavity is achieved based on surgeon preference, either through an open cut-down technique or Veress needle with subsequent optical entry in the left upper quadrant. For most ventral hernias, we prefer to insufflate with a Veress needle and then gain access using an optical entry technique in the left subcostal area along the rectus abdominis muscle as this area is least likely to have intra-abdominal adhesions and is typically far enough away from the hernia to facilitate adequate mesh overlap and fixation. For a laparoscopic approach, we use a 5 millimeter (mm) port to gain access to the abdominal cavity. For a robotic-assisted approach, we use the da Vinci Xi® System (Intuitive Surgical, Sunnyvale, CA, USA) and gain access to the abdominal cavity using an 8 mm optical trocar port.
8. Based on the location of the hernia, we place two additional ports on the ipsilateral side allowing for ease of instrument manipulation and triangulation of the camera. For laparoscopic, periumbilical, midline VHRs, we place one 12 mm port slightly more lateral to the 5 mm optical entry port on the left side of the mid-abdomen parallel to the umbilicus and an additional 5 mm port in the left lower quadrant below the umbilicus within the same plane as the 5 mm optical entry trocar (Figure 21.1a). For robotic-assisted, periumbilical, midline VHRs, we place one 12 mm port and an 8 mm port based on a configuration

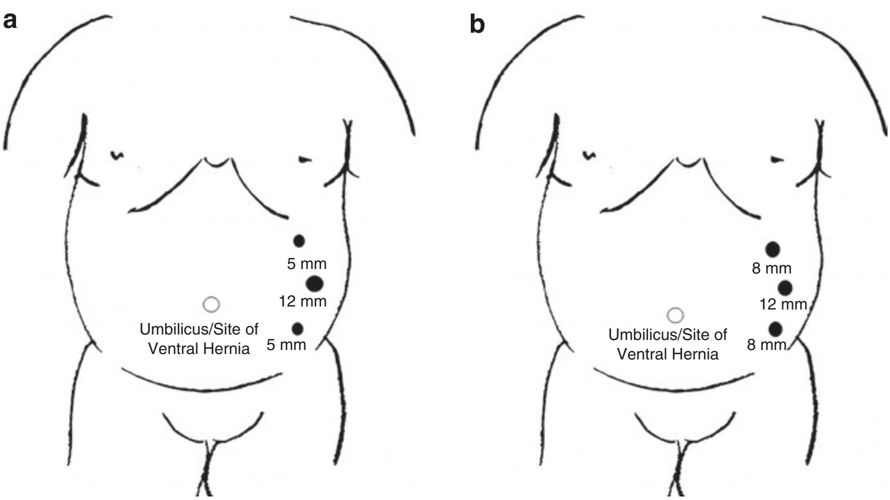

Fig. 21.1 Location and sizes of port used. All of the ports can serve as working ports and locations for camera placement. (**a**) Representation of port placement for laparoscopic, periumbilical ventral hernia repair. The 12 mm port can be used for removal of the hernia sac (when performed) and for introduction of the mesh. If needed, two additional 5 mm ports can be placed on the right side of the abdomen lateral to the rectus abdominis muscle. (**b**) Representation of port placement for robotic-assisted ventral hernia repair. The robot is positioned and docked from the patient's right side

that allows for adequate distance between the robotic arms (Figure 21.1b). The distance between the robotic ports is ideally 8 cm but can be modified based on the patient's abdominal wall surface area. If needed, additional ports can be placed on the lateral aspect of the contralateral side of the abdomen, such as when extensive adhesiolysis is required, to assist with mesh fixation, or as an assist port during robotic-assisted VHR.

9. A 30-degree laparoscope is used to adequately asses the abdominal wall. The anterior abdominal wall is then cleared of any omental and/or intestinal adhesions and the hernia defect and its contents are isolated. Any previous intraabdominal mesh is removed if possible. The falciform ligament and the median/medial umbilical ligaments are also often taken down in order to facilitate flat-lying mesh with adequate overlap of the ventral hernia defect (Figs. 21.2 and 21.3).
10. The ventral hernia is evaluated. If the hernia contains omentum only, a combination of blunt dissection and electrocautery are used to reduce the hernia. If the hernia contains bowel, sharp dissection only is used to reduce the hernia. Exterior downward pressure on the anterior abdominal wall can be applied to help reduce the hernia (Fig. 21.4).
11. The hernia defect is then evaluated and the peritoneum cleared from the fascial edges.
12. The size of the hernia defect is measured. We perform this by inserting spinal needles from the anterior abdominal wall into the abdominal cavity to outline the length and width of the fascial defect. The hernia defect is then measured intraabdominally using a ruler (Figs. 21.5 and 21.6).

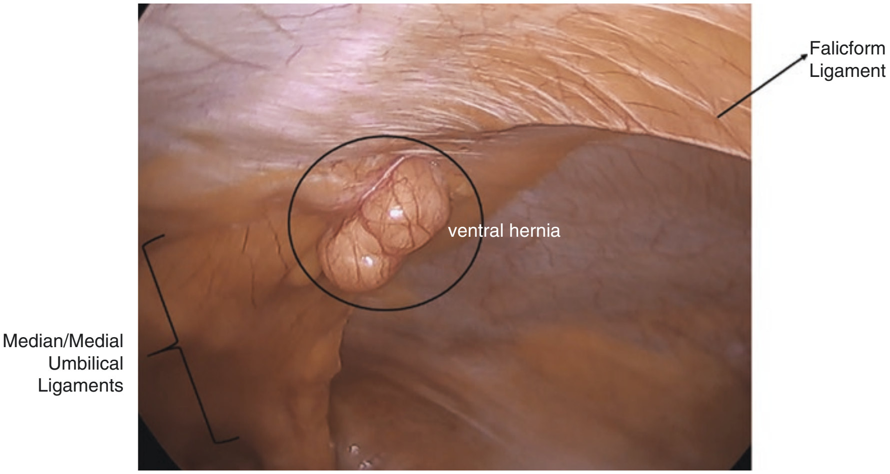

Fig. 21.2 After entrance into the abdominal cavity, the ventral hernia is identified. The location of the ventral hernia relative to the falciform ligament and the median and medial umbilical ligaments is noted. Furthermore, any intra-abdominal adhesions or previous intra-abdominal mesh placement and location is also noted at this time

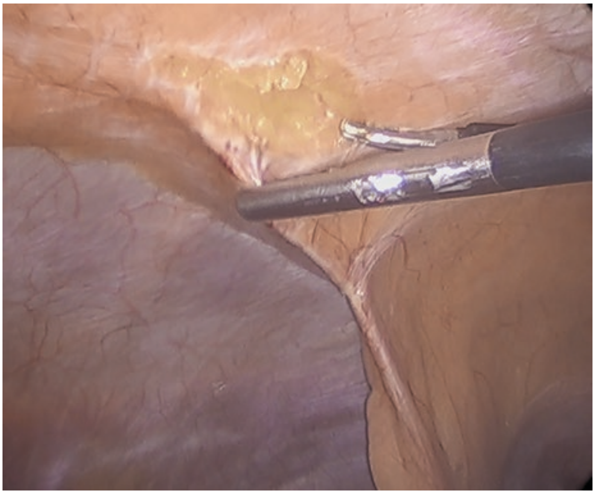

Fig. 21.3 In order to facilitate adequate mesh overlap of the ventral hernia defect, the falciform ligament is taken down with "hot" scissors

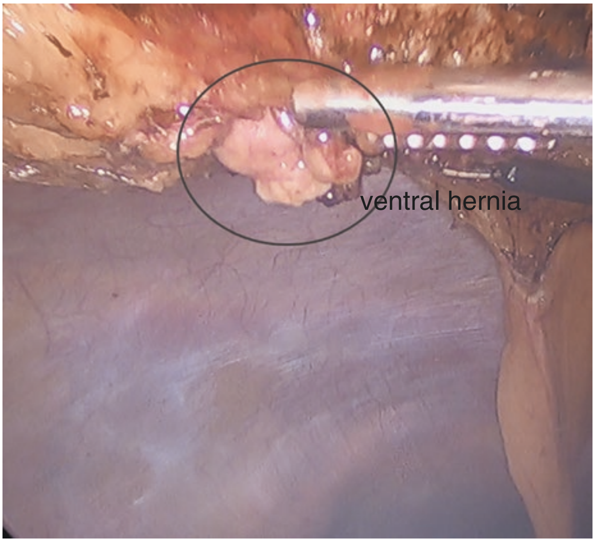

Fig. 21.4 Gentle external downward pressure is placed on the hernia defect to facilitate complete reduction of the hernia contents. Notice that the falciform ligament and the median/medial umbilical ligaments have also been partially taken down in order to ensure that the mesh lays flat along the anterior abdominal wall

13. The hernia defect is closed. Laparoscopically, we utilize a slowly absorbable suture and a "shoelacing" technique as first described by Orenstein et al., by placing sequential figure-of-eight sutures with a laparoscopic suture passer through stab incisions in the skin [31]. The pneumoperitoneum is decreased to 10 to 12 millimeters of Mercury (mm Hg) prior to closing the ventral hernia defect to help decrease the tension on the fascial closure (Figs. 21.7 and 21.8). Robotically, we utilize a slowly absorbable barbed suture that is run the length of the defect, from the proximal (cephalad) aspect distally (caudad) and back again to the proximal aspect (Figs. 21.9 and 21.10). In order to reduce the

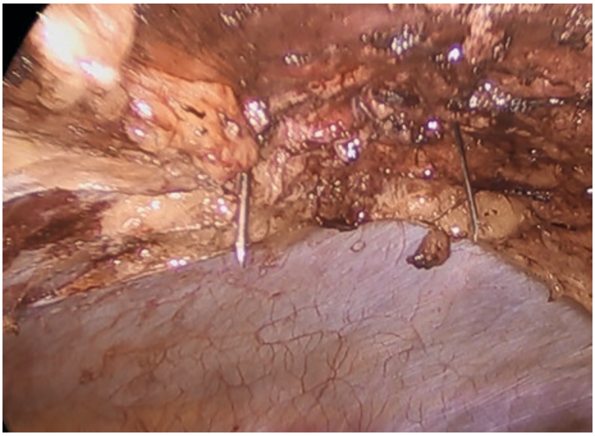

Fig. 21.5 Two 20-gauge spinal needles are used to outline the width of the ventral hernia defect

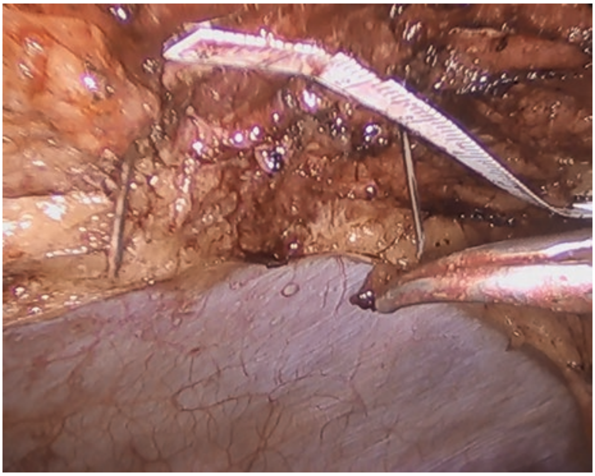

Fig. 21.6 A ruler is placed into the abdomen and the insufflation pressure is dropped to 10–12 mm Hg in order to accurately measure the width of the ventral hernia. Here, the ventral hernia measures approximately 2.5 centimeters. Placement of spinal needles and measurement of the hernia length is also performed to facilitate appropriate mesh size selection

occurrence of postoperative seroma formation, the hernia sac can often be incorporated into this fascial closure.

14. An appropriately sized mesh is chosen. Although 3 cm of mesh overlap is recommended, we prefer a mesh overlap of 4–5 centimeters in all directions. We use a coated synthetic mesh for IPOM VHR. While the type of mesh used will ultimately depend on surgeon preference and what is available at a particular institution, it is important that no uncoated synthetic meshes are placed in an IPOM location due to the increased risk of small bowel obstruction and enterocutaneous fistula formation [32].
15. The mesh is prepared on the backtable. In order to minimize the risk of mesh infection, we do not open the mesh until this part of the operation and only one person handles the mesh. We also ensure that the mesh is prepared on a clean towel. A previously unused marker is used to draw lines across the vertical and

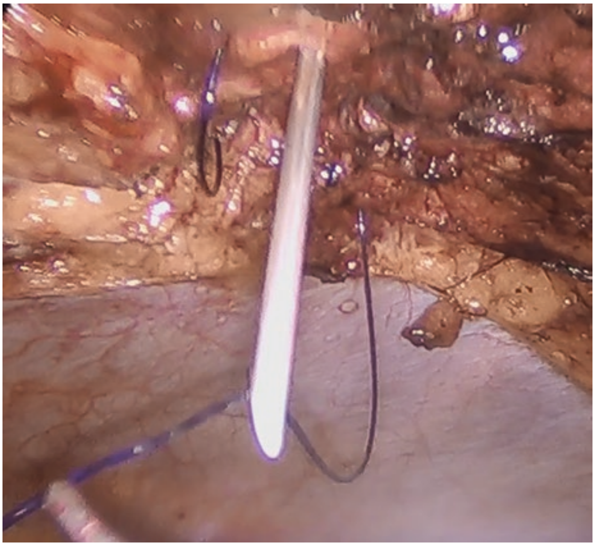

Fig. 21.7 Laparoscopic closure of the ventral hernia defect is performed using a "shoelacing" technique, with the assistance of a laparoscopic suture passer. Slowly absorbable suture is used for closure of the ventral hernia defect

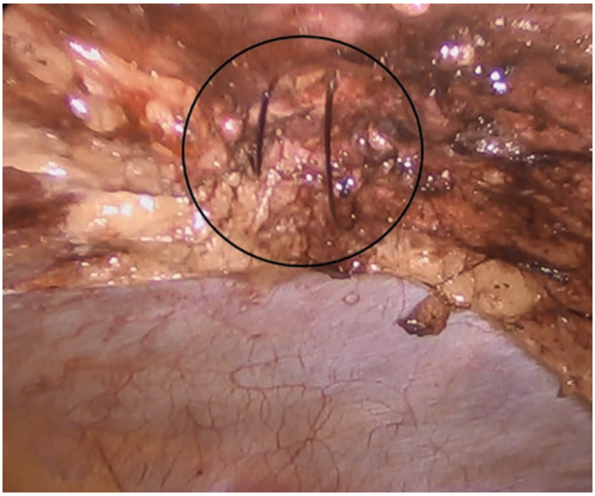

Fig. 21.8 Demonstration of the "shoelacing" technique, which results in a figure-of-eight stitch to aid in closure of the ventral hernia defect

horizontal midlines along the coated side of the mesh so that this is visible to the surgeon during mesh fixation. A vicryl suture (any size available) is then placed in the center of the mesh. For larger pieces of mesh without a positioning system from the manufacturer, intraabdominal mesh can become quite pliable, difficult to manipulate, and fold, obscuring the surgeon's view. Laparoscopically, this is remedied by securing #1 polydioxanone (PDS) sutures to the superior and inferior aspects of the mesh. It is important to note that these sutures are placed with the tails on the uncoated side of the mesh to ensure that the suture knots are in apposition with the abdominal wall following mesh fixation.

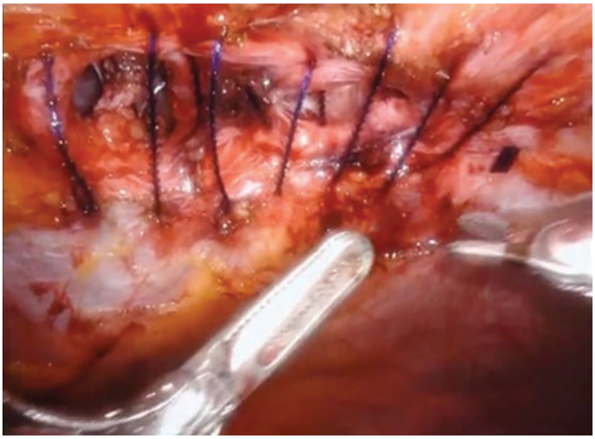

Fig. 21.9 Robotic-assisted closure of the ventral hernia defect is performed using a slowly absorbable barbed suture that is run in a continuous fashion along the length of the hernia defect, from the proximal (cephalad) aspect distally (caudad) and back again to the proximal aspect

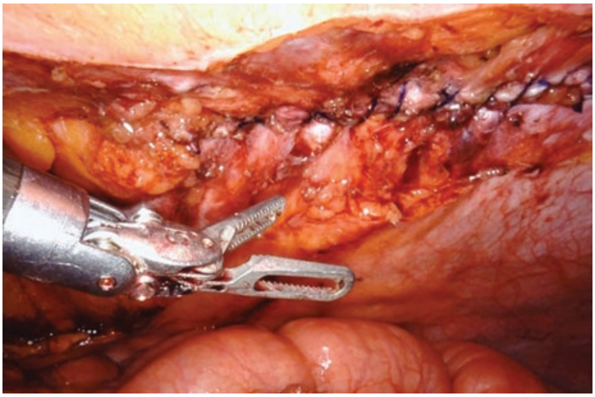

Fig. 21.10 Completion of robotic-assisted fascial closure

16. The mesh is introduced into the abdominal cavity and centered over the hernia defect. To allow for introduction of the mesh, the intra-abdominal pressure is returned to 12 to 15 mmHg. Once the mesh is introduced, the intra-abdominal pressure is decreased back to 10 to 12 mmHg. For a laparoscopic VHR, a laparoscopic suture passer is placed through the middle of the now closed hernia defect, the vicryl suture is grasped, and the mesh is raised towards the anterior abdominal wall (Figs. 21.11 and 21.12). For a robotic-assisted VHR, the vicryl suture is aligned with the middle of the defect and secured in place using a 2–0 absorbable barbed suture.
17. The mesh is aligned in a vertical direction using the previous markings on the coated side of the mesh. If placed, the PDS sutures are now pulled through the anterior abdominal wall using a laparoscopic suture passer and brought up taut against the anterior abdominal wall (Fig. 21.13). Additional fixation of the mesh is then performed using a permanent tacking device (Fig. 21.14). Two rows of fixation are placed and are referred to as an inner and outer crown

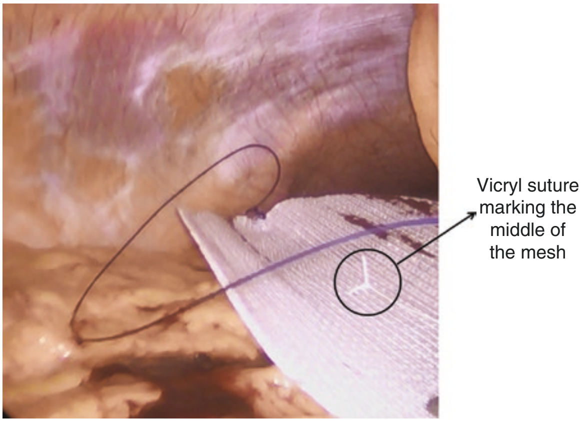

Fig. 21.11 Insertion of the mesh. Note that the knots of the sutures are facing towards the abdominal wall, indicating that the mesh is appropriately placed with the coated side facing towards the abdominal cavity

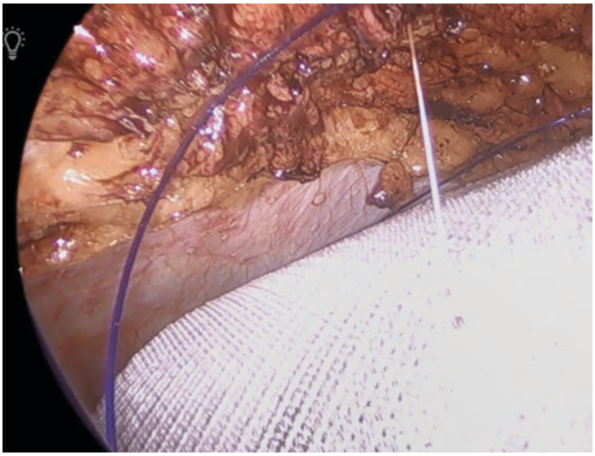

Fig. 21.12 Securing of the middle of the mesh (which is performed for both laparoscopic and robotic-assisted ventral hernia repair) prior to fixation using either a tacking device (laparoscopic) or intracorporeal sewing (robotic-assisted)

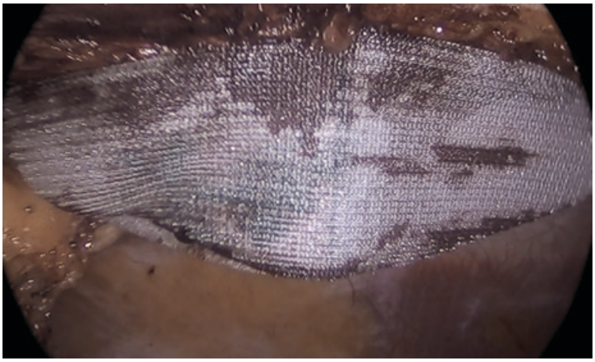

Fig. 21.13 Transfascial sutures are placed at the superior and inferior aspects of the mesh during laparoscopic VHR to ensure that the mesh is taut against the anterior abdominal wall

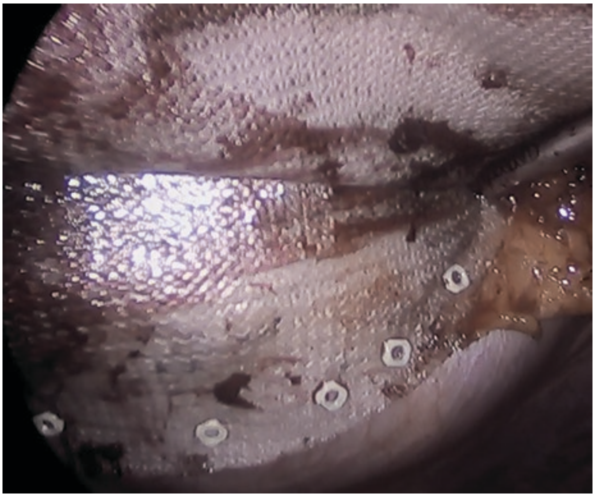

Fig. 21.14 The first row of permanent tacks are placed. This picture demonstrates the use of external downward pressure, creating a 90 degree angle between the abdominal wall and tacking device, to ensure that the tacks are secured to the abdominal wall and to help keep the mesh flat during fixation

Fig. 21.15 A second row of permanent tacks are used to secure the intraperitoneal onlay mesh. Of note, less tacks are used in the second row than in the first (outside) row of tacks

(Fig. 21.15). For robotic-assisted VHR, a 2–0 absorbable barbed suture is used to secure the mesh circumferentially to the abdominal wall (Fig. 21.16). During this step of the procedure, it should be ensured that the mesh is taut along the abdominal wall to minimize the risk of mesh bulging, unsuccessful incorporation into the abdominal wall, or foreign body sensation (Fig. 21.17).

18. Following mesh fixation, the robot is undocked.
19. Bilateral transabdominal preperitoneal (TAP) blocks are performed for postoperative pain control.
20. The 12 mm port site is closed. None of the 8 mm ports for robotic-assisted VHR or the 5 mm ports for laparoscopic VHR are closed.
21. All trocars are removed under direct visualization after which the abdomen is dessuflated.

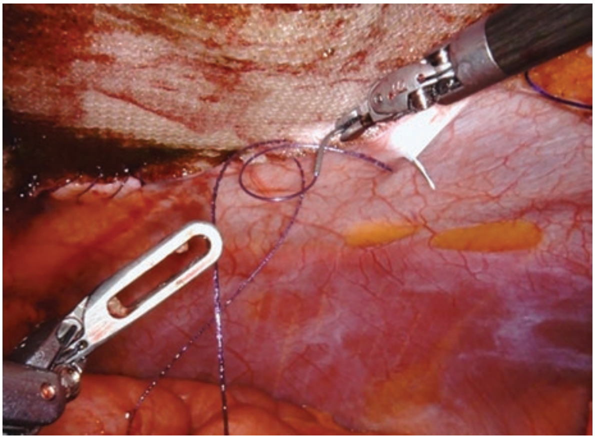

Fig. 21.16 Robotic-assisted mesh fixation. Once the middle of the mesh is secured in place, an additional 2–0 absorbable barbed suture is used to circumferentially fix the mesh to the anterior abdominal wall

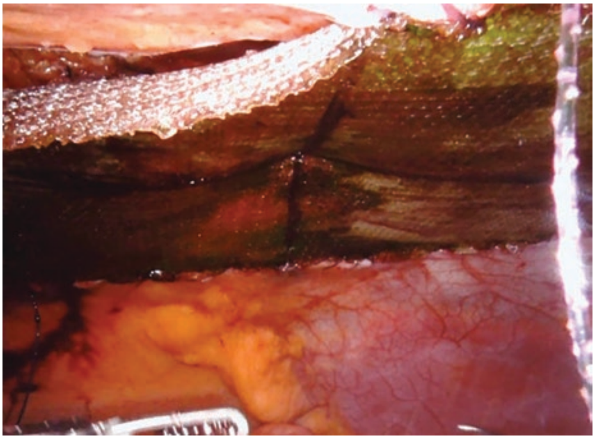

Fig. 21.17 Partially fixated mesh in the intraperitoneal onlay position. It is worth noting that this picture also demonstrates that the lines marking the horizontal and vertical midlines are visible to the surgeon during mesh fixation, ensuring that the coated side of the mesh rather than the uncoated side of the mesh is in contact with the abdominal cavity and intra-abdominal contents

22. All incision sites are closed with subcutaneous sutures and skin glue is placed. If a periumbilical hernia is fixed, a pressure dressing using gauze and a clear adhesive bandage is used. An abdominal binder is placed for external compression. Both of these interventions are performed to help minimize the risk of postoperative seroma formation.

21.4 Postoperative Management and Follow-Up

Patients are transferred to the post-anesthesia care unit (PACU) after emergence from general anesthesia. If a Foley catheter was placed preoperatively, it is removed prior to transfer to the PACU. It is our practice that patients be routinely discharged from the PACU following minimally invasive VHR, assuming that they are able to void and that they meet all PACU criteria for safe discharge home. From a surgical standpoint, factors that would make us consider overnight hospital admission following minimally invasive VHR include a medium- or large-sized hernia defect (i.e. > 4 centimeters) or if extensive adhesiolysis was performed.

A thorough discussion is had with patients in regard to postoperative pain control both during their preoperative appointment as well as in the preoperative area prior to surgery. Additionally, patients are provided with printed information on what to expect around the time of surgery during their preoperative appointment and a similar printout of information is provided to them at the time of discharge from either the PACU or the hospital floor that summarizes the information we have discussed with them regarding postoperative pain control. We believe that a multi-modal approach to postoperative pain is the most effective at minimizing postoperative pain and reducing the use of narcotic medication. In addition to the bilateral TAP blocks performed intraoperatively which should provide local numbing of the surgical site, patients are encouraged to place intermittent cold packs directly over the surgical site the night of surgery. Patients are instructed to take acetaminophen and ibuprofen, as medically able, every six hours in alternating fashion while awake for the first three days postoperatively. It is stressed to patients that narcotic medications are a rescue medication and should only be used when necessary. At the time of discharge, patients without a diagnosis of chronic pain and/or patients not on home narcotic medication are provided with a prescription for no more than ten tablets of narcotic medication. For patients with a diagnosis of chronic pain, we follow the guidance of their pain management specialist. Our practices are consistent with those recommended by the Abdominal Core Health Quality Collaborative (ACHQC) [33].

Patients' activity is limited postoperatively to walking and stairs for the first two weeks with lifting restrictions of no more than 10 pounds. The use of an abdominal binder is encouraged for the first two to six weeks after surgery, depending on the size of the repair, to assist with patient comfort while ambulating. Patients are asked to return to clinic for a routine postoperative visit at two to four weeks postoperatively. At that time, patients are asked how they are doing in general and specific questions related to their postoperative recovery are also asked. A thorough physical examination of the surgical sites and the site of the previous hernia is performed, evaluating for wound healing issues, hematomas, seromas, or ventral hernia recurrence. If patients are without evidence of any of these issues, they are instructed that they may slowly increase their level of physical activity but to continue to limit their lifting to no more than 20 pounds until six weeks postoperatively. For patients that have either a large/symptomatic hematoma or seroma, patients are instructed to return to clinic on a weekly basis until the hematoma/seroma is almost fully resolved. We prefer not to perform percutaneous aspiration or drain placement into a postoperative hematoma or seroma in order to minimize the risk for mesh infection. Often times, patients will complain of discomfort at the site of transfascial sutures (for laparoscopic VHR) or port sites. We recommend that patients begin utilizing desensitization techniques such as light massage over these areas at two weeks postoperatively and we reassure them that this discomfort should continue to abate over time. For patients in whom a ventral hernia recurrence is suspected, either an abdominal ultrasound or computed tomography (CT) scan of the abdomen and pelvis is obtained for further evaluation.

At our institution, we participate in the ACHQC and our postoperative follow-up is consistent with the timeline outlined by the ACHQC. Specifically, patients are seen within 30 days of surgery. We encourage patients to return at six months postoperatively, at one year postoperatively, and annually thereafter, but this rarely occurs for asymptomatic patients. Postoperative wound events are defined as recommended by Haskins et al. and ventral hernia recurrence is determined either by physical examination or by the ventral hernia recurrence inventory [2, 34]. We evaluate our outcomes within the ACHQC on a bi-annual basis and have found that the patient selection, operative technique, and postoperative management of these patients, as detailed above, has improved our overall minimally invasive VHR outcomes.

21.5 Conclusions

Laparoscopic and robotic VHR are safe and effective approaches to the management of many abdominal wall hernias. It is our intention that this chapter will serve as a guide to the perioperative management of patients undergoing minimally invasive VHR. While we recognize that there will be some variation in the surgical technique that we have described, rigorous patient selection, preoperative optimization, and the key steps to performing minimally invasive VHR, as detailed in this article, are essential to producing sound 30-day outcomes and long-term hernia repair durability.

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Chapter 22
Laparoscopic Parastomal Hernia Repair

Dallas D. Wolford and Steven G. Leeds

22.1 Introduction

A parastomal hernia (PSH) is an incisional hernia that developsafter stoma creation and is the most common long-term complication related to stomas [1–5]. According to the Journal of Wound, Ostomy, and Continence Nursing, 100,000 new intestinal stomas are created every year [6]. It is believed to be almost inevitable to have some degree of herniation after colostomy formation [5]. The incidence of PSH depends on the type of stoma created. Parastomal hernias occur anywhere from 4 and 48.1% of the time after end colostomy [7–11], whereas loop colostomies develop PSH in up to a 30.8% of patients [11–15]. With regard to ileostomies, PSH are seen in 1.8–28.3% [9, 10, 16–18]of end ileostomies and in up to 6.2% of loop ileostomies [12, 13, 19–21]. Most PSH develop within the first two years after stoma construction, but can also present 20+ years from the time of surgery [9, 10, 22]. As such, the low incidence of PSH in loop ileostomies can be attributed to the fact that they areoften temporary and thus there is insufficient time for hernia development. There are four types of PSH—peristomal, intrastoma, subcutaneous, and interstitial [23]. Knowing the type of hernia can help guide the type of surgical repair.

1. Peristomal-herniation within a prolapsing stoma.
2. Intrastomal-herniation is at the level of the emerging and everted portion of bowel with the sac extruding along the same tissue plane as the stoma.

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3. Subcutaneous-herniation of sac alongside the stoma in the adjacent subcutaneous tissue.
4. Interstitial-herniation within one of the intermuscular planes adjacent to the stoma.

22.1.1 Clinical Presentation

PSHs are often asymptomatic but can cause many issues along a spectrum of severity [2]. The most concerning of which are obstruction of bowel or colon with potential to progress to strangulation, incarceration, and perforation [24–26]. Typically, patients complain of parastomal discomfort and pain that interferes with activities of daily living, cramping,intermittent nausea and vomiting related to obstructive episodes, skin irritation, leakage and difficulty placing ostomy appliance, and social and psychological sequelae from inability to conceal stoma [2, 27].

22.1.2 Risk Factors

Risk factors for development of PSH are classified as either patient- or technique-related. The most common patient-related factors include age > 60 years, diabetes, COPD, protein-calorie malnutrition, obesity, weight gain after surgical stoma placement, use of steroids and other immunosuppression [5, 22, 28–30]. Of these, obesity has the strongest association with PSH occurrence [28, 30]. Technical factors associated with increased risk of parastomal herniation include open surgical approach (vs laparoscopic or robotic), large diameter trephine, emergent creation of stoma, and the type of stoma created (colostomy vs ileostomy vs end vs loop) [31–33].

22.1.3 Diagnosis

Diagnosis of a parastomal hernia is performed clinically with physical exam and observation of a bulging mass at or adjacent to the stoma site. Removing the stoma appliance is often necessary for performing an adequate exam. A digital examination of the stoma is performed with the patient standing and in Valsalva in order to assess fascial aperture and parastomal tissues. In some cases, it is difficult to demonstrate a hernia clinically in patients who otherwise present with the classical symptoms. In the setting of a high index of suspicion, computed tomography is the imaging modality of choice for detecting PSH in symptomatic patients with an otherwise benign abdominal exam.

22.2 Preventing Parastomal Hernia Occurrence

Given the high rates of PSH after stoma creation, identifying ways to prevent or delay the development of herniation is worth mentioning. While there are a multitude of proposed methods for prevention of PSH formation, prophylactic surgical techniquesis one of them.

22.2.1 Stoma Placement

Pulling the stoma through the rectus abdominis muscle had previously been documented to reduce the incidence of PSH when compared to those lateral to the rectus muscle (3% vs 22%) [34–37]. However, a single-centered randomized trial of 30 patients comparing stomas brought through vs lateral to the rectus muscle showed no significant difference in PSH occurrence [38, 39]. Larger studies need to be done to confirm this conclusion with greater certainty, but there is indication that those early studies may not be valid with the updated procedures done today.

22.2.2 Size of Stoma Aperture

The size of the stomal aperture is directly associated with risk of PSH formation. In 1990, Etherington determined a threshold of 3 cm, above which there was a significant increase in risk of PSH [40, 41]. Another study suggested apertures of 2 cm and 1.5 cm for ileostomies and colostomies respectively [32]. Nguyen demonstrated a simple formula for creating apertures based on the width of the bowel opening when flattened, proposing that the aperture should be 2/3 of the bowel width. It was argued that this technique allowed for precise sizing of the stoma trephine [42]. Exact sizes are difficult to prove as intestinal diameters and strength of abdominal wall fascia vary. Overall, it appears that the narrowest aperture without causing ischemia may show the best resistance to PSH formation.

22.2.3 Extraperitoneal Stomas

Goligher first described this method on 1958, where creation of extraperitoneal stomas essentially follows the same physiologic concept of the Sugarbaker repair, anatomically creating a tunnel between the parietal peritoneum and the posterior rectus sheath [43]. The ostomy conduit travels within this tunnel prior to exiting the abdominal wall either via transrectus or lateral rectus approach preserving the peritoneum underlying the internal aspect of the stoma. PSH occurrence is significantly reduced with extraperitoneal stoma creation when compared to transperitoneal approach (3.5% vs 35%) [9]. This was further supported by a meta-analysis that found an odds ratio of 0.41 with open extraperitoneal colostomy technique (95% CI: 0.23–0.73, P = 0.002) [44]. Supporting studies have all produced lower rates of PSH development with extraperitoneal colostomies, however the difference was not consistently statistically significant [44–46]. Despite these findings, documented opinions regarding clinical significance differ greatly. Additionally, there is a paucity of data and evidence from clinical trials to support the extraperitoneal technique.

22.2.4 Prophylactic Mesh Placement

Given the high probability of developing a PSH, the argument for the placement of mesh prophylactically at the time of the initial stoma creation may be valid. Initially, there was speculation regarding whether the use of mesh in a contaminated field was advisable given the exposure to enteric contents with stoma creation. Other concerns have arose regarding known complications with synthetic meshes including but not limited to infection, fistulization, and erosion. In 2017, a meta-analysis of 8 randomized controlled trials comprised of 430 patients showed a significant reduction in the development of PSH with prophylactic synthetic mesh placement in either the retrorectus plane or intraperitoneal underlay (19.4% vs 43.2%; RR 0.4, 95% CI 0.21–0.75, p = 0.004) [47–58].With the use of biologic mesh there was a non-statistically significant decrease in PSH formation when compared to no mesh (10.2% vs 15.9%, 95% CI: 0.11–2.95, p = 0.510) [58]. Interestingly, there did not appear to be an increase in peristomal complication rates with use of synthetic nor biologic prophylactic mesh, however follow-up intervals varied and long-term outcomes have not been well established. Despite favorable results using prophylactic mesh, limitations regarding length of follow-up, efficacy of biologic mesh, smaller study populations likely explain why the method has not been widely adopted as a standard of care. Thus, further clinical trials with prophylactic mesh placement are necessary to determine whether there is a clear benefit.

22.3 Repair Considerations

Reestablishing gastrointestinal continuity, thereby removing the stoma altogether, is the best modality for management of PSH, however this is not always an option.

A majority of patients with PSH are managed non-operatively. Watchful waiting is a common first step in management approach in those who are asymptomatic or have mild symptoms that are insufficient to warrant surgical repair. A stoma belt or ostomy binder can be used to provide stability and decrease the degree of herniation [5]. It is important that these patients be educated on the signs and symptoms of bowel obstruction and strangulation so they may seek emergent medical.

When possible, surgery should be avoided as PSH recurrence after repair is common. In a French study of 782 patients, 25.6% reported development of PSH, a little over half had symptoms that necessitated operative repair, half of which then recurred [22].

Surgical repair of PSH is indicated in setting of acute complications or in that of chronic symptoms that interfere with activities of daily living and thus quality of life. Acute complications often require urgent or emergent surgical intervention and include intestinal obstruction secondary to incarceration, strangulation, perforation, and ischemic or infarcted bowel [5, 32]. Chronic symptoms that warrant elective surgical repair include recurrent partial intestinal obstruction, PSH-induced chronic abdominal or back pain, enlarging hernia, peristomal skin breakdown, difficulty pouching, appliance leakage or dysfunction, psychological distress, and impending obstruction.

There are multiple surgical approaches described for repair of PSH, all of which have poor long-term outcomes due to the high frequency of recurrence. Generally, parastomal hernia repair (PHR) is achieved by one of the following: primary repair, mesh repair, stoma relocation, stoma reversal.

22.3.1 Primary Repair

Primary repair of local tissue is one possibility but is associated with recurrence rates of 46–100% [17]. Repairing the adjacent fascial tissue primarily is technically simple, avoids a laparotomy, and does not require relocation of the stoma to a new site on the abdomen. In case of primary tissue repair, the hernia is opened, hernia sac dissected away, and non-absorbable sutures are used to reapproximate the fascial edges. Limitations of this approach occur when the fascial defect is too large to allow for a tension-free repair. There is alack of data with long-term outcomes as the poor results have deterred its clinical application [32, 59, 60].

22.3.2 Mesh Repair

The advent of mesh utilization in all types of hernias precipitated the application of mesh in augmenting the primary repair of PSH. Polypropylene, expanded polytetrafluoroethylene, and biologic meshes are available. Surgical techniques for placement of mesh include fascial onlay, intraperitoneal mesh, and preperitoneal mesh placement; no significant differences in PSH recurrence were observed for one type of repair over another. However, when compared to primary repair without mesh, rates of PSH recurrence are lower in mesh repairs [48, 51, 61–71]. In fact, one study by Janson et al. suggest the prophylactic use of mesh in sublay position during open stoma creation to reduce the rate of PSH from 50% to 10% [71].

22.3.3 Intraperitoneal Mesh Repair

The two primary techniques for intraperitoneal mesh repair of PSH are Sugarbaker and Keyhole.

The Sugarbaker technique was first documented in 1980 [72] and consists of fixation of the mesh on 3 sides in a flap-valve fashion with the conduit traversing laterally between the mesh and abdominal wall with at least 5 cm overlap. This lateralizes the otherwise ventral forces of the bowel, specifically the conduit, against the abdominal wall. The sharp angle of bowel flexion initially raised concern for bowel obstruction but that has since been disproved.

Rosin first described the keyhole technique in 1977, where a circular piece of mesh is fashioned cutting a slit through the mesh to create the inner circular "keyhole" [73]. The mesh is placed circumferentially around the conduit and tacked to the abdominal wall, with bowel passing through the center of the mesh. The challenge with this technique is sizing of the keyhole. A key hole that is too small will cause a bowel obstruction, and one that is too large will increase risk of recurrence. This technique is shown to be a less effective approach to repair owing to insufficient coverage of the edges of the abdominal wall immediately surrounding the stoma, where PSH's tend to recur [60].

In a meta-analysis of 15 articles with 469 patients, DeAsis reported a 10.2% recurrence rate of PSH for the laparoscopic Sugarbaker technique vs 27.9% for the keyhole technique [74].

Other modified versions of these techniques have been reported, however there is insufficient large-scale data supporting these approaches.

22.3.4 Stoma Relocation

Stoma relocation is typically reserved for patients with permanent ostomies or those that require continued diversion where stoma reversal is not an option. Generally, relocation involves new stoma creation mirroring the current one on the contralateral abdomen. When comparing short-term outcomes of primary and mesh repair, recurrence after re-siting the stoma was lower than that of primary suture repair, but higher than mesh repair [3, 60, 75]. Specifically, the recurrence rate following stoma site relocation is 24–40% [76]. This corresponds with the risk of PSH formation after initial stoma creation. Subsequent relocations will raise the likelihood of recurrence upwards of 70% [3]. When the relocation site is on the ipsilateral abdominal wall, the risk of PSH recurrence increases to 80–86% [77]. While in the short-term, re-siting the stoma appears to have improved outcomes when compared to primary fascial repair, long-term outcomes appear to be similarly high for both.

22.3.5 Stoma Reversal

Reversal of the stoma is the most ideal method for repairing a PSH, however not all patients are candidates. It is generally perceived to be a safe procedure with minimal complications but is not entirely risk free from developing subsequent incisional hernia [78, 79]. Recent studies have reported an incidence of stoma-site incisional hernias (SSIH) to be 30–35% after primary repair without mesh [80–82]. Maggiori found that the incidence of SSIH decreased substantially with the use of prophylactic biologic mesh at the time of stoma reversal when compared to no mesh(3% vs 19%, p = 0.43) [83]. Synthetic mesh is generally avoided during ostomy reversal due to the risk of contamination [84, 85].

22.4 Preoperative Evaluation and Patient Selection

When evaluating patients with PSH, it is important to consider if ostomy reversal is an option. Ostomy take down is favored over PHR due to the significant rates of PSH recurrence after repair. Reversal and reestablishment of enteric continuity converts the PSH into an incisional hernia. When compared to PHR, repair of stoma site incisional hernias are associated with lower rate of hernia recurrence and improved long-term outcomes [86–89].

If the patient is not a candidate for ostomy reversal, prior surgical history (operative reports when available) and CT scans should be obtained to determine whether laparoscopic approach to PSH repair is an option. Patient-specific factors and comorbidities should be thoroughly reviewed and optimized where possible. Laparoscopy should be avoided in patients that cannot tolerate increased intraabdominal pressures from pneumoperitoneum or general anesthesia.

When urgent or emergent surgical intervention are not required, patients are encouraged to achieve adequate weight loss to BMI <35, abstain from tobacco use for a minimum of 6 weeks, and improve HbA1c levels if indicated prior to undergoing repair.

Hernia specific factors including size of fascial defect, location of hernia, and type of stoma involved in the repair should be addressed. Generally speaking, patients are considered for laparoscopic approach to PSH if the following criteria are met: fascial defect is less than 7 cm, prior surgical history does not complicate nor preclude minimally invasive approach, and concurrent hernias are amenable to laparoscopic repair if present.

Aside from patient and hernia specific factors, there are circumstances that require special consideration. Fascial defects larger than 10 cm make laparoscopic repair more difficult but is not an absolute contraindication and thus surgeon skill would need to be factored. Prior operations including previous mesh placement may complicate a laparoscopic approach. Additionally, larger hernia sacs in setting of small fascial defects may prove too cumbersome to repair laparoscopically and is associated with higher rates of conversion to open surgery. In setting of incarcerated hernias, there is risk of bowel injury when attempting to reduce the incarcerated viscera and a higher likelihood of converting to open. Significant abdominal wall defects from prior traumatic injuries, concurrent large ventral hernias, or prior abdominal wall reconstruction with flap creation or component release could make it impossible to re-approximate fascial defects laparoscopically. The presence of any of these situations complicates but does not signify absolute contraindication to laparoscopy. However, depending on surgeon expertise, experience, and comfortability, open approach should be considered [90].

22.5 Surgical Technique

This section outlines our method for a laparoscopic PHR of the fascial defect with composite mesh in Sugarbaker configuration with placement of intraperitoneal mesh. Our approach has been laparoscopic, but recently transitioned to robotic for the advantages it provides. However, this description can be used with either technique. The photos shown in this chapter are adopted from a robotic approach to the procedure.

Variations of technical practice exist depending on surgeon experience, type of mesh determined by facility inventory, and mesh configuration, thus modifications should be made where necessary for optimizing patient safety and surgeon comfort.

Routine preoperative evaluation is performed and the patient is brought back to the operative suite and transferred to the operating bed in supine position. Perioperative antibiotics are administered, sequential compression devices are placed. General endotracheal anesthesia is induced, and an orogastric tube and foley catheter are placed for gastric and bladder decompression. If a difficult dissection is anticipated, the ostomy can be catheterized to facilitate intraperitoneal identification of the conduit. Use surgical clippers to remove hair from entire abdomen; midaxillary line to midaxillary line, subxyphoid to pubis.

Both arms are tucked ensuring adequate padding of elbows and other pressure points. The abdomen is prepped and draped in standard fashion. Alternative options include covering the abdomen with Ioban or similar iodine impregnated adhesive surgical drape, taking care to protect the stoma with surgical gauze. Once prepped and draped, it is important to evaluate the abdomen for trocar placement to achieve optimal triangulation of the stoma.

Typically, the contralateral abdomen is accessed via Veress needle technique followed by intraabdominal insufflation and trocar placement under direct visualization. Two additional working ports are placed, triangulating the ostomy. An initial assessment of the peritoneal cavity with the laparoscope is performed. When present, adhesions and omentum fixed to anterior abdominal wall are cleared. Adhesiolysis should be performed according to surgeon preference; bluntly, sharply with laparoscopic scissors, and/or with electrocautery with care to avoid thermal injury to the viscera.

Once the PSH is identified and isolated, the contents of the hernia are reduced carefully with atraumatic graspers, taking care to preserve the blood supply to the ostomy. External downward pressure on the abdominal wall can be a helpful adjunct for difficult to reduce PSHs. Additional lysis of adhesions is often required to isolate the intestinal ostomy conduit from the herniated contents and for full mobilization of the conduit. In more severe cases, it is not uncommon to encounter a hindrance to distinguishing the primary bowel segment from the hernia sac. If anticipated preoperatively, catheterization of the stoma aids in identification of conduit when separating interloop bowel adhesions. Typically, intraoperative endoscopy of the stoma is used to aid in delineation if needed.

Dissection of the conduit is complete once it has been isolated from hernia sac, fully mobilized away from fascial edges, all interloop adhesions are taken down, and a single segment of bowel is seen exiting through the abdominal wall (Figure 22.1a). At this point, a ruler is used intraabdominally to measure the fascial defect.

A slowly absorbing monofilament—barbed or non-barbed—is used to close the fascial defect in sequential, interrupted figure-of-eight fashion creating a "shoelace" configuration. This primary repair is performed medial to lateral, and lateral to the

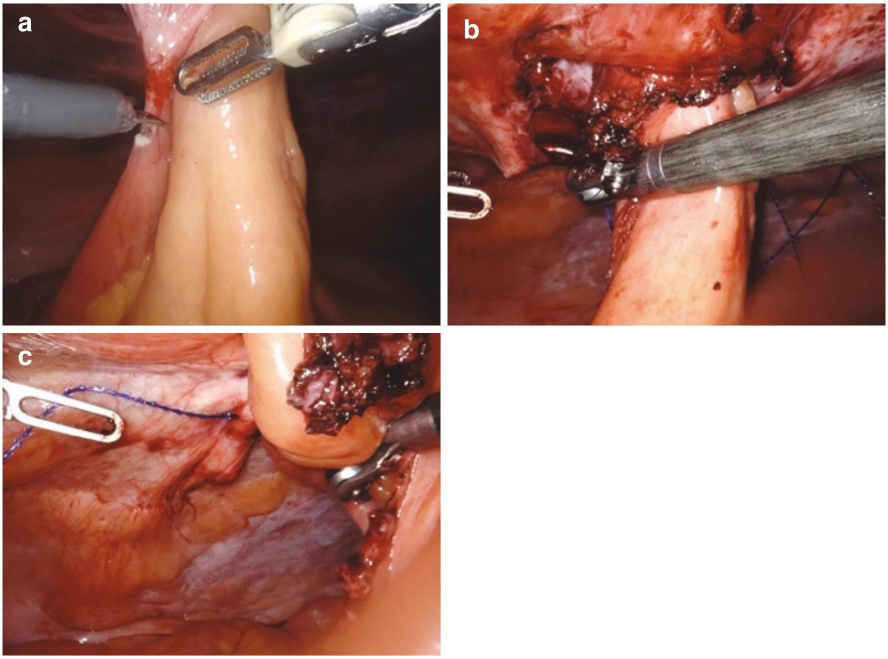

Fig. 22.1 (**a**) Enterolysis with reduction of hernia contents. (**b**) Close fascia to approximate colostomy and reduce dead space. (**c**) After repair of fascial defect

stomaso there is adequate lateralization of the stoma conduit when the mesh is implanted (Figure 22.1b). It is crucial to ensure that remaining fascial opening is neither too tight, causing strangulation nor too loose, which would potentiate recurrence of PSH (Figure 22.1c).

The lateralized bowel is then cradled up against the abdominal wall and an intracorporeal ruler is used to determine mesh size, accounting for at least 5 cm of overlap of the closed fascial defect. While we routinely use biologic mesh for PHR, the type of mesh utilized depends on institutional availability and surgeon preference. The mesh of choice is prepared on the back table on a sterile towel. A fresh marking pen is used to mark out the borders of the mesh according to the measurements obtained. Mayo scissors are used to cut the mesh at desired dimensions and the mesh is then rolled up and is passed through a trocar into the peritoneal cavity. With laparoscopic graspers, the mesh is unrolled and laid out flat, holding it up to the defect to ensure adequate overlap of the defect, stoma, and lateralized bowel. Following standard Sugarbaker technique, flex the conduit to allow for it to traverse laterally between the mesh and abdominal wall, covering the defect entirely. Desufflate the abdomen to 10–12 mmHg. This minimizes wrinkling of the mesh that can occur if it is sutured in place on full insufflation and then desufflated fully. Using 0 Prolene sutures on a laparoscopic needle driver or suture passer, place four anchoring stitches in each corner (Figure 22.2a**)**. Next, suture along the three edges

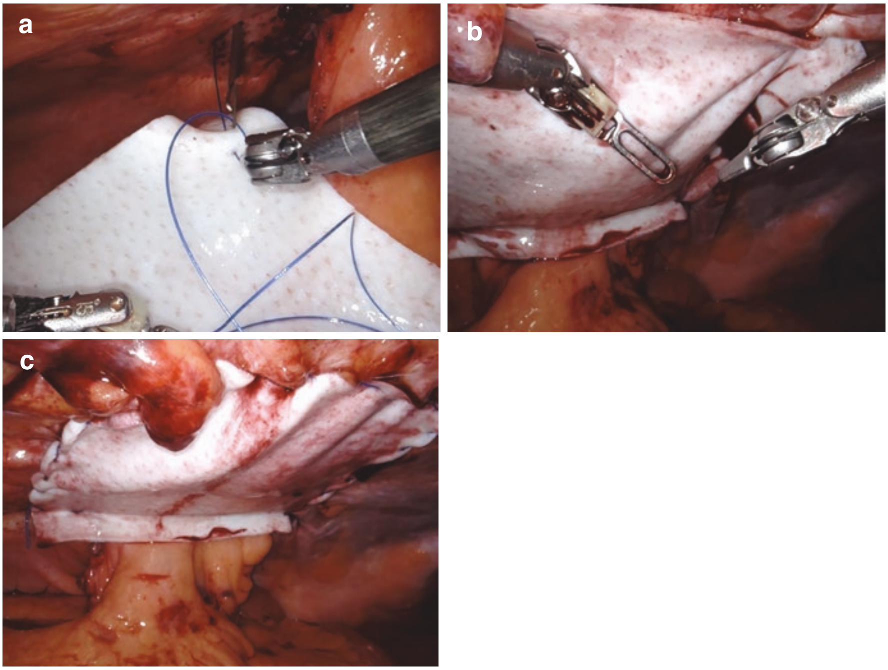

Fig. 22.2 (**a**) Fixation of mesh using a suture passer. (**b**) Continued underlay of mesh over ostomy fascial defect. (**c**) Final appearance showing stoma conduit traversing laterally between mesh and anterior abdominal wall

of the mesh to fix it in place using a nonabsorbable 2-0 V-loc in running fashion (Figure 22.2b). We do not suture the final edge of the mesh containing the conduit in order to avoid sharp angulation of the bowel as it exits the stoma (Figure 22.2c).

Using the laparoscope, perform bilateral transabdominal preperitoneal blocks for optimal postoperative pain control. Evaluate the surgical site for hemostasis. Slowly release insufflation and assess bowel orientation with mesentery medially, bowel laterally. Once completely desufflated, remove trocars under direct visualization. Close all incisions with absorbable suture in subcuticular fashion and apply skin glue.

Evaluate the stoma postoperatively to ensure viability, then place ostomy appliance. We recommend placing an abdominal binder with a hole cut at the location of the ostomy to provide external compression and stability in the immediate postoperative period.

The orogastric tube is removed, patient is awakened from anesthesia, extubated, and transferred to the post-anesthesia care unit (PACU).

22.6 Postoperative Management and Follow Up

Postoperatively, patients are admitted to the hospital for pain control and to monitor return of bowel function. A clear liquid diet is started and advanced as tolerated and as ostomy output resumes. Initiate a multimodal pain regimen immediately with scheduled acetaminophen, methocarbamol, gabapentin, and as needed narcotics. Diet is advanced as tolerated and according to ostomy function. Consult wound ostomy care nurses to evaluate for possible adjustments in ostomy supplies as the contour of the abdominal wall may have changed with the repair.

The patient can be discharged once the patient is tolerating a regular diet, ostomy function has resumed, and pain is controlled with oral medications. Prior to discharge, a discussion is held with patients and any family if present regarding expectations. The use of scheduled non-narcotic medications such as acetaminophen for pain control is stressed, emphasizing that narcotics are used for breakthrough pain control and should only be taken as needed. Counseling patients on activity limitations is imperative. Our restrictions include cardiovascular activity restricted to walking and stair climbing for two weeks, with a maximum lifting weight of 15 pounds for at least six weeks. It is advised that while showering is okay, submerging should be avoided for at least 2 weeks or until the incisions are completely healed.

Follow up appointments should be scheduled for 2–3 weeks postoperatively. A subjective assessment is performed as well as a thorough physical exam assessing surgical site for evidence of poor wound healing, hematomas, seromas, or hernia recurrence. In the case of symptomatic postoperative hematoma or seroma, the patients should be reassured of eventual dissolution over time and be monitored more frequently until complete resolution. We recommend against percutaneous aspiration or drain placement into postoperative fluid collections as this carries significant risk for mesh infection potentially requiring explantation unless greater than 3 months out from surgery. A CT scan should be obtained to evaluate patients with persistent seroma or hematoma as well as in the setting of suspected PSH recurrence. Further follow up is provided where indicated.

22.7 Conclusions

PSHs are the most common and nearly inevitable complication following ostomy creation and a multitude of surgical repair techniques have been described. As with any elective surgery, all patients should be medically and clinically optimized pre-operatively. Laparoscopic approach to the Sugarbaker technique for repair of PSH is safe and efficacious for management of symptomatic PSH. Laparoscopic approach to repair is preferred over open repair due to lower wound and mesh infection rates [91, 92]. When compared to primary suture repair, mesh repair substantially reduces the risk of PSH recurrence [17, 32, 59] (suture repair confers and odds ratio of 8.9, $P < 0.0001$ for recurrence) [60]. Stoma relocation has also been proven to be inferior to mesh repairs [3, 60, 71, 75–77]. Parastomal hernias repaired in accordance with the Sugarbaker technique are associated with a greater reduction in recurrence (OR 2.3, $P = 0.016$) [60].

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Part V
Colorectal

Chapter 23
Laparoscopic Ileocolic Resection

Aimal Khan and Alessandro Fichera

23.1 Introduction

Crohn's disease is a chronic inflammatory condition which can involve any part of the alimentary tract from mouth to anus. The most common site of involvement is the terminal ileum making ileocolic resection the most commonly performed surgery for these patients [1]. Introduction of biologics and immune modulators have drastically changed the management of Crohn's disease over the past three decades. Surgery, however, continues to be pivotal in management of patients with medical refractory and complicated Crohn's disease. Up to 70% of these patients will require surgery at some point in time in their lifetime [2].

Laparoscopic ileocolectomy has been shown to be a safe and effective alternative to open resection with comparable short and long term outcomes [3]. Laparoscopic approach also benefits patients with a shorter length of stay, decreased rates of surgical site infection, and faster return of bowel function [4–7]. Moreover, hospital costs associated with laparoscopic ileocolectomy are significantly lower than open resection [7].

23.2 Clinical Presentation

The most common indication for surgery in Crohn's disease is failure of medical management. Specifically the inability of medical therapy to control the symptoms, excessive side effects of the medications or recurrence of symptoms when trying to

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wean off aggressive medical therapy. For terminal ileal Crohn's disease strictures and perforating disease with intraabdominal sepsis are two additional indications. We present a case of limited terminal ileal Crohn's disease that failed medical management.

23.3 Preoperative Planning

It is vital to have a thorough understanding of the patient's condition and wishes prior to attempting any surgery for Crohn's disease. Important factors to consider include: the patient's clinical course and compliance with medical therapy, disease location, available imaging, current medications, co-morbidities, nutritional status, and mental health. There should a clear understanding of goals of surgery, as surgery for Crohn's is not curative and can only help alleviate symptoms. The need for a possible diverting stoma should be discussed with the patient beforehand, and preoperative consultation with an ostomy nurse should be obtained preoperatively when indicated.

All patients undergoing colorectal surgery at our institution are enrolled in an enhanced recovery after surgery (ERAS) program prior to surgery. Key components of this program include; minimizing IV fluids, avoiding narcotic pain medications, early feeding, and frequent mobilization. In addition, we routinely use mechanical and oral antibiotic bowel prep for all colectomies. The antibiotic portion of the bowel prep includes two doses of oral metronidazole and neomycin that are to be taken at 3 pm and 11 pm the day before surgery.

Patients are advised to keep hydrated while taking the bowel prep and are allowed to have clear liquids up to two hours prior to the surgery. Prophylactic subcutaneous heparin or lovenox is administered prior to administration of anesthesia. Prophylactic IV antibiotics are administered within one hour prior to incision.

23.4 Surgical Technique

23.4.1 Patient Positioning and Operating Room Setup

The patient is placed in a modified lithotomy position after induction of anesthesia (Fig. 23.1). A Foley catheter is inserted, and the sequential compression devices are checked to be properly positioned and working. For efficiency, the Foley catheter is usually inserted while transverses abdominus plane (TAP) blocks are being administered by anesthesia. The patient's arms are tucked using the draw sheet the patient is laying on, and a safety strap is placed around the patient's chest to secure them to the bed. If needed, the patient's abdominal hair is trimmed using a standard OR clipper. The main monitors is positioned over the patient's right side and a second

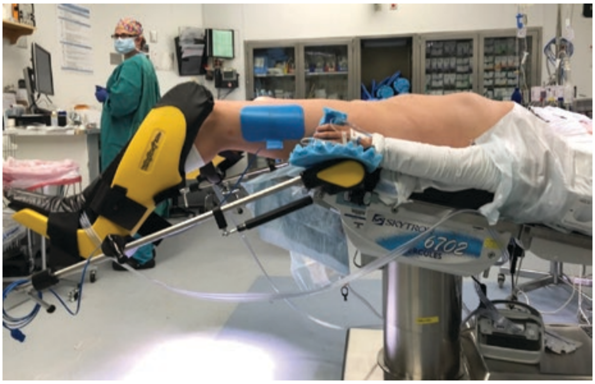

Fig. 23.1 Patient positioning. Patient in lithotomy and Trendelenburg position. Arms secured, legs flexed at the knee

Fig. 23.2 Position of the surgeon, assistants, and monitors, relative to the patient

monitor is positioned over the patient's left side just above their shoulder. A third monitor, if available, is placed on the patient's right side by their legs (Fig. 23.2).

Troubleshooting: In a difficult ileocolectomy, the surgeon or the assistant can stand between patient legs which can help decrease the ergonomic burden of surgery.

23.4.2 *Trocar Placement*

Access to the abdomen is gained using the Hasson technique at the infraumbilical location. A 12 mm portis inserted at this site and the abdomen is insufflated to 15 mm Hg. A 5 mm port is placed in the left upper quadrant which is followed by the placement of an additional 5 mm port in line with the infraumbilical port on the left side of the abdomen. All ports are placed at least 10 cm away from each other to allow for triangulation during surgery. This port configuration allows us to

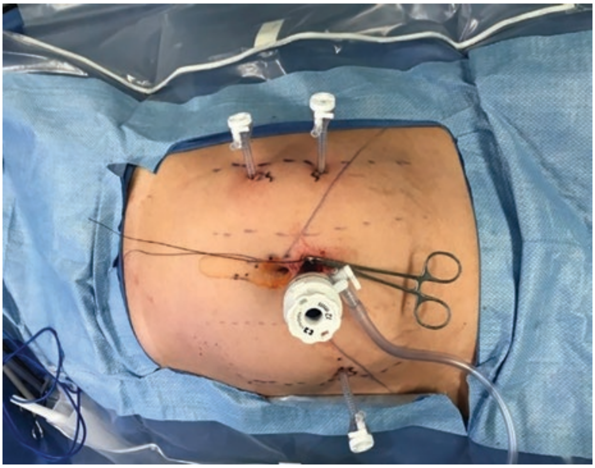

Fig. 23.3 Trocar placement. The head of the patient is on the left

operate in the right upper and lower quadrants of the abdomen. A fourth5mm port is placed on the right side of the abdomen in line with the left infraumbilical port; this port is mainly used by the assistant to help with retraction. The final port configuration shown in Fig. 23.3.

Troubleshooting: In order to gain access to the abdomen, it is recommended that surgeons utilize whichever technique they are comfortable with and have another technique available as back up. Backup option in our practice involves Optiview at Palmer's point. In case of extensive disease involvement of the ascending colon when a formal right hemicolectomy is indicated a fifth 5 mm port is placed in the right upper quadrant in line with the left upper quadrant port site. This port is used to facilitate mobilization of the hepatic flexure.

23.4.3 Intraabdominal Inspection and Positioning Bowel

With the patient in 10–15 degrees Trendelenburg, the surgery is started by inspection of all four quadrants of the abdomen. Using atraumatic graspers, the greater omentum is flipped over the stomach exposing the transverse colon, mesocolonas well as the small bowel underneath it. The extent of ileal disease is assessed, as well as any surrounding bowel or structures that may be involved are examined. The ileocolic junction is identified, and the small bowel is inspected in its entirety. The small bowel is then gently positioned on the left side of the abdomen. This may require tilting the patients left side down by a few degrees. These maneuvers help expose the right mesocolon, duodenum, and ileal mesentery. The final position of the bowel prior to starting any dissection is depicted in Fig. 23.4.

Troubleshooting: It is common to have adhesions between the greater omentum and the right colon or mesocolon. In these, we recommend lysing these adhesions

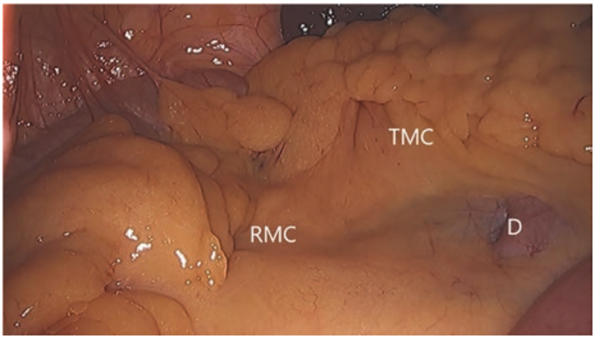

Fig. 23.4 Bowel setup prior to dissection. D-Duodenum, RMC-Right mesocolon, TMC-Transverse mesocolon

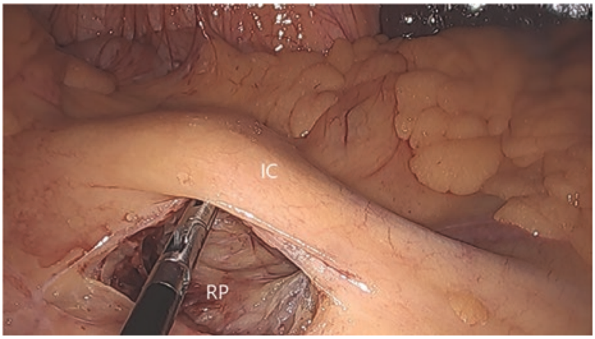

Fig. 23.5 Medial to lateral mobilization. IC-Ileocolic vessels, RP-Retroperitoneum

and then flipping the greater omentum as it helps with restoring normal anatomy before starting dissection. It is important to have an unobstructed view of the duodenum and origin of the ileocolic vascular pedicle.

23.4.4 Medial to Lateral Mobilization

Using a locking grasper through the assistant port, the cecum is retracted caudally and laterally. This maneuver helps in in identifying the ileocolic vessels by putting them under tension and creates a shiny sulcus underneath these vessels. The visceral peritoneum overlying this sulcus is divided using a bipolar energy device and the avascular plane between the Gerotas fascia and the right mesocolon is entered as shown in Fig. 23.5. Blunt dissection is then carried out as laterally and medially as possible.

Troubleshooting: In patients with severe inflammation, the mesentery is often thickened and friable. In these case a more proximal dissection and transection of the vessels may be indicated. Furthermore the retroperitoneal avascular plane can be difficult to identify especially when dealing with a psoas abscess. One can prepare for this by using lighting stents though the efficacy of these in preventing ureteric injuries has yet to be demonstrated.

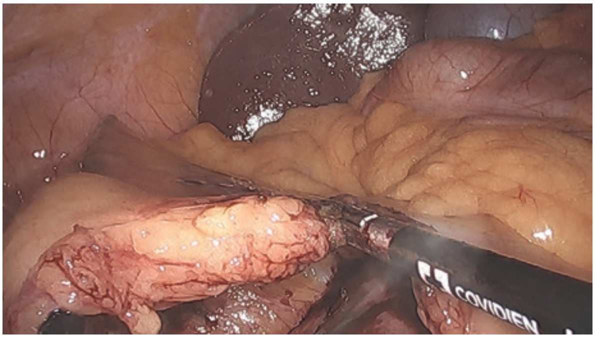

Fig. 23.6 Ileocolic artery and vein division

23.4.5 Division of the Ileocolic Vessels

Initially when developing the retroperitoneal plane, we keep the ileocolic vessels as they provide necessary traction in keeping the mesocolon tented up. When a safe dissection cannot be carried out any further, we divide the ileocolic vessels first by skeletonizing them and then dividing them with bipolar energy device. It is imperative to ensure that the duodenum has been separated from the right mesocolon prior to division of ileocolic vessels to avoid any thermal injuries to it during this step (Fig. 23.6).

Troubleshooting: Although we routinely do not look for the right ureter, in cases with severe inflammation and distortion of normal anatomy without a good plane, it is good practice to make sure the ureter has not been inadvertently lifted prior to division of the ileocolic vessels.

23.4.6 Continue Dissection and Dividing the Right Colic Vessels

With the ileocolic vessels divided further dissection can usually be carried out in the retroperitoneal plane. Lateral and superior dissection planes are extended up to the abdominal wall and hepatic flexure respectively. The mesocolon is further dissected off the duodenum and head of the pancreas, as shown in Fig. 23.7. The right colic artery, if present, is divided and the mesocolon is divided up to the intended site of transection on the colon. For isolated ileocolic disease the hepatic flexure does not need to be routinely mobilized.

Troubleshooting: The right colic artery can arise separately from the superior mesenteric artery, or as branch of the ileocolic artery.

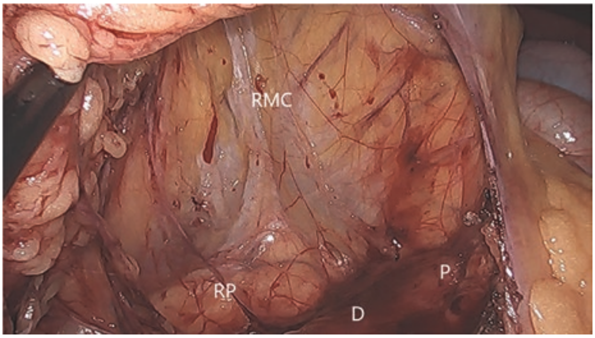

Fig. 23.7 Blunt dissection of the duodenum from the mesocolon. D-Duodenum. P-Pancreas, RMC-Right mesocolon, RP-Retroperitoneum

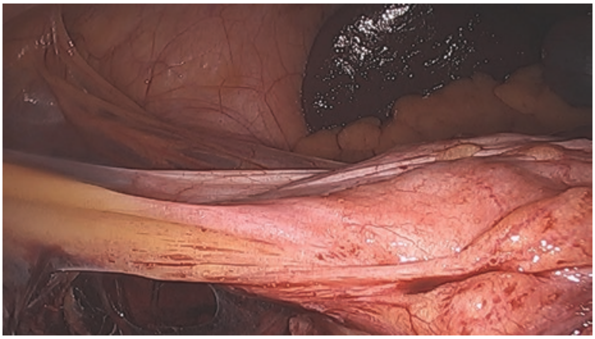

Fig. 23.8 Mobilization along white line of Toldt

23.4.7 Mobilization of Hepatic Flexure and White Line of Toldt

When a full mobilization of the hepatic flexure is indicated, the Trendelenburg tilt is removed, and patient is placed supine or in moderated reversed Trendelenburg. The transverse colon is retracted inferiorly and the gastrocolic ligament is divided medial to laterally. Next, the hepatic flexure of the colon is retracted medially and inferiorly, exposing the visceral peritoneum connecting liver to the right colon. This area will usually have purplish hue as a result of the dissection from the inferior aspect. The hepatic flexure is mobilized with a bipolar energy device upto the white line of Toldt. The right colon is retracted medially, the white line of Toldt is opened up and the two areas of dissection are joined (Fig. 23.8).

Troubleshooting: Mobilization of the white line of Toldt may be easier using the assistant port on the right side with the bipolar device.

23.4.8 Exteriorization of Specimen

Once the specimen has been completely mobilized, a locking grasper is placed on the specimen and the abdomen is de-sufflated. An appropriately sized midline incision is made, and a wound protector is placed. The specimen is then carefully exteriorized avoiding excessive pulling. Once successfully exteriorized, all the ports are removed, and all sites are inspected for any signs of bleeding. The small bowel can also be exteriorized up to duodenojejunal flexure for inspection if needed.

Troubleshooting: It is imperative to have adequate dissection prior to attempting exteriorization, as this can lead to excessive tension on mesenteric vessels resulting in usually difficult to control bleeding.

23.4.9 Resection and Anastomosis

The large and small bowel are assessed to determine the point of transection, which is usually 1–2 cm beyond the palpable thickened bowel. Both large and small bowel are divided using a linear GIA stapler. Restoration of intestinal continuity is based on patient related factors (nutritional status, comorbidities, and medical therapy) and intraoperative findings (presence contamination, dilated bowel, blood loss, length of surgery). Patients should have an understanding of what to expect before the surgery. If a decision is made to restore intestinal continuity, this can be done using either handsewn or stapled anastomosis. In our practice we routinely perform a two-layer hand-sewn wide lumen anastomosis as we believe that the size of the lumen has a major impact on surgical recurrence in Crohn's disease. Halstedian principles of good blood supply and zero tension should be observed when creating the anastomosis.

23.4.10 Abdominal Closure

The bowel is returned to abdominal cavity after completion of anastomosis. If present, the omentum is used to drape over the anastomosis for added security. The abdominal cavity is then inspected for any signs bleeding. Once satisfied with hemostasis, the wound protector is removed, and the midline fascia is closed using an absorbable suture (0-vircyl) in interrupted fashion. The wound is then irrigated, and the skin is closed with a 4–0 Monocryl in subcuticular fashion (Fig. 23.9).

Troubleshooting: We routinely do not irrigate the abdominal cavity or leave intraabdominal drains. Only in cases with contamination irrigation is performed.

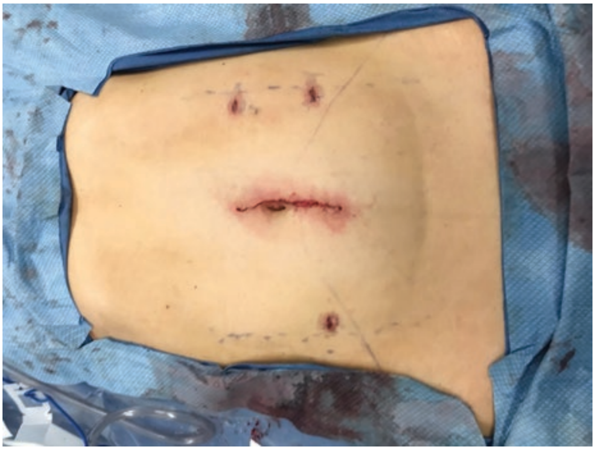

Fig. 23.9 Closed incisions

23.5 Postoperative Care

Post-operative management is carried out adhering to principles of ERAS. Unless indicated, the Foley and orogastric tube are removed at the end of surgery. Patients are started on clear liquid diet the day of surgery and advanced to a regular diet as tolerated. Multimodal analgesia consisting of IV and PO acetaminophen, celecoxib and gabapentin are used with the goal minimizing narcotics. IV fluids are stopped on postoperative day one as long as the patient is tolerating a diet.

Patients are encouraged to ambulate starting the day of surgery and are expected to walk around the hallway multiple times every day. Most patients are discharged within 48–72 hours and are instructed to avoid excessive activities for the next two weeks.

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Chapter 24
Robotic Right Colectomy with Complete Mesocolic Excision and Intracorporeal Anastomosis

Ajaratu Keshinro, Fadwa Ali, and Martin R. Weiser

24.1 Introduction

Minimally invasive colon cancer surgery has become standard and is associated with less postoperative pain, reduced length of stay and faster return of bowel function, leading to faster recovery, all without compromising the oncologic outcome [1–3]. With recent advancements in technology, robotic surgery offers superior visualization, a stable camera platform, and improved ergonomics and dexterity [1, 4]. Consequently, surgeons can overcome the technical limitations often encountered with laparoscopy.

A benefit with robotic right colon resection is the relative ease of performing complete mesocolic excision, which has been associated with improved outcomes [5–7]. Complete mesocolic excision ensures an anatomic dissection and complete lymphadenectomy.Although the current standard is to evaluate a minimum of 12 lymph nodes for adequate staging, recent data shows that local disease recurrence is reduced with a higher lymph node yield, even in node-negative disease [6–10]. Complete mesocolic excision consists of central vascular ligation and resection of the entire mesocolon by dissecting between the embryological planes and preserving the overlying visceral peritoneum [5, 6, 10]. In the medial approach, the ileocolic vessels are dissected along the superior mesenteric vein (SMV), with the dissection continued cephalad until the middle colic vessels are exposed at the origin. It is crucial that the right colon mesentery and the retro peritoneum are separated without violating the visceral fascia, with the endpoint at the confluence of the colic veins with the gastro-pancreatico-colic trunk [11]. The challenges of lymph node dissection around the vascular variability of right colon and intraoperative complication risks experienced laparoscopically are reduced robotically, improving the safety of the procedure [5, 6].

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24.1.1 Indications

The indications for robotic right colectomy include pathology between the ileocecal valve and the proximal transverse colon. These include malignant disease such as adenocarcinoma or carcinoid tumor of the appendix, cecum, or right colon. In addition, a patient who has undergone endoscopic resection of a malignant polyp may require a formal colectomy if the margins are positive or if high-risk features such as lymphvascular invasion, poor differentiation, or invasion beyond the sub mucosal layer are present [1, 3].

24.1.2 Preoperative Evaluation

A complete diagnostic evaluation includes a full history and physical examination, laboratory workup, full colonoscopy and radiographic imaging prior to surgical intervention. Colonoscopy is important for tissue diagnosis and evaluation of the entire colon for other pathology, including synchronous lesions. Radiographic imaging consists of computed tomography (CT) of the chest, abdomen and pelvis with oral and intravenous contrast for staging of regional nodal and distant disease prior to intervention. Further evaluation of significant abnormalities detected on CT can be done with magnetic resonance imaging or positron emission tomography. If colonoscopy is not completed preoperatively, alternatives include CT colonography or colonoscopy 3 months after surgery or after completion of adjuvant chemotherapy. Finally, a patient with multiple comorbidities or of advanced age requires medical consultation for preoperative risk stratification and medical optimization [3].

Starting in the preoperative stage, patients are enrolled in the enhanced recovery after surgery (ERAS) program, which reduces the overall morbidity rate and length of stay. The preoperative component includes patient education regarding anticipated postoperative milestones, a mechanical bowel preparation including a clear liquid diet and polyethylene glycol combined with oral antibiotics the day prior to surgery, carbohydrate loading 4 h before anesthesia induction, multimodal pain management including transverse abdominis plane block, and starting alvimopan (a gut-specific μ-opioid receptor antagonist that expedites return of bowel function) [3, 12–14]. Other preoperative components of ERAS are the administration of systemic antibiotics prior to incision and prophylaxis for venous thromboembolism [3, 13, 14]. Intraoperative aspects of ERAS include maintaining euvolemia, normothermia, and glucose control and administering prophylaxis against postoperative nausea.

24.2 Surgical Technique

24.2.1 Patient Position

Once under general anesthesia, the patient is secured in a supine position over a positioning pad system that has anti-slip properties, with both arms tucked at the sides. Straps around the chest and lower extremities may be needed to support the patient in a tilted Trendelenburg position.

The da Vincirobotic system includes the robotic cart, the vision cart, and the surgeon's console. The robotic cart is placed on the patient's right side, with the bedside assistant and scrub technician on the patient's left (Fig. 24.1).

24.2.2 Port Placement

Pneumoperitoneum can be achieved via insertion of the Veress needle at Palmer's point. Alternatives include Optiview or Hasson's technique, depending on the surgeon's preference. Five ports are used: four 8-mm robotic working ports and one5-mmaccessory port for the bedside assistant and insufflation (Fig. 24.2). After port placement and prior to docking of the robot, the patient is placed in a Trendelenburg position with a 10- to 12-degree left-sided tilt. After initial inspection of the peritoneal cavity, the omentum and transverse colon are retracted cephalad over the liver with laparoscopic instruments, and the small bowel is retracted to the left to expose the ileocolic pedicle. The pairing of the robotic arms and the instruments is as follows: arm 1,ProGrasp forceps; arm 2,fenestrated bipolar forceps; arm 3,0-degree robotic camera; arm 4,monopolar cautery scissor or vessel sealer. For intracorporeal anastomosis, a 12-mm port (arm 4) is used in the left upper quadrant for robotic stapling. The needle driver can also be paired with arm 4 as needed for intracorporeal suturing. The assistant port is useful for introducing laparoscopic instruments for additional retraction or suturing and for suctioning/irrigation as needed.

Troubleshooting: Quick evaluation consisting of localizing the pathology and exposing the right colonic mesentery during the initial laparoscopy facilitates optimal positioning prior to docking the robot.

24.2.3 Dissection Along the Superior Mesenteric Vein

A medial-to-lateral approach is utilized. The terminal ileum and cecum are retracted to the right lower quadrant with arm 1, which elevates and places the ileocolicpedicle on tension. Using a laparoscopic bowel grasper, the assistant retracts the transverse colon cephalad, which elevates the middle colic pedicle and exposes the SMV

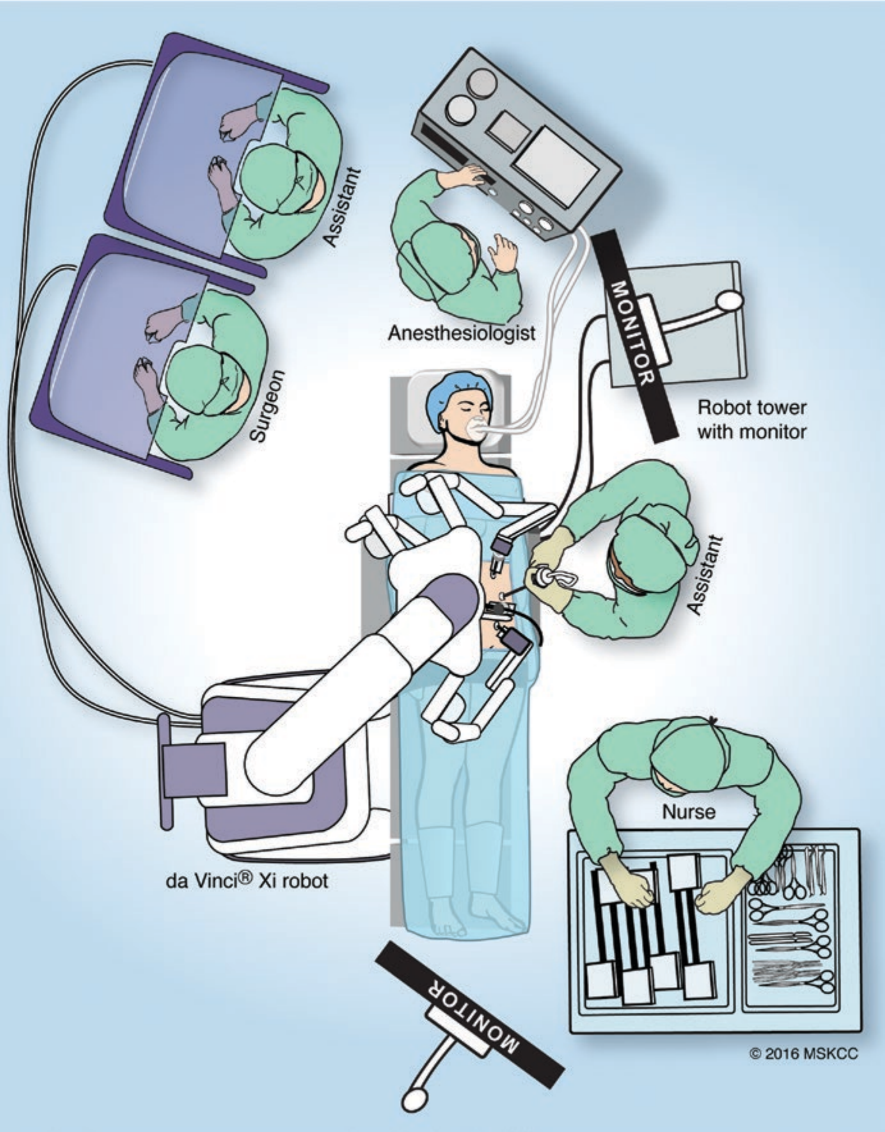

Fig. 24.1 Configuration of the operating room

(Fig. 24.3a). With the fenestrated bipolar grasper in arm 2 and the bipolar scissor in arm 4, the peritoneum overlying the SMV is incised. The fibrofatty, lymph node-bearing tissue (D3 lymph nodes) is reflected medially off the SMV and resected enbloc with the specimen (Fig. 24.3b). The peritoneum below the ileocolic pedicle is incised, and the submesenteric dissection is initiated in the avascular plane just below the level of the duodenum (Fig. 24.3c).

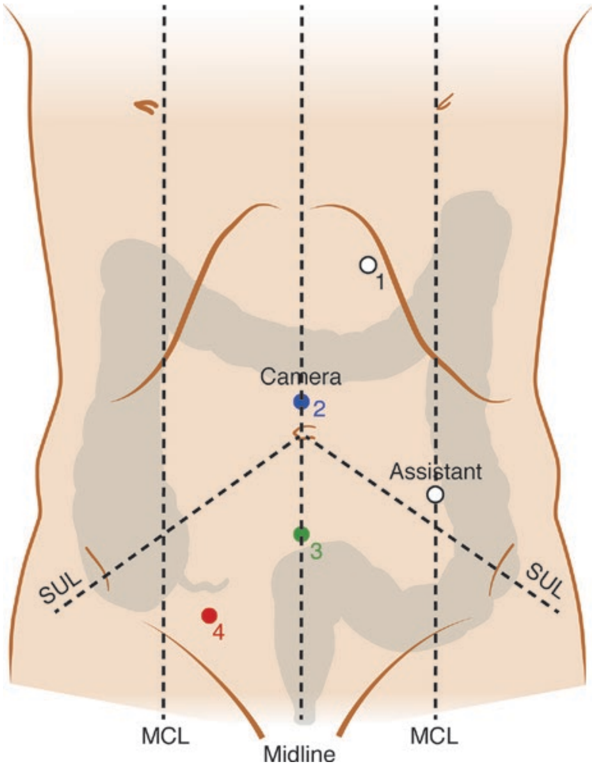

Fig. 24.2 Port placement. MCL, midclavicular line; SUL, spine-umbilical line

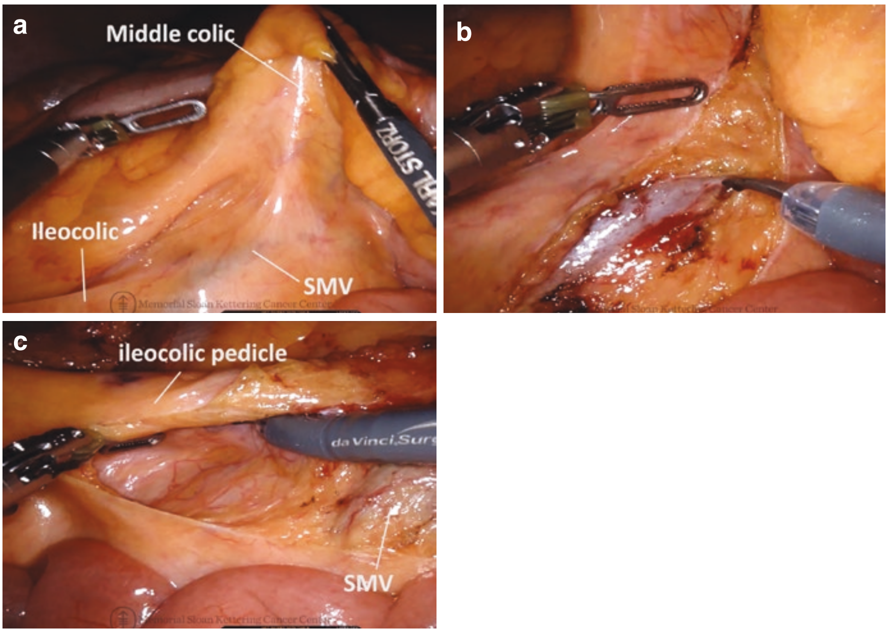

Fig. 24.3 Dissection along the superior mesenteric vein (SMV). (**a**) SMV exposure; (**b**) incision of peritoneum overlying the SMV; (**c**) submesenteric dissection

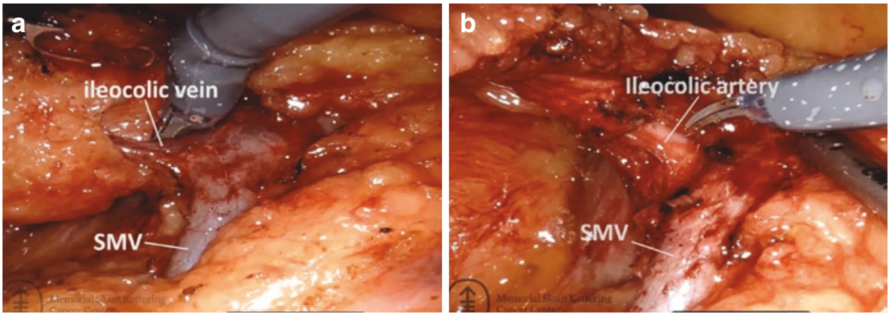

Fig. 24.4 Division of the ileocolic pedicle. The origin of the ileocolic vein and artery at the level of the superior mesenteric vein is indicated (**a**) ileocolic vein originating from the SMV (**b**) ileocolic artery

24.2.4 Division of the Ileocolic Pedicle

Once the right-colon mesentery is dissected off the duodenum, the vascular pedicles are addressed. The ileocolic vein and artery are taken at their origin at the level of the SMV (Fig. 24.4).

Troubleshooting: The ileocolic vein often runs anterior to the ileocolic artery. Variations in the position of the ileocolic artery and vein exist. Review of the vascular anatomy in the preoperative CT scan can aid intraoperative planning.

24.2.5 Dissection of the Middle Colic Pedicle

The mesenteric dissection is continued superiorly to identify the main middle colic pedicle at its origin. The right branch of the middle colic artery is ligated and divided using the vessel sealer (Fig. 24.5a). The middle colic vein is identified and ligated with the vessel sealer as well (Fig. 24.5b). Submesenteric dissection continues, with visualization and maintenance of the duodenum, head of pancreas, Gerota's fascia, gonadal vessels, and ureter in the retroperitoneal position (Fig. 24.5c). The dissection continues laterally, using the bipolar forceps to provide counter-tension until the abdominal wall is reached.

Troubleshooting: The presence of a right colic artery as an independent branch from the superior mesenteric artery is an infrequent variant and occurs in about 10% of patients [15]. If present, the artery often heads toward the ascending colon. It can be taken at its origin using the vessel sealer device.

24.2.6 Mobilization of the Transverse Colon

Next, the omentum is dissected off the transverse colon with entry into the lesser sac (Fig. 24.6a). The omentum attached to the proximal transverse colon is generally divided outside the gastroepiploic arcade. With the transverse colon placed on

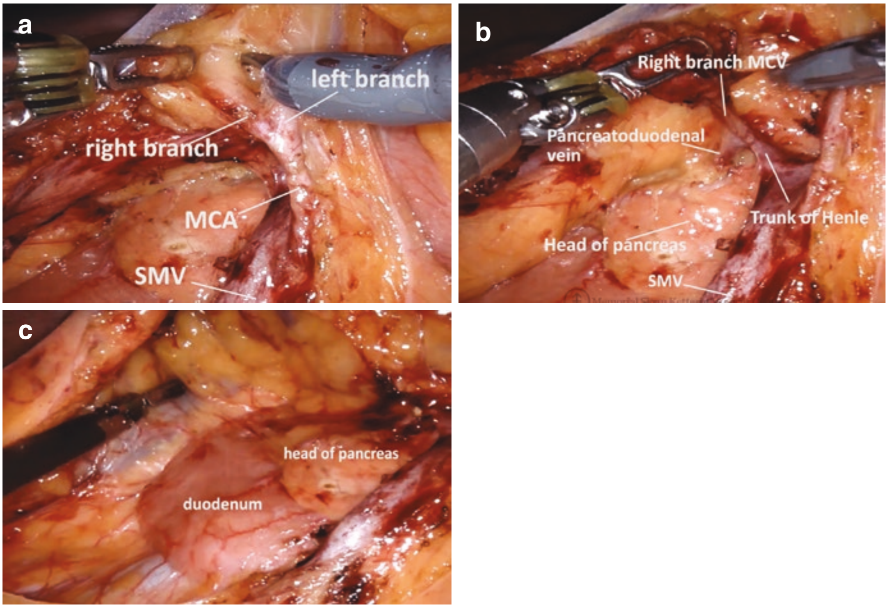

Fig. 24.5 Dissection of the middle colic pedicle. The right branches of the middle colic artery (MCA) (**a**) and middle colic vein (MCV) (**b**) are identified, and key structures are maintained in retroperitoneal position with the mesocolon ventrally (**c**). Right branch MCV is the right superior colic vein emanating from the trunk of Henle. SMV, superior mesenteric vein

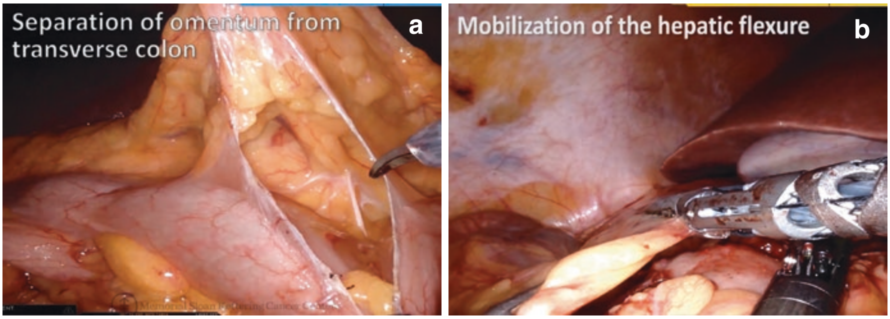

Fig. 24.6 Mobilization of transverse colon. (**a**) Dissection of omentum off the transverse colon; (**b**) mobilization of the hepatic flexure

caudal tension, omental attachments and the hepatic flexure are divided in a medial-to-lateral fashion (Fig. 24.6b). This dissection is facilitated by previous submesenteric dissection. The cecum, appendix, and terminal ileum are mobilized by dividing the peritoneal attachments in the right lower quadrant. The small bowel mesentery is freed to the level of the duodenum. Finally, the terminal ileum mesentery is divided to the bowel wall.

24.2.7 Intracorporeal Anastomosis

The terminal ileum and transverse colon are divided using the robotic Sure Form 60-mm stapler. An isoperistaltic side-to-side anastomosis is created with alignment of the distal terminal ileum medial and adjacent to the transverse colon. To ensure antimesenteric orientation, an enterotomy and a colotomy are created at the distal aspect of the ileum (Fig. 24.7a). The jaw of the robotic stapler is first inserted into the small bowel, which is then brought over to the colon (Fig. 24.7b). The stapler is deployed, and the common enterotomy/colotomy is closed with intracorporeal suture in two layers: an inner layer with running Ethibond suture and an outer layer with interrupted Vicryl suture in a Lembert fashion (Fig. 24.7c, d).

Troubleshooting: When performing an intracorporeal anastomosis, it is important to ensure that the staple line is antimesenteric by properly aligning the small bowel and colon. The common enterotomy/colotomy is sewn from the inferior edge and then from the superior edge. The sutures are tied in the middle.

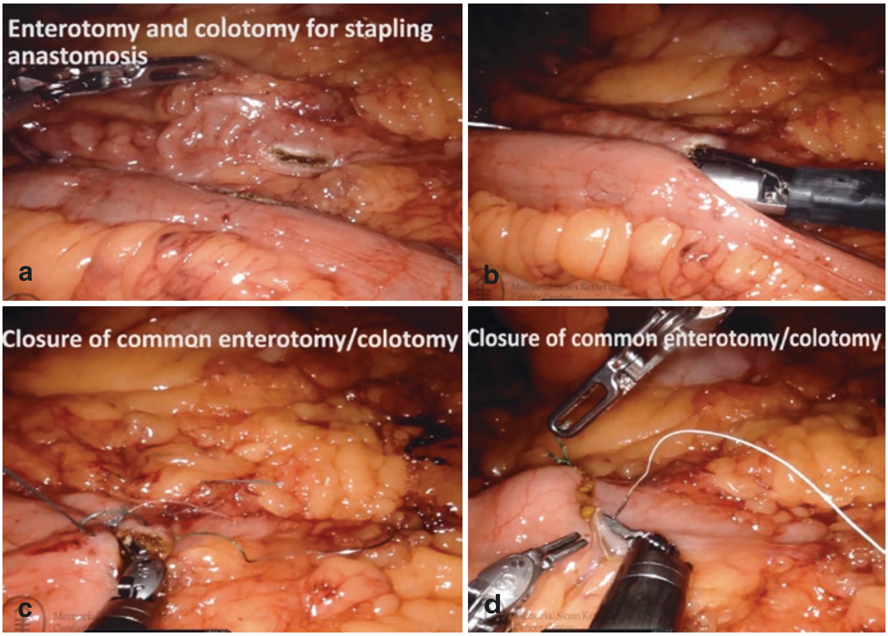

Fig. 24.7 Intracorporeal anastomosis. (**a**) Creation of enterotomy and colotomy; (**b**) insertion of the robotic stapler; (**c** and **d**) closure of the common channel in two layers with Ethibond and Vicryl, respectively

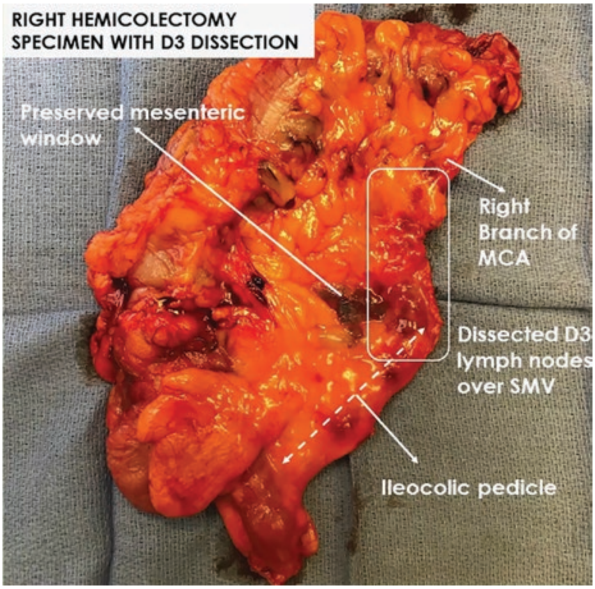

Fig. 24.8 Specimen from a complete mesocolic excision. MCA, middle colic artery; SMV, superior mesenteric vein

24.2.8 Specimen Extraction and Closure

The fascia of the 12-mm port is closed using a Carter-Thomason port closure system. A Pfannenstiel or an upper midline incision is created for specimen extraction over a wound protector. The ports are removed. Fascia is closed. A sample specimen of the right colon after complete mesocolic excision is shown in Fig. 24.8.

24.3 Postoperative Course

Postoperative management is a continuation of the ERAS program, with early oral feeding and mobilization, optimization of nonnarcotic pain medications, and early removal of the urinary catheter. Patients are fed a clear liquid diet and ambulate on postoperative day 0.Then the diet is advanced to regular on postoperative day 1. Prophylaxis for venous thromboembolism is continued in the postoperative period unless it is contraindicated. Patients are discharged home once diet is tolerated and bowel function is resumed, usually on postoperative day 2 or 3 [3, 13].

The overall 30-day complication rate after a robotic right colectomy is similar to that seen with laparoscopic colectomy ~~20–25%~~.Most of the complications are Clavien-Dindo grade I or II, and prolonged ileus and surgical site infection are the most common. Anastomotic leak occurs in 1–2% of patients and can be managed with bowel rest and antibiotics, as well as percutaneous drainage or diversion when the leak is clinically significant [6, 7, 16].

24.4 Conclusion

Robotic right colectomy is a proven safe and feasible technique, with outcomes equivalent to those of laparoscopy. The robotic approach simplifies complex surgical steps such as intracorporeal anastomosis and complete mesocolic excision, lowers the rate of conversion to open surgery, and achieves a complete surgical resection with optimal lymph node harvest.

Disclosure The authors have no conflict of interest.

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Chapter 25
Laparoscopic Left Colectomy

Nicolás H. Dreifuss, Francisco Schlottmann, Jose M. Piatti, and Nicolas A. Rothotlz

25.1 Introduction

The first laparoscopic and laparoscopic-assisted colon surgery were reported in 1991 [1, 2]. Since then, the laparoscopic approach has been successfully used for a wide variety of colonic diseases. Colon cancer is the fourth most frequently diagnosed cancer and the second leading cause of cancer death in the United States [3]. Recurrent diverticulitis affecting patient's quality of life and other benign diseases (volvulus, inflammatory bowel disease, polyps not amenable to endoscopic resection, etc.) are also common indications of laparoscopic left colectomy.

Laparoscopic colorectal surgery has rapidly evolved and is currently the gold standard approach [4]. When compared to open colectomy, laparoscopic resections have been associated with faster recovery and similar long-term outcomes [5, 6]. Deep knowledge of surgical anatomy and embryologic planes is necessary to perform a safe and effective laparoscopic left colectomy. When performed for malignancy, the goal is to completely remove the tumor with at least 5 cm of proximal and distal margins, along with the regional lymph nodes. Two main approaches for

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laparoscopic colorectal mobilization have been described: medial-to-lateral and lateral-to-medial. The 2004 European Association of Endoscopic Surgeons (EAES) consensus statement recommended the medial-to-lateral approach [7, 8].

25.2 Clinical Presentation

Patients with colorectal cancer, diverticular disease or inflammatory bowel disease can present with a wide range of signs and symptoms such as occult or overt rectal bleeding, anemia, change in bowel habits, unintentional weight loss and/or abdominal pain. However, most patients with colorectal cancer remains asymptomatic until an advance stage of the disease is reached. New onset of gastrointestinal bleeding often requires a prompt endoscopic evaluation.

25.3 Preoperative Evaluation

All patients who are candidates for a laparoscopic left colectomy should undergo a preoperative evaluation that include the following: (1) colonoscopy, (2) computed tomography (CT) scan, and (3) laboratory tests.

25.3.1 Colonoscopy

A complete colonic mucosal inspection after optimal bowel preparation is key before any laparoscopic colectomy. Colonoscopy allows the visualization of tumors, synchronic lesions, stenosis, diverticula and/or subtle mucosal lesions. Biopsies can also be obtained for preoperative histologic characterization. In addition, endoscopic ink tattooing of the tumor helps to localize the lesion during the operation. Patients undergoing colectomy for diverticular disease should also have an endoscopic evaluation to confirm the diagnosis and rule out malignancy.

25.3.2 Computed Tomography

A staging contrast enhanced CT of the chest, abdomen and pelvis is mandatory before any elective left colectomy for cancer in order to rule out metastatic or advanced disease. In patients with diverticular disease, abdomen and pelvis CT scan may be useful for detecting chronic complications (stenosis or fistula) or abscesses and perforation in acute presentations.

25.3.3 Laboratory Tests

In addition to a complete blood count and coagulation profile, preoperative serum carcinoembryonic antigen (CEA) concentrations should be obtained in patients with colorectal cancer.

25.4 Surgical Technique

25.4.1 Position of the Patient

After induction of general endotracheal and spinal anesthesia the patient is positioned in modified lithotomy position with the lower extremities on Lloyd-Davis stirrups, with knees flexed 20°–30°. This position allows an adequate anal access during the procedure and operate between patient's legs if necessary. The arms are secured on the patient's side to allow maximum tilt and mobility of the surgical team. Trendelenburg's position with right side tilt is used for optimal exposure. The surgeon and the first assistant stand on the patient's right side. Patient's position can be adjusted intraoperatively at the stage of splenic flexure mobilization. Additional assistants may be placed between the legs or on the patient's left side if needed (Fig. 25.1).

25.4.2 Trocar Placement and Exposure

Four 10 mm ports are used in the procedure. The first port is placed in the mid-line about 3–4 cm above the umbilicus. It is used for the insertion of the scope for exploratory laparoscopy and then by the surgeon's left hand for the insertion of a Babcock clamp for traction. The second port is placed in the right lower quadrant and is used by the surgeon's right hand for the insertion of dissecting instruments and the stapler for distal transection. The third port is positioned at the right upper quadrant and is used for the scope (first assistant's right hand). It is important to shape a triangle between these three ports to achieve an optimal view. The fourth trocar is positioned in the left lower quadrant and is used by the first assistant's left hand to insert a Babcock clamp (Fig. 25.2). After an adequate mobilization of the omentum and small bowel, the rectosigmoid junction is exposed.

Troubleshooting: In cases of malignancy, preoperative ink tattooing of the tumor is very useful for the intraoperative localization of the lesion.

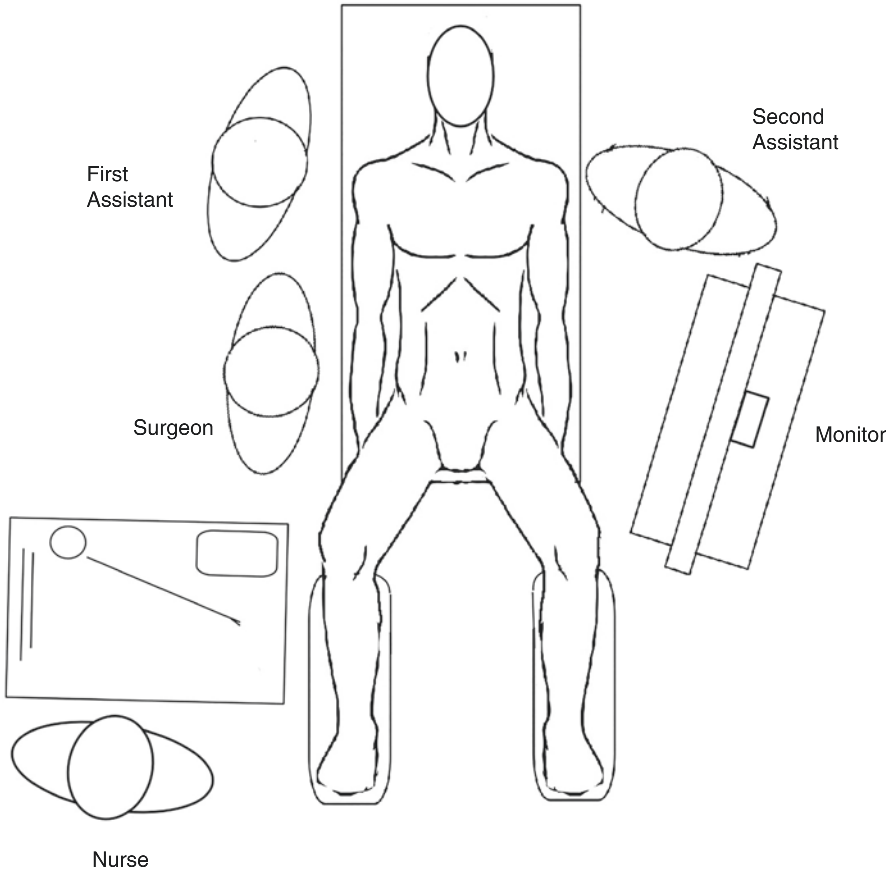

Fig. 25.1 Position of the patient and surgical team

25.4.3 Medial to Lateral Approach and Ureter Identification

Medial to lateral approach starts with mobilization of the sigmoid colon by dividing attachments to the retroperitoneum, adjacent organs, and abdominal wall. After gentle traction of the sigmoid colon towards the anterior abdominal wall, an avascular triangle between the inferior mesenteric artery (IMA), right iliac vessels and the rectumis identified (Fig. 25.3). Medial peritoneum leaf is incised following a line a few centimeters over the right iliac vessels with the harmonic scalpel. The line of fusion between the posterior aspect of the colonic mesentery and the retroperitoneum marks the line of dissection. As this is an embryologic avascular plane, this maneuver should be bloodless. The sigmoid mesentery is then easily retracted away

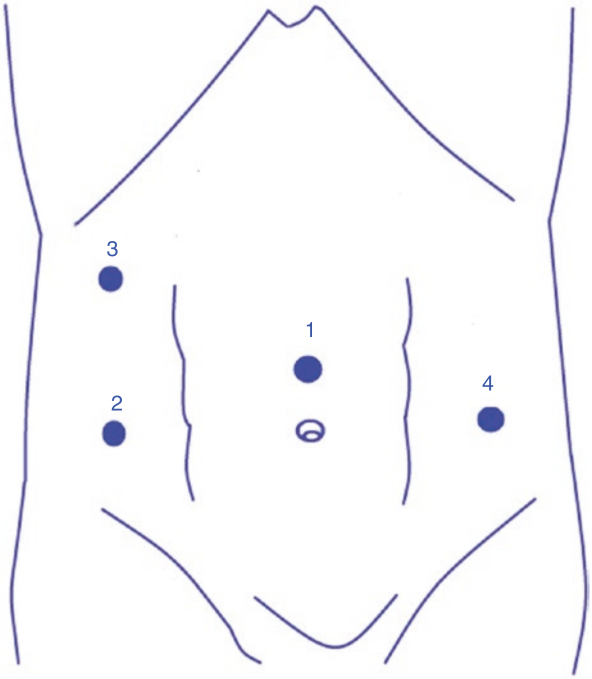

Fig. 25.2 Trocar positioning. Four 10-mm ports are used: supraumbilical (*1*), right lower quadrant (*2*), right upper quadrant (*3*), and left lower quadrant (*4*)

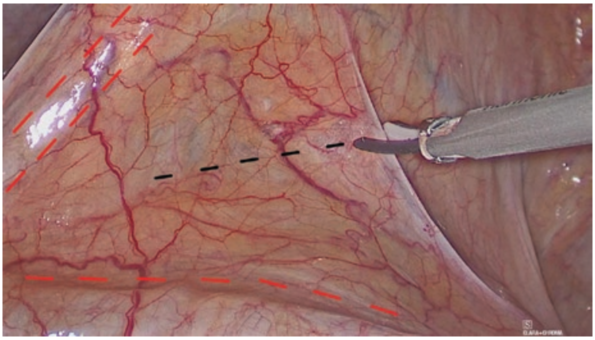

Fig. 25.3 Avascular triangle between right iliac artery (inferior *red dot lines*), inferior mesenteric artery (*left red dot lines*) and rectum. *Black dot lines* represent the peritoneal leaf incision

from the retroperitoneum creating a medial window with blunt dissection. The left ureter, left common iliac artery, gonadic vessels, and psoas muscle will be exposed and identified after this maneuver. Proper identification of the left ureter is mandatory before dividing any vascular structure (Fig. 25.4).

Troubleshooting: In cases of severe inflammation due to chronic diverticulitis or locally advanced cancer, ureteral stents may help identification of the left ureter.

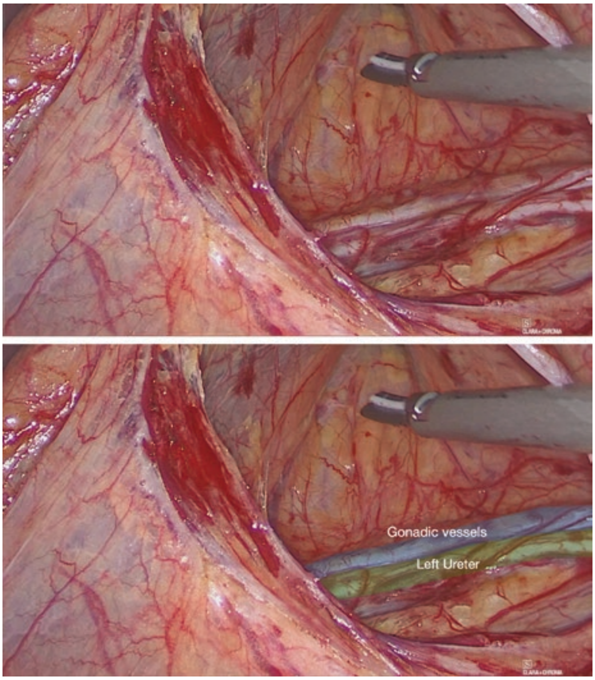

Fig. 25.4 Identification of retroperitoneal structures: ureter (*green*) and gonadic vessels (*blue*)

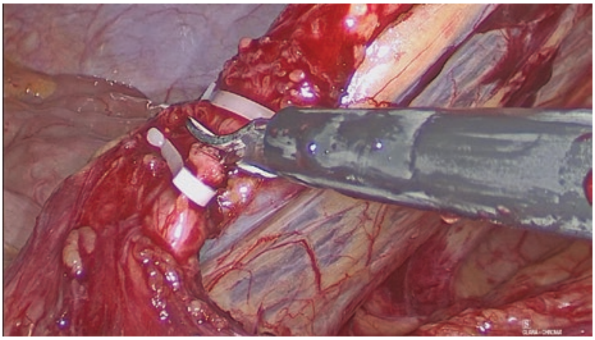

Fig. 25.5 Division of inferior mesentery artery between clips

25.4.4 Division of Mesenteric Vessels and Colonic Mobilization

Blunt dissection continues both cephalic and distal along the avascular plane between the colonic mesentery and retroperitoneum. When the IMA creates tension and does not allow to continue this maneuver, the vessel should be divided. The IMA is isolated and the angle with the aorta identified. To avoid multiple vascular ligations, the IMA is transected at its origin in both benign and malignant diseases (Fig. 25.5). Dissection continues cephalad until the ligament of Treitz and the inferior mesenteric vein (IMV) are identified (Fig. 25.6). At this point the IMV is

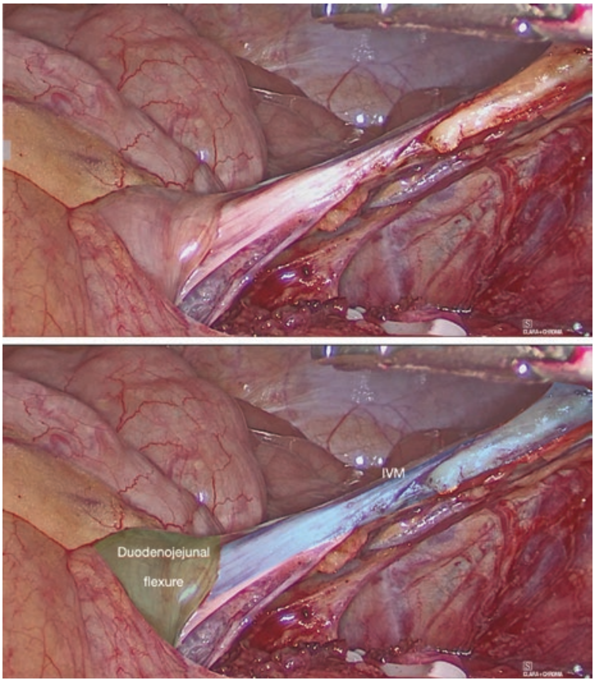

Fig. 25.6 Identification of the duodenojejunal angle (*green*) and inferior mesenteric vein (*blue*)

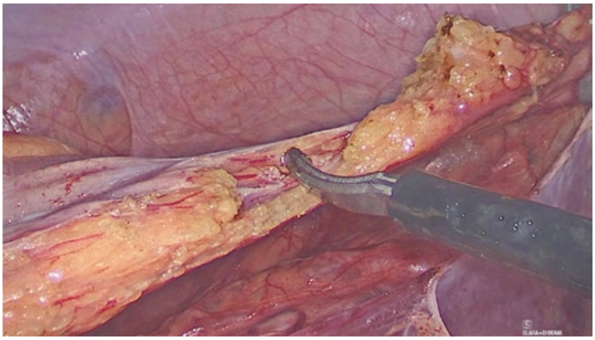

Fig. 25.7 Section of left colon's lateral peritoneal reflection

isolated, clipped and divided below the inferior margin of the pancreas. After completion of the medial dissection, lateral attachments of the colon are divided. Lateral dissection of the line of Toldt starts at the peritoneal reflection of the sigmoid colon over the left iliac vessels. The sigmoid colon is gently retracted medially, and the peritoneal reflection is incised from distal to proximal (Fig. 25.7). The medial and lateral dissection should encounter and the peritoneum is fully divided up to the splenic flexure.

Troubleshooting: Caution should be taken with the duodenojejunal flexure when clipping and dividing the inferior mesenteric vein.

25.4.5 Splenic Flexure Mobilization

Reverse Trendelenburg's position with right lateral tilt is helpful during this step. There are three approaches to accomplish the splenic flexure mobilization: medial, anterior and lateral. The combination of at least two of them is usually necessary for complete mobilization. The distal transverse colon is retracted medially and caudally. The greater curvature of the stomach is elevated and the gastrocolic ligament is exposed. The midpoint of this ligament is transected below the gastroepiploic vascular arch allowing entry into the lesser sac. The inferior border or tail of the pancreas is identified, and the remaining gastrocolic ligament is transected up to the level of the spleen´ inferior pole. Gentle caudal traction of the colon helps exposing the spleno-colic ligament and other attachments that can be safely divided with harmonic scalpel (Fig. 25.8). At this point, the left colon is fully mobilized and well vascularized by the Drummond marginal artery.

Troubleshooting: Care must be taken when dividing firm attachments to the spleen in order to avoid lacerations and major bleeding.

25.4.6 Rectal Dissection and Transection

Dissection continues to the pelvis after prolonging the peritoneal incision line caudally. The distal limit of the dissection is the sacral promontory and as no complete mesorectal excision is needed for this procedure, the level of transection will be localized in the upper rectum. The sigmoid colon is retracted towards the anterior abdominal wall to expose the recto-sigmoid junction. Medial and posterior dissection of the rectum with cauterization of superior hemorrhoidal vessels is performed. At this point, the left ureter should be identified again. Once the upper rectum is fully dissected, the linear stapler is introduced through the right lower quadrant port and the rectum is transected using one or two 60 mm green loads (Fig. 25.9).

Troubleshooting: Avoid extensive mesorectal dissection to prevent ischemia of the anastomosis.

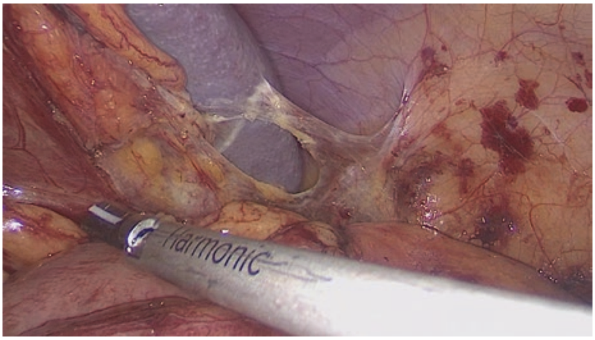

Fig. 25.8 Splenic flexure mobilization. Caudal and medial traction of the left colon helps exposing attachments to the spleen that will be divided with harmonic scalpel

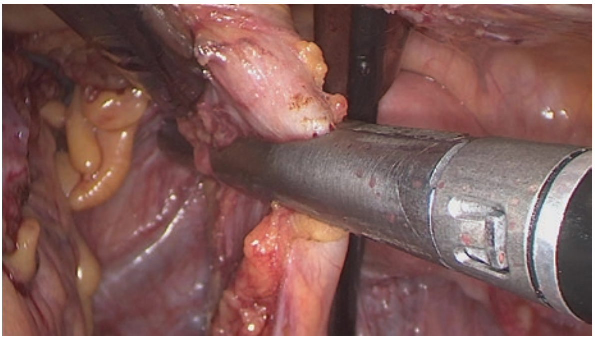

Fig. 25.9 Distal transection with a linear stapler

25.4.7 Specimen Retrieval and Colon Resection

The transected colon is grasped with the right iliac' fossa forceps. For specimen retrieval, a mini-laparotomy is performed extending the left lower quadrant trocar incision or using a C-section incision. A wound protector device should be used to avoid wound contamination and facilitate exposure. Once the mobilized colon is exteriorized, the proximal site of transection is chosen according to the tumor's location and vascularization. The proximal colon is transected and the specimen retrieved. A purse-string is performed in the proximal colon stump with 3.0 nylon suture. The anvil of a circular stapler is introduced and the purse-string is tightened. The colon is replaced into the abdominal cavity, the laparotomy is closed, and the pneumoperitoneum reestablished.

Troubleshooting: Avoid epigastric vessels injury during laparotomy. Assessment of colon vascularization with indo cyanine green (ICG)and fluorescence imaging helps choosing a safe colonic transection site.

25.4.8 Colorectal Anastomosis

The anastomosis is performed by inserting a circular stapler through de anus. The rectal stump is perforated, and after checking the correct orientation of the descended colon, the anvil is connected and the circular stapler is fired (Fig. 25.10). The stapler is removed, and the integrity of the doughnuts is inspected. Peritoneal cavity is rinsed with saline and a pneumatic air leak test is always performed.

Troubleshooting: Endoscopic inspection of the anastomosis can be helpful for detection of major bleeding or performing the air leak test. ICG fluorescence imaging can also be used to assess perfusion of the anastomosis.

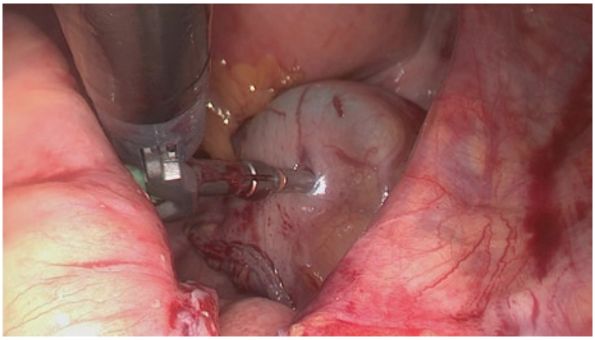

Fig. 25.10 Colorectal anastomosis with a circular stapler

25.5 Postoperative Course

Early mobilization and oral intake are encouraged. The Foley catheter is removed after 24 hours of the operation. Multimodal pain control without opioids is recommended. Patients are considered fit for hospital discharge when the following criteria are met: normal vital signs, adequate oral intake, satisfactory pain control, and ability to ambulate. Patients usually resume their regular activity within 2–3 weeks.

25.6 Conclusions

Laparoscopic left colectomy is the main treatment of left colonic malignancies and benign diseases affecting the left colon such as diverticular disease. Deep knowledge of surgical anatomy and technique is crucial to avoid troublesome side effects and obtain optimal postoperative outcomes.

Conflict of Interest The authors have no conflict of interest to declare.

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Chapter 26
Laparoscopic Low Anterior Resection

Katerina Wells

26.1 Introduction

Preoperative Planning: Multidisciplinary Evaluation and National Accreditation Program for Rectal Cancer (NAPRC).

Outcomes of the rectal cancer patient are highly dependent on the specialization, training and volume of the physicians and centers providing the care. [1, 2] In an effort to reduce variability in care and optimize patient outcomes, the National Accreditation Program for Rectal Cancer (NAPRC) was developed with the purpose of employing a multidisciplinary, evidence-based approach to guide the processes of rectal cancer care. The standards set forth by the NAPRC provide performance measures to be met along the critical steps of patient care processes and guidelines for a program structure that supports performance improvement as a way to standardize a high level of quality via real-time auditing. Ultimately the NAPRC will foster designation of rectal cancer surgery to specialized centers with experienced surgeons to ensure that surgical standards are consistently achieved [3].

26.2 Pre-operative Evaluation: Tumor Localization and Total Colon Clearance

Tumor localization prior to planned rectal resection is necessary for multiple reasons. The distance from the anal verge provides the surgeon with prognostic information about tumor behavior, option for sphincter preservation and functional expectations after resection. Localization of a rectal cancer by convention is

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described by its relationship to the anal verge. It is necessary to perform this assessment prior to initiation of neoadjuvant therapy as identification of the primary lesion after therapy is compromised in the case of significant clinical response. In anticipation of this possibility, India ink tattooing aids in localization with a low risk of associated morbidity [4]. Although different techniques can be used for tattooing, it is important to be consistent in the pattern of marking and document the method in the colonoscopy report. The authors recommend that tattooing be performed in 3 separate areas around the circumference of the lumen distal to the lesion. Intraoperative proctosigmoidoscopy can be employed when intraoperative localization measures fail.

Evaluation of the entire colon is also necessary as patients with primary colorectal cancer carry a 1–7% risk of having synchronous lesions [5]. Colonoscopy is 85% sensitive and 95% specific for the detection of malignancy and is the gold standard for evaluation of the colon [6]. In the case of obstructing tumors that prevent colonoscopic colon clearance, CT colonography (CTC) is an accurate and well tolerated method of noninvasive assessment with a sensitivity of 100% in detecting proximal synchronous cancers, specificity of 87.5% for cancers >15 mm and a negative predictive value of almost 100% [7].

26.3 Preoperative Evaluation: Local Staging with Rectal Cancer Protocol MRI

Rectal cancer protocol MRI has replaced endorectal ultrasound (ERUS) for local staging of rectal cancer. Rectal cancer protocol MRI is superior to ERUS as it allows for surgically relevant information beyond T and N stage including involvement of the circumferential resection margin (CRM) and surrounding pelvic structures that determine resectability. MRI also allows for identification of emerging oncologically prognostic features including extramural vascular invasion (EMVI) status, the presence of mucin, and tumor regression grade [8]. These radiologic findings play an important role in guiding risk stratification and perioperative therapy.

26.3.1 Technique

The principles of LAR for rectal cancer outlined by National Comprehensive Cancer Network guidelines include total mesorectal excision (TME) to address draining lymphatics and obtain adequate circumferential and distal resection margins. The surgeon must therefore be experienced in TME [9].

Minimally invasive LAR can be performed through a straight laparoscopic, hand-assisted laparoscopic, or robotic-assisted approach as there is no difference in long-term oncologic outcomes [10–17].

26.3.1.1 Technique: 1. Patient Positioning and Port Placement

The patient is placed in dorsal lithotomy to allow access to the perineum for anastomosis and assessment. Attention is placed on offloading the lateral knees and calves in stirrups to prevent decubitus injury and deep vein thrombosis. Fixation devices to prevent shifting of the body during steep Trendelenburg should be employed and tested prior to draping. A rectal preparation of betadine is performed to reduce bacterial burden at the time of rectal transection.

For a laparoscopic technique, ports are placed in a manner that allows for triangulation of the target anatomy with lateral ports placed medially enough to allow for unimpeded access of instruments over the sacral promontory. For a robotic-assisted technique, ports will vary based on the platform but should keep in mind access to the left upper quadrant for mobilization of the splenic flexure in addition to the pelvis.

A hand port or extraction port can be placed in the suprapubic, periumbilical or right lower quadrant depending on operator preference. The suprapubic position in either a midline or Pfannenstiel orientation is a versatile location as this allows access to the pelvis for dissection and anastomosisin addition to extraction of the specimen.

26.3.1.2 Technique: 2. Exploration of the Peritoneal Cavity

Upon entry into the abdomen inspection of peritoneal surface and surfaces of intraperitoneal organs is performed for identification of metastatic disease. A systematic approach by quadrants is recommended making note of the surfaces of the liver, bilateral diaphragms, the anterior peritoneal surface and the pelvis. In women, the adnexa of the uterus are inspected. It is not necessary to perform extensive dissection outside of the primary resection site for the purpose of exploration. Clinically suspicious lesions beyond the field of resection should be biopsied and/or removed, if possible; however extensive resection of M1 lymph nodes is not indicated [9].

26.3.1.3 Technique: 3. Medial to Lateral Approach

Minimally invasive LAR typically employs a medial to lateral approach and begins with identification and elevation of the superior rectal artery at the level of the sacral promontory (Fig. 26.1).

The peritoneum is incised from the sacral promontory to the origin of the IMA. Pneumoperitoneum aids in separation of the mesocolon from the retroperitoneum and this plane is further propagated byreflecting the retroperitoneum posteriorly and widening this window.

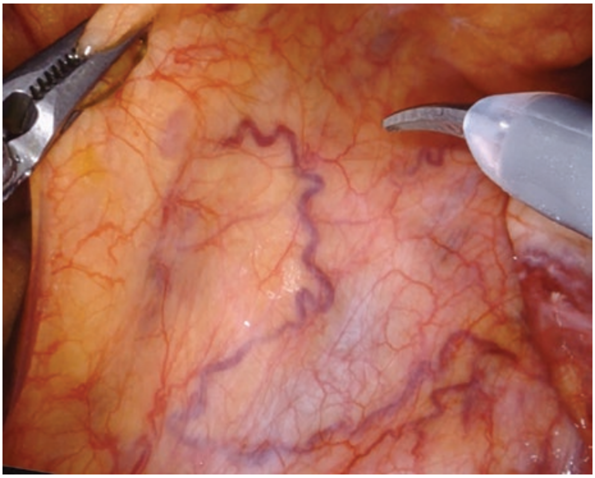


Fig. 26.1 Medial to lateral approach: elevation of the IMA

Troubleshooting: Identification of the Left Ureter

Identification of the ureter is facilitated using a three-step approach. The first step is identification in the retroperitoneum via the mesenteric window between the sacral promontory and the inferior mesenteric artery. If the ureter is not identified in this window, a mesenteric window between the IMV and IMA is created. At this level, the proximal ureter and this retroperitoneal plane is extended caudadto meet the original plane of dissection at the level of the sacral promontory. If this maneuver does not expose the ureter, a lateral to medial approach is applied. Failure to identify the ureter with this stepwise approach should prompt conversion to an open approach or placement of ureteral stents for the purpose of palpation via a hand-assisted technique at the discretion of the surgeon.

Though ureteral injury is rare, reported at 0.5–4.5% [18], placement of ureteral stents has gained popularity with the concern over loss of tactile feedback with minimally invasive techniques. Ureteral stents have been shown to aid in intraoperative identification of ureteral injuries through there is no evidence that ureteral stents reduce or prevent ureteral injury [19]. Placement of ureteral stentsare associated with slight to modest increases in total operative time. They are generally safe with no significant differences seen in postoperative urinary complications on a recent review [20]. Illuminated stents and ICG illumination are also described for intraoperative ureteral identification (Fig. 26.2).

26.3.1.4 Technique: 4. High Ligation of the IMA and IMV

Once the ureter is identified, the IMA is isolated and ligated at its origin. Care is taken to avoid division of branches of the hypogastric plexusin order to preserve sexual function. The IMV is then similarly isolated and ligated. High ligation of the primary feeding vessel ensures removal of all potential mesenteric nodal disease and maximizes lymph node harvest for pathologic assessment. There is no

Fig. 26.2 Medial to lateral approach: identification of the Ureter

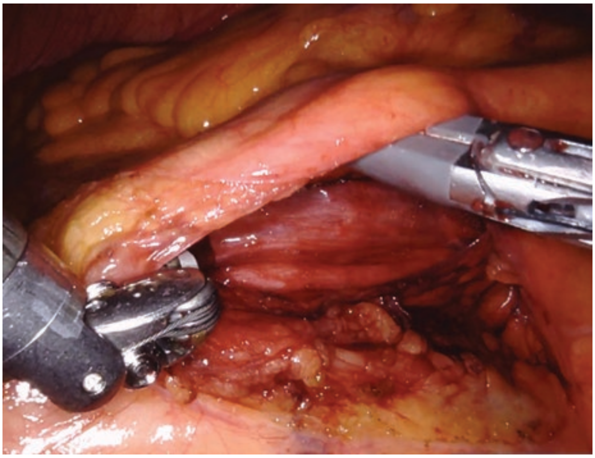
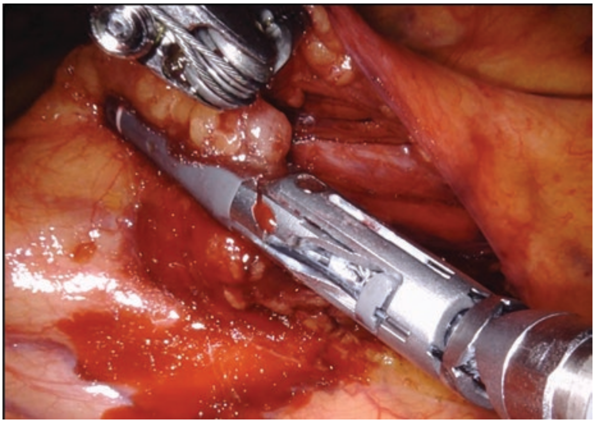


Fig. 26.3 High ligation of the IMA



difference in morbidity associated with high ligation, with the benefit of increased disease-free survival with this technique [21–23]. High ligation is also recommended to ensure optimal reach of the distal descending colon to the pelvis to allow for colorectal anastomosis. For example, division of the superior hemorrhoidal vessel will cause the descending colon mesentery to remain tethered at the left colic artery or origin of IMA. Similarly low division of the IMV will result in tethering of the proximal descending colon by splenic flexure venous branches.

Troubleshooting: Vessel Ligation

Care should be taken to avoid traction on the IMA or IMV at the time of ligation. Excessive traction can result in incomplete vessel sealing and retraction of the bleeding vessel (Fig. 26.3).

26.3.1.5 Technique: 5. Mobilization of the Splenic Flexure

Retromesocolic dissection proceeds along the inferior border of the pancreas, laterally to the white line of Toldt, and extends beyond the splenic flexure to allow for ease of mobilization of the remaining lateral attachments of the colon. Dissection of the remaining lateral attachments proceeds caudally to cranially from the pelvic inlet to the splenic flexure.

Troubleshooting: Splenic Flexure Mobilization

Splenic flexure mobilization is aided through entry into the lesser sac via the avascular attachments of the greater omentum to the mid-transverse colon. The remaining attachments along the inferior border of the pancreas are then divided completing splenic flexure mobilization. These attachments can be divided to the midline effectively freeing the transverse colon mesentery to the level of the middle colic artery.

26.3.1.6 Technique: 6. Total Mesorectal Excision (TME)

TME begins by sharply incising the areolar tissue behind the mesorectal envelope at the level of the sacral promontory. This avascular plane of loose areolar tissue is the guiding plane of dissection investing the mesorectum from the pelvic brim to the pelvic floor. Posterior dissection extends just beyond the level of intended distal margin in the case of tumor specific TME and to the level of the pelvic floor in the case of complete TME. Dissection extends into the upper anal canal if ultralow resection is needed (Fig. 26.4).

The lateral ligaments containing the middle hemorrhoidal vessels and splanchnic nerve branches are then divided. The rectum is retracted medially to aid in correct

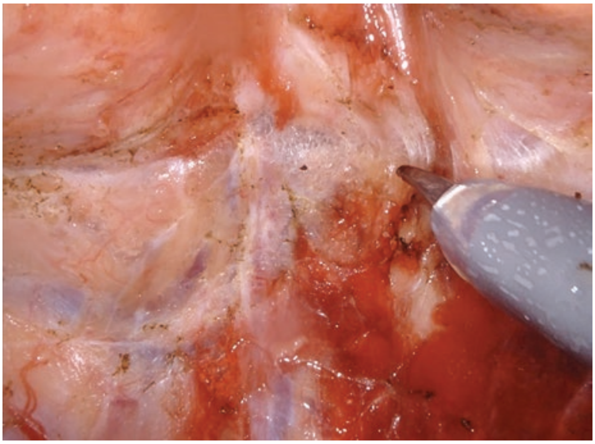


Fig. 26.4 Total Mesorectal Excision (TME): posterior dissection

identification of the plane of division and prevent dissection of pelvic plexus nerves and ureters within the lateral pelvic sidewall. Sharp or electrocautery instruments along with the magnified view of the laparoscope allows for this precise dissection (Fig. 26.5).

The anterior dissection plane is determined by the location of the tumor. For posterior tumors, Denonvillier's fascia is preserved. For anterior tumors, Denonvillier's fascia should be included in the TME to ensure a negative margin at the expense of thecavernous nerves and pelvic plexus nerves travelling to the bladder, prostate and sexual organs (Fig. 26.6).

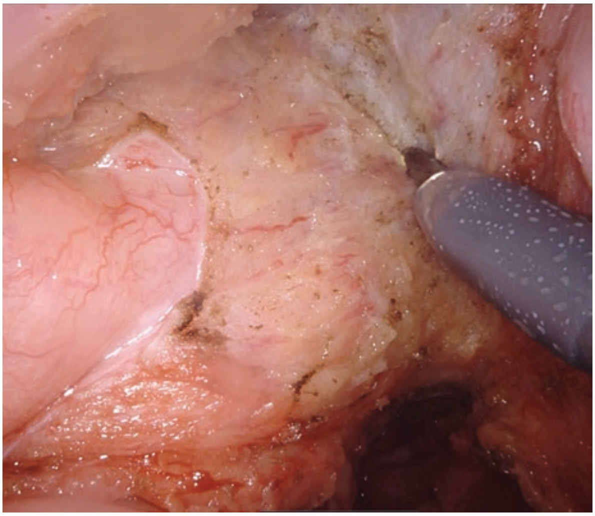


Fig. 26.5 Total Mesorectal Excision (TME): lateral dissection

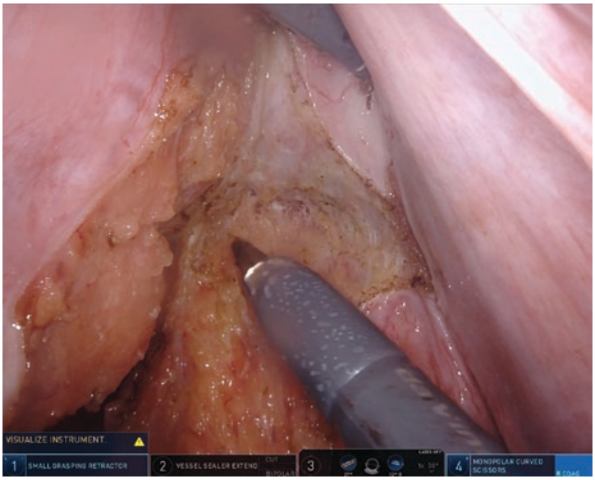


Fig. 26.6 Total Mesorectal Excision (TME): anterior dissection and preservation of Denonvillier's fascia

Troubleshooting: Presacral Bleeding

Injury to the presacral venous plexus can result in large volume hemorrhage due to the lack of valves and high hydrostatic pressure present in this system. Presacral bleeding is initially managed with direct pressure at the point of bleeding. At this time, communication to the anaesthesia provider and surgical team should be performed to prepare for potential hemorrhage. Packing of the pelvis in combination with topical hemostatic agents is usually successful in controlling small-vessel venous bleeding. Direct ligation of the bleeding vessel can be attempted for larger vessels. If this measure fails use of metallic thumbtacks have been described. Rectal muscle flap fragment welding can also be performed.

26.3.1.7 Technique: 7. Determination of the Proximal Margin

A variety of approaches are used for proximal and distal transection. This can be performed in an open-approach through the hand-port. Alternatively the distal rectum can be divided intracorporeally and the proximal colon transected upon extraction of the specimen. Alternatively resection and anastomosis can be performed entirelyintracorporeally. Ultimately the proximal point of transection should be one that that is well perfused, reaches the pelvis without tension, and satisfies a 5 cm margin from the tumor. This margin length is based on the concept that colon cancers do not typically extend longitudinally along the mucosa but grow circumferentially and extend radially along the bowel wall. Moreover, resection length is a corollary for adequate lymphadenectomy. A retrospective study by Rorvig et al. describes a 37% rate of node positivity for tumors with a < 5 cm margin vs a 51% rate of node positivity with a > 5 cm margin [24].

Troubleshooting: Assessment of Perfusion

Assessment of adequate perfusion of the proximal point of transection is typically a gross assessment of bowel wall perfusion. Perfusion can be assessed by checking for back-bleeding from the marginal artery of Drummond prior to ligation or by the presence of arterial bleeding after sharp dissection of an epiploic appendage. Indocyanine green (ICG)-induced fluorescence angiography (FA) using near infrared (NIR) light can also aid in assessment of microperfusion of the bowel wall prior to transection and after anastomosis. FA is a safe and feasible adjunct togross assessment of perfusion for left sided anastomosis [25] and is readily available on most minimally invasive platforms (Fig. 26.7a, b).

26.3.1.8 Technique: 8. Determination of the Distal Margin

The distal resection margin (DRM) is more variable as it is tailored to the specific conditions of the patient. NCCN guidelines recommend that the DRM extend

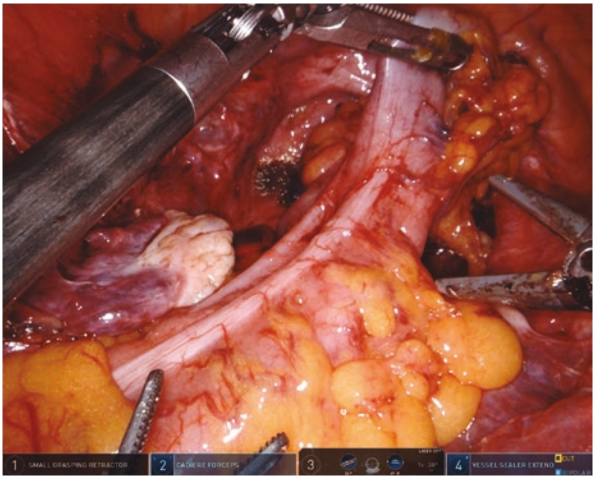


Fig. 26.7 (**a**) Determination of the proximal margin: gross assessment

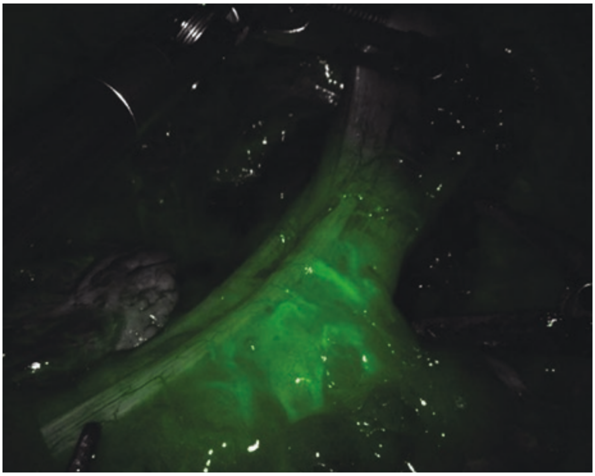


Fig. 26.7 (**b**) Determination of the proximal margin: fluorescent angiography

4–5 cm below the distal edge of the tumor for an adequate mesorectal excision. However in the case of low rectal tumors (<5 cm from the AV) several studies have demonstrated that distal tumor extension is confined within 2 cm of the primary lesion and that a DRM of 2 cm from the distal edge of the tumoris oncologically sufficient [26]. Among patients receiving preoperative chemoradiotherapy, a DRM of 1 cm andin some cases <1 cm is oncologically non-inferior and acceptable when balanced against a goal of sphincter preservation.

The mesorectum is transected perpendicular to the axis of the mesorectum without coning of the mesorectum in the vicinity of the tumor. The TME specimen is a circumferentially encased fascial envelope with a bilobed configuration of the posterior mesorectum. Complete and near complete grading of TME is considered acceptable.

26.3.1.9 Technique: 9. Colorectal Anastomosis

The double staple anastomosis technique in either an end-to-end or side-to-end coloproctostomy is most commonly performed. Creation of a colonic J pouch reservoir is also an acceptable option though more technically demanding. Each offer similar rates of postoperative morbidity and long term functional outcomes [27]. Once the proximal bowel is prepared, the EEA anvil is inserted and secured in a purse-string fashion. It is important to ensure that the mucosal edges are well everted against the anvil and no gaps occur between the bowel wall and shaft of the anvil. The EEA stapler is then inserted transanally to the level of distal transection. The spike of the EEA is deployed through the top of the distal point of transection and mated to the anvil. Attention should be directed to ensure that the proximal bowel is properly oriented and reaches without tension. The anastomosis should be inspected circumferentially to ensure that that no intervening tissue is entrapped in the staple line prior to firing.

Troubleshooting: Transanal Passage of the EEA Stapler

In the case of resistance with passage of the stapler, the rectum should be evaluated for stricture, adhesion or valves that may limit passage to the staple line. This can be performed with sequential sounding of the rectum with EEA sizers followed by proctoscopy if needed. If this is encountered, lysis of adhesion with rectal mobilization is performed to straighten the rectum and allow passage of the EEA to top of the rectal stump. In the case of stricture, the rectum should be divided below the stricture to prevent obstruction distal to the colorectal anastomosis and stasis that can occur in the redundant rectal stump (Fig. 26.8).

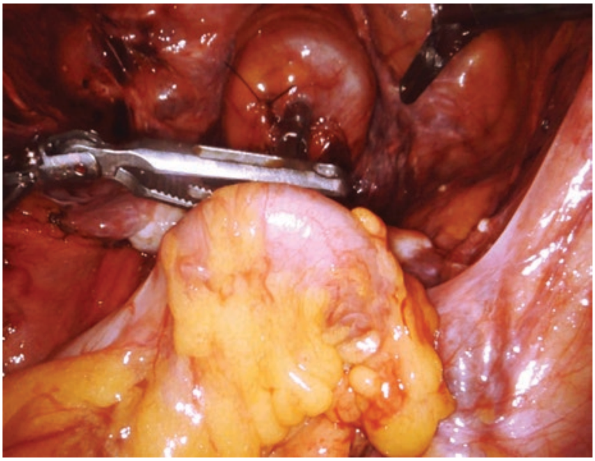


Fig. 26.8 Colorectal anastomosis: side to end intracorporeal anastomosis

26.3.1.10 Technique: 10. Anastomotic Assessment

Anastomotic assessment is performed with insufflation of the rectum under saline. Routine intraoperative sigmoidoscopy offers direct visualization of the anastomosis for bleeding and integrity. In a prospective review by Kamal et al., the finding of an endoscopic abnormality was highly correlated with a positive leak test and should prompt repair [28]. Intraluminal fluorescence angiography is also available to assess staple-line perfusion [25].

Anastomotic assessment by leak testing with or without endoscopic visualization is necessary due to the high risk of leak with coloproctostomy. In a retrospective review by Ricciardi et al. of 998 patients undergoing coloproctostomy, the overall leak rate was 4.8%. The rate of clinically evident leak rates following a positive air leak test was 7.7% compared to 3.8% following a negative air leak test. Suture repair was less effective at preventing clinically evident leaks compared to anastomotic revision or proximal diversion [29].

Troubleshooting: Positive Leak Test

If anastomotic assessment is positive for leak, an effort should be made to identify the focus of the leak. In the case of a well defined and small defect, the site of leak can be oversewn directly and should be similarly oversewnon either side of the defect. Anastomotic assessment is then repeated. If a leak persists, the anastomosis should be revised. In the case of a diffuse leak or a large defect, the anastomosis should be revised and assessment repeated. Diversion or resection with end colostomy is performed at the surgeon's discretion.

26.4 Post-operative Management: MIS LAR and ERAS

Enhanced Recovery after Surgery (ERAS) Programs work in conjunction with minimally invasive LAR to improve outcomes and is the standard of perioperative care forcolorectal surgery. Kehlet and colleagues first introduced ERAS as a "bundle" of interventions that cumulatively reduce postoperative stress, reduce recovery time, and decrease postoperative morbidity [30]. The main principles of ERAS include a minimally invasive approach, mechanical and oral antibiotic bowel preparation, low dose carbohydrate/balanced electrolyte preoperative hydration, multimodal analgesia including regional analgesia for reduction of narcotic use, and early mobilization and feeding.

26.5 Post-operative Management: Short-term Outcomes

The short-term benefits of minimally invasive LAR are clearly demonstrated including shorter hospital stay by 2 days (95% CI −3.22 to −1.10), shorter time to defecation by approximately one day (95% CI −1.17 to −0.54), fewer wound infections (OR 0.68; 95%CI 0.50 to 0.93), bleeding complications (OR 0.30; 95% CI 0.10 to 0.93) and similar 30 day morbidity (OR 0.94; 95% CI 0.8 to 1.1) compared to open resection at the expense of slightly increased operative times (MD = 37.23 minutes, 95% CI 28.88–45.57, $p < 0.0001$, 31,32). Minimally invasive resection also affords lower analgesic use, pain scores and significantly shorter incision length (MD −12.83; 95% CI −14.87 to −10.80) [31].

The cost of minimally invasive technologies, while higher in the operating room, has been shown to be lower overall, due to these reduced complications, length of stay and standardization of resource utilization [32, 33].

26.6 Long-term Outcomes

Multiple nonrandomized studies support the use of minimally invasive techniques for rectal cancer with acceptable oncologic outcomes including survival, recurrence, lymph node harvest and ability to resect locally advanced, emergently operated, obstructed tumors and in elderly and high risk patients [15, 31, 34–36]. In addition, level 1 evidence reported over the last 20 years has also solidified the oncologic efficacy of minimally invasive rectal cancer surgery with similar rates of OS, DFS and local recurrence compared to open resection with a generally low rate of conversion [10–17, 37].

26.7 Conclusion

Management of the rectal cancer patient is complex and requires expert multidisciplinary care under the guidance of the NAPRC. A standardized preoperative evaluation is key to optimize the patient for resection and offer the best possible oncologic and functional outcomes including sphincter preservation for distal lesions. In the same vein, minimally invasive LAR is a high-risk procedure best performed by an experienced surgeon. Regardless of minimally invasive technique, the goal of the operation is complete TME to reduce local recurrence. Minimally invasive surgery when paired with an Enhanced Recovery After Surgery Program improves postoperative outcomes with reduced morbidity, decreased length of stay and readmission.

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Chapter 27
Hand Assisted Total Colectomy

Sarah Stringfield and Alessandro Fichera

27.1 Introduction

A total colectomy may be performed for a variety of reasons. A common indication for total colectomy is patients with Ulcerative Colitis (UC) that have failed to respond to medical therapy, or when the side effects of medical therapy outweigh the benefits. Ulcerative Colitis also increases a patient's risk for cancer and dysplasia [1]. Either of these findings in the setting of chronic pancolitis isan indication for surgery in UC [1]. Additional indications for total colectomy can include colonic inertia, familial cancer syndromes, toxic megacolon, hemorrhage, perforation, or obstruction. In the case of patients with acute UC or in unstable patients requiring an emergent operation, an end ileostomy is given rather than performing an anastomosis. The technique of hand-assisted laparoscopic total colectomy with end ileostomy will be the focus of this chapter.

The laparoscopic approach has been shown to be safe in acute UC [2–4]. A minimally invasive approach to colectomy reduces morbidity, length of stay, readmission rates, and results in better cosmesis than an open approach [5]. A hand-assisted approach for total colectomy facilitates colonic mobilization and is associated with a reduction in operative time and rate of conversion to open when compared to straight laparoscopy, with no difference in complication rates or short-term outcomes [6–8]. Compared to the open approach, patients with severe colitis that

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undergo laparoscopic total colectomy have a faster recovery, leading to quicker progression to completion of restorative proctocolectomy [9].

27.2 Clinical Presentation

Patients with life-threatening sepsis, hemorrhage, or perforation must be taken to the operating room emergently. Patients with refractory UC should be initially resuscitated with intravenous fluids and medically optimized prior to surgery. This includes optimizing medical management of their colitis, typically with steroids and rescue therapy of infliximab or cyclosporine [10]. These patients also often have severe malnutrition that may require preoperative parenteral nutrition. Anemia is a common finding secondary to chronic disease as well as blood loss from the colon, and should be corrected with blood transfusions and/or iron infusions based on the severity. If the patient fails to respond to medical management after a time period of 3–5 days for corticosteroids or 5–7 days for other rescue therapies, then operative intervention in the form of total colectomy should be considered [10].

27.3 Preoperative Evaluation

The patient should be marked for an ileostomy by the enterostomal therapist. Preoperative marking to ensure optimal stoma location increases the ability of the patient to care for the stoma and maintain a secure seal without leakage. Improperly located stomas lead to leakage of stool, peristomal skin inflammation and excoriation, emotional stress, and increased cost [11]. Preoperative education on life with an ileostomy and caring for an ostomy can help prepare a patient mentally and alleviate concerns.

The patient undergoes mechanical bowel preparation with the addition of oral antibiotics, in our practice metronidazole and neomycin. This practice has been shown to make the colon easier to handle during surgery and decrease the incidence of surgical site infections [12]. Patients are given clear liquids the day before surgery and up to 2 hours prior to the operation.

To reduce opioid use and ileus rates, patients are started preoperatively on a multimodal pain management protocol that includes celecoxib, gabapentin, acetaminophen, and alvimopan. Intravenous broad-spectrum antibiotics are given within 1 hour of skin incision in accordance with surgical quality guidelines. Stress dosing of steroids may be required for patients that have been on chronic corticosteroid therapy. Prophylactic dosing of enoxaparin or subcutaneous heparin and sequential compression device (SCD) stockings are placed prior to induction of anesthesia to prevent venous thromboembolism.

27.4 Technique

27.4.1 Patient Positioning

The patient is placed on a self-securing pad with a chest strap to prevent slippage with changes in bed position. Following induction of general anesthesia, an orogastric tube and indwelling urinary bladder catheter are placed. The patient is placed with buttocks at the bottom of the table in a modified lithotomy position using Yellofin ® Stirrups (Allen Medical, Acton, MA) with the thighs even with the hips and knees in line with the contralateral shoulder. All pressure points are appropriately padded, ensuring no pressure on the peroneal nerves. Both arms are tucked in the adducted position. Rectal irrigation is performed and a mushroom tip catheter is left in the rectum, connected to a drainage bag. The skin is prepped with 2% chlorhexidine-based solution and the patient is draped in a standard manner. Laparoscopic monitors are placed on either side of the patient at the shoulder.

Troubleshooting: Placement in lithotomy position allows access to the rectum for irrigation and placement of the drainage tube, and also allows the surgeon or assistant to stand between the legs which is helpful when operating in the upper abdomen. Patient must be well-secured to the bed due to steep changes in position throughout the operation.

27.4.2 Port Placement

A circular incision is made at the future ileostomy site. Dissection is carried down through the subcutaneous tissue to the fascia. The fascia is freed from the subcutaneous tissue and a pursestring of 0 Vicryl suture is placed. The anterior rectus sheath is opened longitudinally, muscle fibers are retracted, and the posterior rectus sheath is opened longitudinally. A 12 mm trocar is inserted and secured in place with the pursestring. Pneumoperitoneum is established and maintained at 15 mm Hg. Two additional 5 mm trocars are placed in the umbilicus and left lower quadrant. The abdominal cavity is laparoscopically explored with a 5 mm camera at the umbilical port site, and if a laparoscopic operation appears to be feasible the hand port incision is created. A 7 cm transverse incision is made 2–3 cm superior to the pubic symphysis anddissection is carried to the fascia. The fascia is opened transversally for 7 cm, the muscle is dissected free from the anterior rectus sheath, and the midline and peritoneum are opened. A GelPort is placed (Applied Medical, Rancho Santa Margarita, CA) and pneumoperitoneum is reestablished (Fig. 27.1).

- *Troubleshooting: The open approach to placing the 12 mm trocar at the stoma site allows for safe access to the abdominal cavity using an incision that will be needed irrespective of the surgical approach. The purse-string suture must be tight enough to prevent pneumoperitoneum from escaping. We tighten the*

Fig. 27.1 Port placement

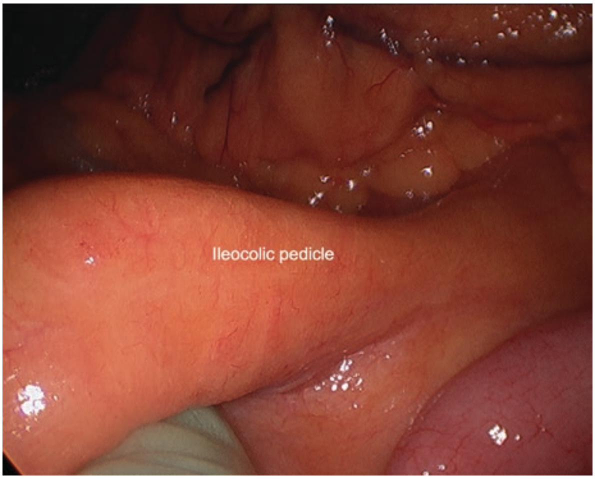

Fig. 27.2 Identification of ileocolic pedicle

pursestring to the fascia by placing a small section of red rubber catheter over the suture and pushing it down to the fascia with a hemostat in the fashion of a Rommel tourniquet.

27.4.3 Specimen Mobilization

The patient is rotated to the left and in slight Trendelenburg position.With the surgeon standing on the patient's left side with the left hand in the GelPort, right colon dissection is started in a medial to lateral fashion. The omentum is placed over the stomach into the left upper quadrant and small bowel swept to the left side. The cecum is retracted upward to the anterior abdominal wall to identify the ileocolic pedicle. The pedicle is grasped and elevated (Fig. 27.2). The avascular plane below

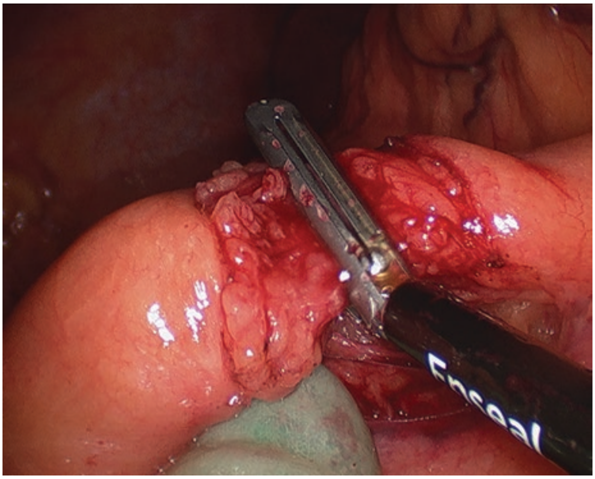

Fig. 27.3 Division of ileocolic pedicle

the vascular pedicle is incised and dissected free to allow clear visualization of the duodenum below the mesentery. The vessel is divided using a vessel-sealing device such as the Ethicon EnSeal device (Ethicon Endo-Surgery, Cincinnati, OH) (Fig. 27.3).

- *Troubleshooting: Identification of the duodenum during isolation of the ileocolic pedicle is important prior to dividing the vessels. The duodenum can be in close proximity to the ileocolic vessels and can be injured if not identified and swept downward and away from the vessels.*

Medial to lateral mobilization of the ascending colon is performedby using a posterior sweeping motion in the avascular plane to allow the mesentery and cecum to separate anteriorly from the posterior structures. The right colon should be completely mobilized from the retroperitoneum all the way out to the side wall of the abdomen using the left hand for retraction upward and a laparoscopic grasper or sealing device in the surgeon'sright hand to develop the plane. This is performed down to the cecum and up to the third portion of the duodenum and towards the hepatic flexure (Fig. 27.4). The duodenum should be separated from the overlying mesentery of the right colon using the left hand for anterior retraction of the mesentery all the way up to the hepatic flexure peritoneal attachments. Care is taken when sweeping the duodenum medially (Fig. 27.5).

- *Troubleshooting: mobilization of the mesentery from the retroperitoneum should be carried out as lateral as possible to the abdominal side wall laterally and to the hepatic flexure superiorly. This more clearly defines the lateral avascular plane and prevents dissection into the retroperitoneum when performing lateral mobilization.*

The terminal ileum is released from inferior and lateral attachments to provide enough length to allow for a tension-free ileostomy (Fig. 27.6).The colon is retracted

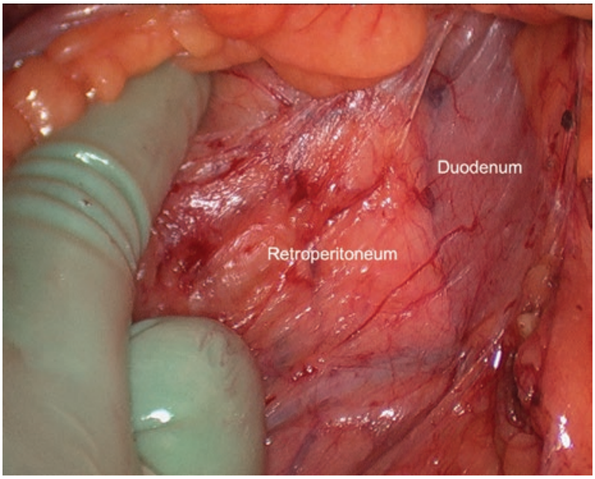

Fig. 27.4 Dissection of mesentery from retroperitoneum, with visualization of duodenum

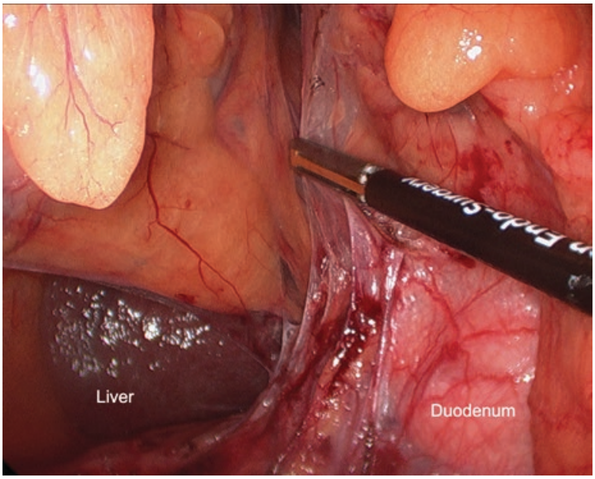

Fig. 27.5 Medialization of duodenum and dissection from mesentery

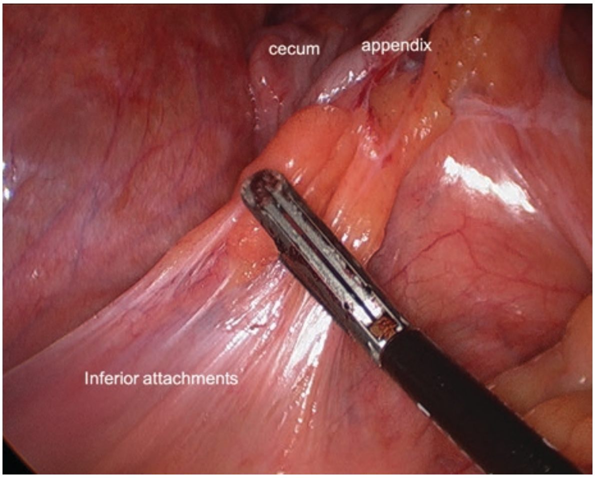

Fig. 27.6 Division of lateral attachments at cecum and terminal ileum

medially and the lateral attachments of the right colon are divided sharply, being careful to stay in the lateral avascular plane (Fig. 27.7).The right colon should now be mobilized completely from the retroperitoneum, exposing the entire sweep of the duodenum, a portion of the head of the pancreas, and right psoas muscle.

- *Troubleshooting: The right ureter may be visible near the base of the cecum as it passes over the iliac artery. Staying in the attachments close to the cecum and terminal ileum can prevent dissection into the retroperitoneum and possible injury of the ureter and vascular structures.*

The patient is placed in reverse Trendelenburg position and an initial gentle left tilt. The surgeon moves to the patient's right side with the assistant between the legs. The hand is used to apply downward traction on the omentum as the stomach is retracted cephalad. The omentum is divided with the specimen just distal to the gastroepiploic arcade to enter the lesser sac (Figs. 27.8 and 27.9).

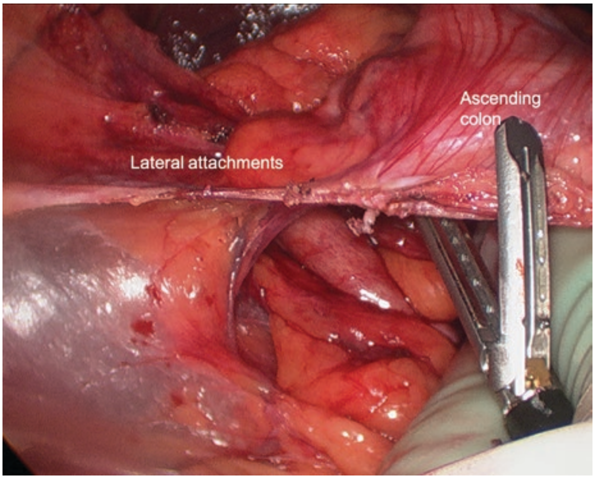

Fig. 27.7 Division of lateral attachments

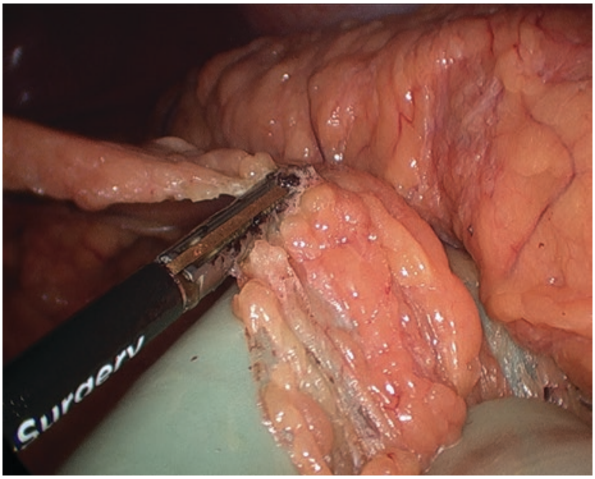

Fig. 27.8 Division of the greater omentum

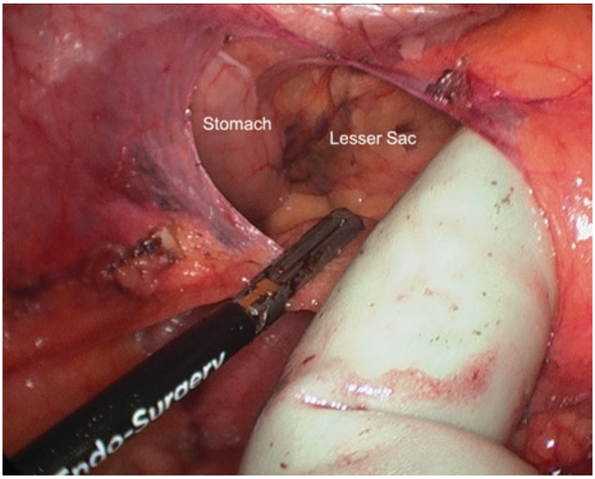

Fig. 27.9 Entering the lesser sac

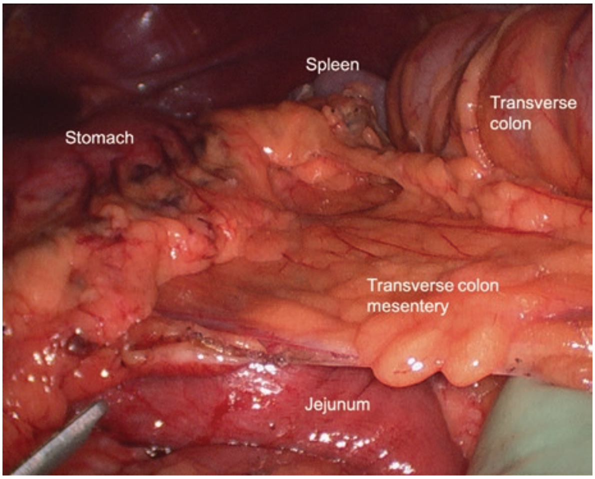

Fig. 27.10 Division of transverse colon mesentery

- *Troubleshooting: Staying close to the transverse colon provides dissection of the omentum in a relatively avascular plane and prevents injury to the gastric vessels. The posterior wall of the stomachshould be visualized as the lesser sac is entered.*

This dissection plane is continued from right to left, progressively rotating the patient to the right. This is continued toward the splenic flexure, fully exposing the lesser sac and facilitating exposure of the transverse colon mesentery. Once the omentum is divided, the transverse colon is grasped and elevated anteriorly. Beginning at the edge of mesentery created by dividing the ileocolic pedicle, the transverse mesocolon is divided from the patient's right to the left (Fig. 27.10). Care is taken to isolate the middle colic vessels prior to dividing with the energy device to ensure hemostasis (Fig. 27.11).

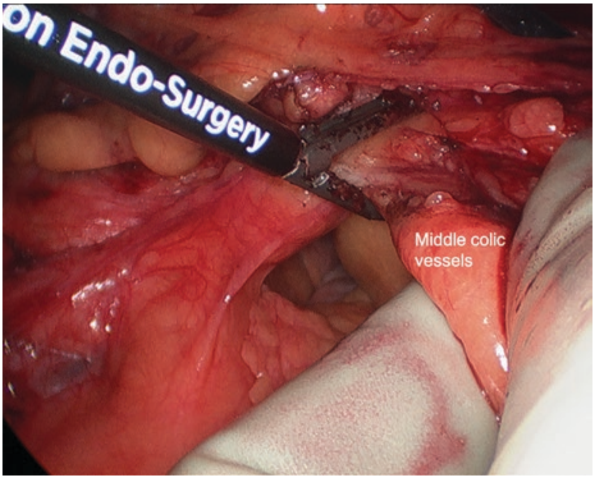

Fig. 27.11 Division of middle colic vessels

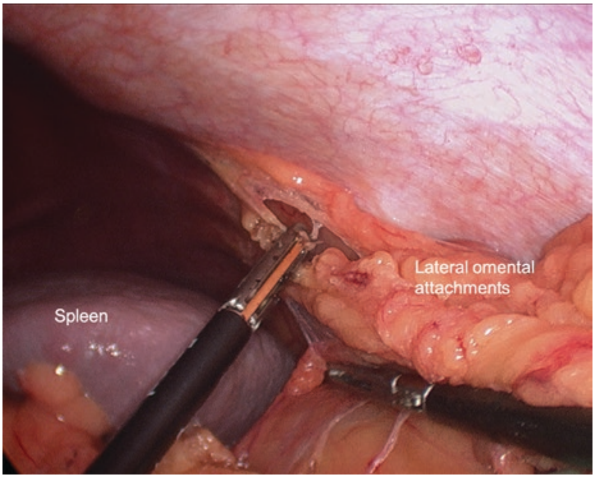

Fig. 27.12 Division of omental attachments at the splenic flexure

- *Troubleshooting: When dividing the major vessels to the colon, including the ileocolic and the middle colic arteries, occasionally there is incomplete hemostasis and bleeding results. Use the intraabdominal hand to grab the base of the pedicle during division. This allows for placement of a vessel loop or repeat cauterization prior to possible retraction of the vessel into the mesentery which can make it difficult to identify and ligate.*

The patient is fully tilted to the right and the small bowel is swept to the patient's right side. The splenic flexure is mobilized bluntly and by using the vessel sealing device to sharply dividethe distal transverse mesocolon and attachments to the greater omentum (Fig. 27.12).

The tip of the spleen and the anterior surface of the kidney are exposed as the suspensory ligaments are divided and the splenic flexure is mobilized medially. This

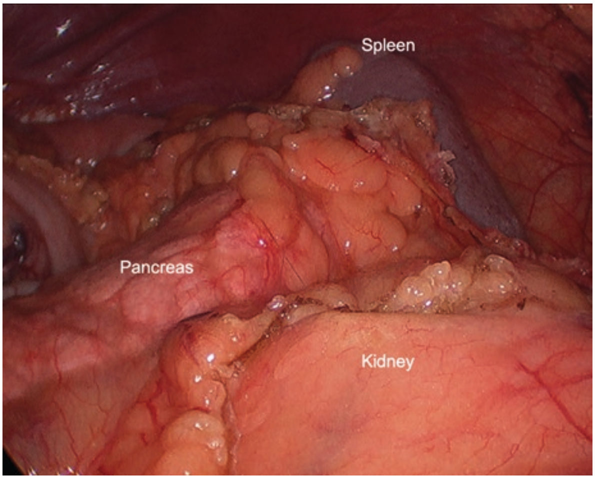

Fig. 27.13 Exposure of the left retroperitoneum

sharp dissection is continued into the lateral attachments and down to the pelvic brim as the colon is retracted medially. Blunt dissection in the avascular plane is used to mobilize the left colon medially and expose the retroperitoneal structures including the tail of the pancreas (Fig. 27.13).

- *Troubleshooting: The splenic flexure may be difficult to visualize and mobilize. Approaching from both the medial and lateral sides can help identify attachments which need to be divided. Retraction of the omentum must be done carefully, as attachments to the spleen can be present and can cause significant bleeding if tears in the splenic capsule result.*

The colon is retracted anteriorly, elevating the mesentery which is divided continuing at the edge just past the division of the middle colic vessels and into the descending colon,progressively moving back into Trendelenburg position until the pelvic brim is reached.

We typically preserve the Inferior Mesenteric Artery and its branches to the rectum when this operation is performed for benign disease. In patients with acute colitis, with possible immunosuppression and malnutrition, there is concern for breakdown of the rectal stump staple line. Preserving the Superior Rectal Artery improves perfusion to this segment of bowel. In addition, limiting dissection below the sacral promontory preserves intact pelvic planes for future operations and minimizes injury to the sympathetic nerves.

27.4.4 Transection

After the specimen is fully mobilized, the GelPort cap is removed and the specimen is delivered through the incision (Fig. 27.14). The terminal ileum is dissected free from its mesentery and divided with an linear cutting stapler. The rectosigmoid junction is dissected from the mesorectum and divided with a linear stapler. The specimen is sent to pathology for permanent section. The specimen should be

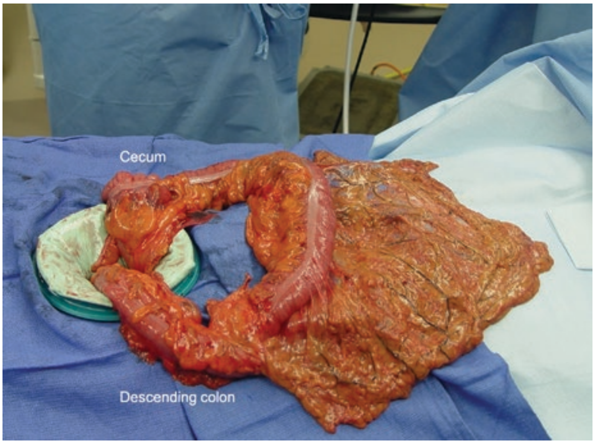

Fig. 27.14 Externalization of the specimen

opened on the back table in oncologic cases to assess for margins. The GelPort and laparoscopic trocars are removed and the pursestring suture is removed from the ostomy site. The terminal ileum is properly oriented and delivered through the previously developed ileostomy site.

- *Troubleshooting: The trocars can be removed under direct visualization through the Pfannenstiel incision to ensure there is no intraabdominal bleeding. The rectosigmoid junction staple line can be oversewn prior to returning it to the abdomen if there is concern for integrity in patients with acute UC and a rectal tube for decompression is used in severely inflammed rectal stumps.*

27.4.5 Closure of Incisions and Creation of Ileostomy

The Pfannenstiel incision is closed in layers. The peritoneum is closed with a running 3-0 Vicryl suture and the fascia is closed using interrupted 0 Vicryl suture. The skin of the Pfannenstiel incision and port sites are closed using running 4-0 Monocryl suture in a subcuticular fashion and sealed with sterile surgical glue.

The incisions are protected with a sterile towel. The staple line is excised and the ileostomy is matured in the standard Brooke fashion using 3-0 chromic interrupted suture (Fig. 27.15). An ostomy appliance is placed around the ileostomy.

27.5 Postoperative Management

Patients are placed on an Enhanced Recovery After Surgery (ERAS) protocol. Multimodal analgesia is used to decrease opioid use. Scheduled acetaminophen, gabapentin, and celecoxib are given. Tramadol is used for breakthrough pain and low dose ketamine drip is added as needed. Alvimopan is given in opioid-naïve

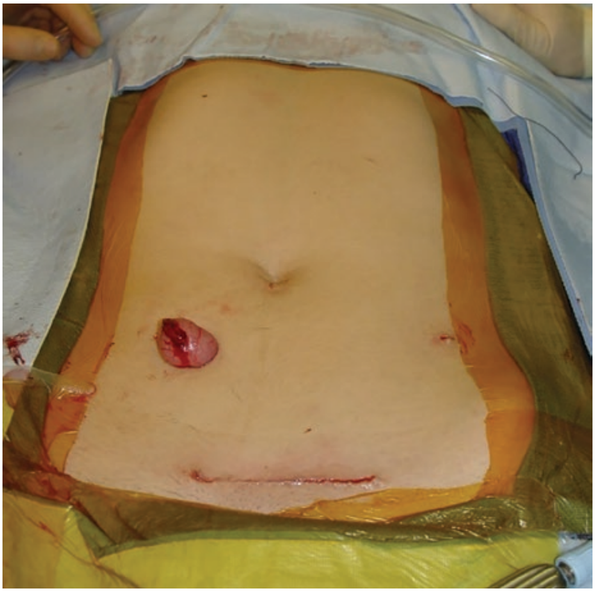

Fig. 27.15 Completion, prior to maturing the end ileostomy

patients until return of bowel function. Patients are offered clear liquids following surgery and given a low residue diet on the first postoperative day. The bladder catheter is removed in the morning on the first postoperative day. The rectal tube is removed on postoperative day 2. Patients are encouraged to use incentive spirometry. Patients are given deep vein thrombosis prophylaxis, SCDs are used, and they are encouraged to ambulate a minimum of 3 times daily. Patients are discharged when they tolerate a diet with adequate ileostomy output, pain is controlled on oral medications, and the patient or family is able to care for the ostomy, typically within 2–3 days.

Conflict of Interest The authors have no conflict of interest to declare.

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Chapter 28
Single Port Laparoscopic Total Colectomy

Savas T. Tsikis and Evangelos E. Messaris

28.1 Introduction

Total colectomy involves the removal of the entire colon while the rectum is left behind. Depending on the indications for surgery as well as the patient's clinical status, the operation may involve either an end ileostomy or an ileorectal anastomosis. Traditionally, the open operation was performed via a large midline incision from the xiphoid process (access to hepatic and splenic flexure) to the pubic symphysis (access to the rectosigmod junction).

The first minimally invasive laparoscopic colectomy was first performed in 1991 [1]. Since then, advances in techniques and familiarity with the use of minimally invasive instruments have made this approach more popular. The reasons include less postoperative pain, shorter length of stay, smaller scars and earlier recovery of bowel function. These observations have been consistently shown to be true in randomized controlled studies and metanalyses [2, 3]. Furthermore, the minimally invasive approach has also been shown to have equivalent oncologic outcomes compared to the open approach [2]. For all these reasons the field has grown exponentially in the past two decades.

One of the important advances in minimally invasive surgery has been single portlaparoscopic surgery (SPS). With this approach a single incision is made and all instruments including the camera enter the abdomen through that incision. This approach was first described for colon resections over a decade ago [4, 5]. The

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primary goals are to minimize trocar related complications, reduce the tissue response to injury, and improve cosmetic outcomes. Lack of familiarity with SPScolectomies as well as the use of the instruments necessary for this approach may prevent surgeons from adopting it in their practice.

There have been several randomized control trials comparing SPS to traditional laparoscopic surgery for colectomy. The individual studies had a small amount of patients ($n < 100$) but have shown that is a safe alternative to laparoscopic surgery with similar mortality, lymph node sampling and perhaps less post-operative pain [6, 7]. Furthermore, a meta-analysis comparing SPS to conventional laparoscopy for colorectal disease found that patients who had a SPS approach had shorter hospital stay, lower blood loss and shorter time to flatus [8]. The review included 14 studies but only one was a randomized study. Only two studies examined the rate of incisional hernias, but did not find a difference between SPS and conventional laparoscopy. Large-scale randomized control studies are still needed to confirm these observations [8].

The purpose of this chapter is to describe the basic steps of the operation when done for the purpose of a total abdominal colectomy. These steps would also be applicable to partial colectomies. We also aim to increase the readers familiarity with the indications for the procedure as well as basic post-operative management.

28.2 Clinical Presentation

28.2.1 Indications

A total abdominal colectomy can be performed in the emergent or elective setting. In the emergent setting it can be done for fulminant *C. difficile* infection, toxic megacolon or acute severe ulcerative colitis, or colonic perforation in the setting of septic shock. Given that the minimally invasive approach is usually reserved for elective operations we will focus on its main indications in that setting.

28.2.2 Inflammatory Bowel Disease

The surgical treatment of patients with inflammatory bowel disease differs widely based on the distribution of the underlying pathology. Patients with ulcerative colitis typically eventually require a total proctocolectomy with either an end ileostomy or an ileal pouch-anal anastomosis [9]. The first step of either a three-stage or modified two-stage restorative proctocolectomy could be a total abdominal colectomy with end ileostomy. A total abdominal colectomy may also be a good option in patients with Crohn’s disease with sparing of the rectum. Typical indications in IBD patients in the elective setting include the following:

(1) Persistent symptoms of IBD despite optimal medical management (steroid dependent disease) or in patients who can no longer tolerate medical therapy
(2) Patients with increased cancer risk as demonstrated by the presence of dysplastic or adenomatous polyps on colonoscopy
(3) Patients with longstanding disease who want to reduce their cancer risk
(4) Development of colonic strictures or fistulae (specific to Crohn's or indeterminate colitis)

A very small subset of patients with ulcerative colitis can have rectal sparing and a total abdominal colectomy with either an end ileostomy or ileorectal anastomosis can be considered in these patients. Many of these patients will eventually require removal of the rectum due to recurrent disease [10]. Other candidates include young women who wish to maintain fertility, patients with indeterminate colitis, or patients who refuse an ileostomy and who would not be candidates for an ileal pouch-anal anastomosis

28.2.3 Neoplasm

A total abdominal colectomy with ileorectal anastomosis or end ileostomy may be indicated in patients with familial genetic syndromes who have an increased risk of developing colon cancer during their lifetimes. The most common of these are Hereditary Non-Polyposis Colorectal cancer syndrome (HNPCC) and Familial Adenomatous Polyposis (FAP).

The onset of cancer in HNPCC is usually in the 4th decade of life. Mutations in DNA mismatch repair proteins including MLH1, MSH2, PMS2, and MSH6 lead to an increased risk of developing various cancers including colon cancer over a patient's lifetime. Patients with HNPCC who would prefer to not have yearly colonoscopies or have poor follow up may be good candidates for a total abdominal colectomy. Patients with a prior occurrence of colon cancer may also be good candidates for this surgery. These patients still require surveillance sigmoidoscopies every year and may eventually need removal of the rectum.

Patients with FAP have an inherited mutation in the adenomatous polyposis coli (APC) gene that leads to the development of polyps and colon cancer during a patient's lifetime. The syndrome is inherited in autosomal dominant fashion and has 100% penetrance. These patients will eventually require a total proctocolectomy. However, a small subset of patients have sparing of the rectum or only a few polyps. These patients have an attenuated version of FAP, and a total abdominal colectomy with ileorectal anastomosis may be considered. These patients still require annual surveillance with a sigmoidoscopy after surgery.

A total colectomy with ileorectal anastomosis may also be considered in certain patients with colon cancer in the absence of an underlying genetic syndrome. For example, patients with distal colonic obstructing cancers may develop marked colonic dilation making the remaining colon unsuitable for an anastomosis.

Furthermore certain non-obstructing transverse colon cancers may be suitable for a total colectomy or subtotal colectomy with ileosigmoid anastomosis. This avoids creating an anastomosis in anatomic watershed regions or in areas with poor blood supply.

28.2.4 Lower Gastrointestinal Bleeding

Total abdominal colectomy for patients with recurrent lower gastrointestinal bleeding is generally considered last resort in the overall management of this condition. However there are certain patients who have severe recurrent bleeding that may even be life threatening. These patients will have undergone prior diagnostic evaluation including colonoscopy, CT angiography with or without embolization and tagged red blood cell scanning to localize the source of bleeding. If the above interventions fail or if the patient is found to have multiple lesions (e.x. diffuse diverticulosis or angiodysplasia), a total colectomy may be offered. Careful patient selection is essential.

28.2.5 Colonic Inertia & Constipation

Certain patients with chronic constipation refractory to medical management with or without a diagnosis of colonic inertia may be offered a total abdominal colectomy as a treatment option for their underlying pathology. These patients should have an extensive preoperative work up including defecography, anal manometry and electromyography to exclude underlying pelvic floor dysfunction. Furthermore, gastric and small intestinal transit should be evaluated with a gastric emptying study and lactulose breath hydrogen study. This is important as a total colectomy will not improve symptoms in patients with delayed gastric emptying of pan-intestinal dysmotility.

28.3 Preoperative Evaluation

The work up of patients who are candidates for a SPS approach is similar to those undergoing laparoscopic surgery and depends on the underlying indication for surgical intervention. Regardless of the indication, assessment begins with a careful and thorough history and physical examination. This should include a rectal examination to assess sphincter tone, and the presence of any fistulae or rectal abscesses. Furthermore any prior surgical scars that could impact laparoscopic access should be thoroughly documented. The patient's overall nutritional status should also be documented including recent weight loss or gain. This is especially important since the lack of nutritional optimization can increase the risk of post-operative complications such as an anastomotic leak.

28.4 Preoperative Work Up

Patients with underlying IBD being considered for a total abdominal colectomy should have a prior colonoscopy that demonstrates rectal sparing. Furthermore, biopsy of any suspicious lesions is important as the presence of an underlying malignancy will favor a complete oncologic resection. Preoperative imaging should include a CT scan of the abdomen and pelvis to evaluate for any abscesses or fistulas which may require further work up.

For patients with diagnosed FAP or underlying malignancy who are pursuing a total abdominal colectomy, a complete colonoscopy should also be done in the preoperative setting. Laboratory work up includes a complete blood cell count, chest x-ray, metabolic panel, liver function tests as a well as a preoperative CEA level to document a baseline. We tailor additional work up to the history of the individual patient.

28.5 Skin Marking of Ostomy Site

The importance of pre-operative stoma marking and discussion with the patient cannot be understated. During our preoperative clinic visit we coordinate a simultaneous session with our dedicated stoma nurses. This session covers the basics of stoma care, what to expect in the post-operative period and common issues related to having a stoma. The patients will also undergo pre-operative marking at this time wearing their everyday clothes in order to optimize location of the ostomy. Furthermore, the patients watch a 15 minute video with ostomy education footage. All their questions are addressed. The surgeon should make a decision on whether she/he will use the future ostomy site as the point of entrance in the abdomen.

28.6 Technique

The operation is described in a series of sequential steps. Refer to the appropriate figures for each step and the associated troubleshooting comments for assistance. One important difference compared to multi-port laparoscopic surgery is that your instruments are working in parallel to one another which requires flexibility in retraction and overall operative technique.

Equipment:

There are several options for cameras and instruments. There are more than 5 ports currently in the market from several companies. These include the GelPOINT ® system (Applied Medical, Rancho Santa Margarita, CA, USA), SILS ™ device (Covidien, Dublin, Ireland), Triport+®, Triport15®, and Quadport+a® (Advanced Surgical Concepts, Bray, Ireland), Uni-X Single Port® (PNavel Systems, Cleveland, OH, USA). See below for website link information:

Website Information:

Gelpoint system®: https://www.appliedmedical.com/Products/Gelpoint

SILS™ from Covidien: https://www.medtronic.com/covidien/en-us/products/trocars-access/single-incision-transanal-surgery.html#sils-port

Advanced Surgical Concepts: http://www.advancedsurgical.ie/home/home.2.html

Uni-X ™ from PNavel Systems: unable to find product website

Recommended Setup:

- *Access*: Routine setup of open instruments for access. *Tip: recommend use of small retractors (i.e. small "army navy", "lady finger" "richardson") which will allow for better ease of access)*
- *Camera*: 5 mm, 0 or 30 degree. *Tip: use of the camera with a flexible tip can provide the best visualization and less friction between the instruments*
- *Laparoscopic instruments*: 2 bowel grasping instruments are needed ("babcock" or "slots"), laparoscopic scissors are used on an as needed basis, and laparoscopic monopolar energy device if the surgeon uses it for routine laparoscopy. No other instruments should be needed for laparoscopy.

Energy device: any commercially available 5 mm energy device is recommended. The surgeon should choose an energy device that can ligate up to 7 mm vessels such that no additional staplers are needed. Such devices include Caiman 5 (C5; Aesculap, Inc., Center Valley, PA), Harmonic Scalpel Ace Plus (HA; Ethicon Endosurgery, Cincinnati, OH), Harmonic Ace +7 (HA7; Ethicon Endosurgery), LigaSure (LS; Covidien, Mansfield, MA), and Enseal G2 (ES; Ethicon Endosurgery).

Steps:

1. **Positioning**

The positioning is similar to a multi-port laparoscopic colectomy. The patient is placed supine in the modified lithotomy position with both arms tucked (Fig. 28.1). The lead surgeon initially stands on the patient's right while the assistant will stand on the left. Positioning of the lead surgeon will change throughout the procedure as dissection requires.

2. **Incision and access**

The necessary instruments for SPS access are prepared on the Mayo stand (Fig. 28.2a, b, c). If an ileostomy is planned, the chosen ostomy site is utilized for entry, otherwise we use the umbilicus (Fig. 28.3a).

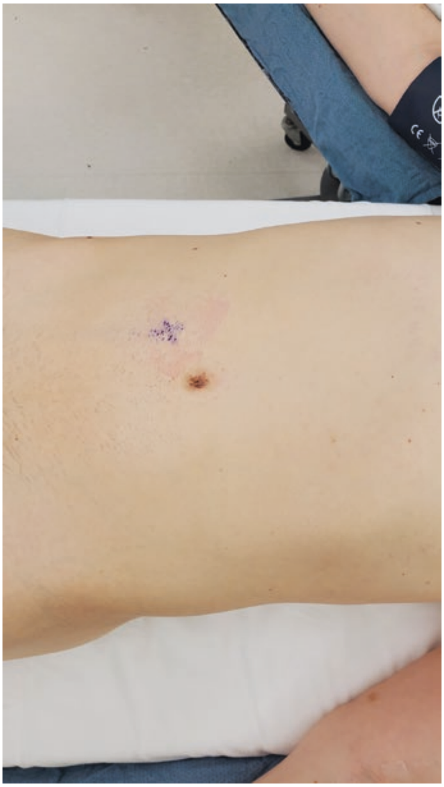

Fig. 28.1 Initial patient positioning for SPS. The patient is placed supine in the lithotomy position with both tucked

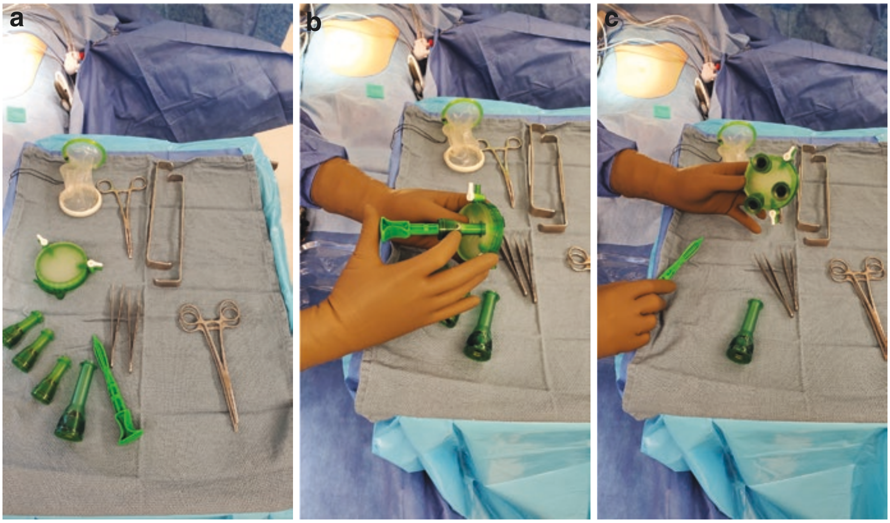

Fig. 28.2 (**a**) Instruments required for access to the abdominal cavity and creation of the single incision port site. These include the SPS port, trocars, a small size wound protector, two army navy, and Kocher's. (**b**) Demonstration how to insert the access ports through the SPS device. (**c**) After assembling the various components

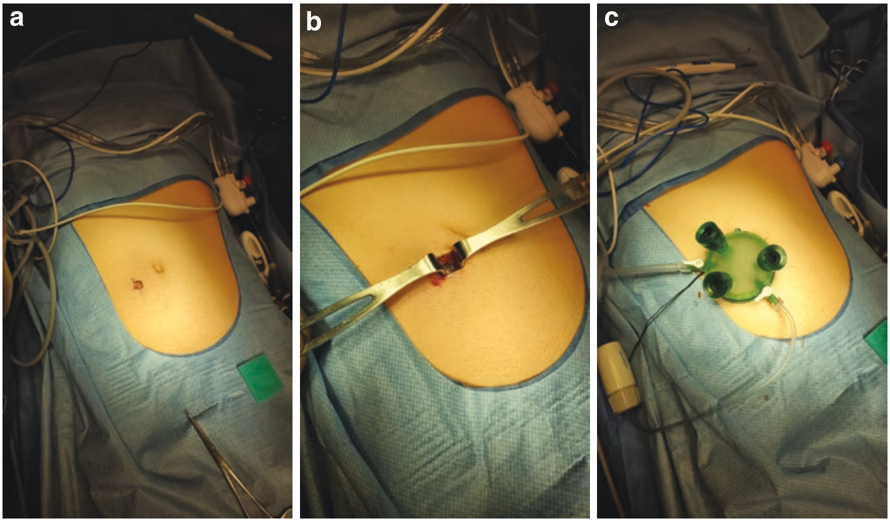

Fig. 28.3 (**a**) Demonstration of access site at proposed ileostomy site. (**b**) Direct access to the abdominal cavity. (**c**) Final port insertion and assembly

Trans-umbilical incision: A single skin incision from the skin to the subcutaneous tissue is performed and extended through the midline abdominal fascia to enter the peritoneal cavity. At the level of the umbilicus, within the umbilical anatomical ring, there is thinning of the midline and access to the abdominal cavity is instant.

Ostomy incision: A small 2 cm skin incision is performed from the skin down to the subcutaneous tissue. The anterior fascia is opened longitudinally and we expose the rectus abdominus muscles. The fibers are then separated along their orientation and the peritoneal cavity is entered by grasping the peritoneum and incising it. For upper abdominal ostomie the posterior fascia of the rectus sheaths will have to be divided.

We elect to enter the peritoneal cavity under direct vision (Fig. 28.3b). A single-site laparoscopic trocar is introduced into the peritoneal cavity (Fig. 28.3c). The abdomen is then insufflated in a standard fashion to a maximum pressure of 15 mm Hg using Carbon dioxide and the camera is inserted through the SPSport. We inspect the peritoneal cavity for any evidence of metastatic disease and examine the liver, stomach, spleen, large and small intestine as well as the pelvic organs. In the absence of any contra-indication to proceed,we begin the procedure with mobilization of the transverse colon as detailed below. In terms of the dissection, there are two well-known approaches: medial-to-lateral and lateral-to-medial. We prefer the lateral-to-medial approach for total abdominal colectomy, which we describe here.If desired, a transverse abdominis plane (TAP) block can also be done at this step by injecting large volume (>25 cc) of local anesthetic under direct visualization in bilateral transverse abdominis planes (Figs. 28.2 and 28.3a, b, c)

3. **Mobilization of the transverse colon**

The patient is positioned in the reverse Trendelenburg position for this step of the operation. The one instrument is used to retract the omentum cephalad and anterior towards the abdominal wall and then using gravity from the reverse trendelemburg position the transverse colon in separated and retracted towards the pelvis without the need to use any instrumentation. The transverse colon is first mobilized by taking down all the omental adhesions to the transverse colon. Furthermore, the gastrocolic ligament is transected paying particular attention to avoid injury to the gastroepiploic vessels. A thermal energy device is utilized during this step. This maneuver allows the surgeon to enter the lesser sac and retract the stomach in a cephalad direction. The dissectionis then extended through the splenocolic ligament to the left of the patient and the hepatic flexure to the right. During this step, the second portion of the duodenum is dissected off the mesocolon and the first two segments of the duodenum are fully exposed.

The transverse colon is then lifted cephalad and the transverse mesocolon is incised at its base after the branches of the middle colic artery are clearly identified. The middle colic artery is identified, dissected free of surrounding tissues, and transected using the thermal energy device. The high ligation of the vessel occurs on top of the pancreas and attention should be given not to injure the pancreatic capsule or perform an incomplete transection of the vessel that will then retract under the pancreas and make hemostasis very complicated.The remainder of the transverse mesocolon from the hepatic flexure to splenic flexure is transected at its junction with the retroperitoneum. It is important to pay particular close attention at this step to nearby structures such as the duodenum,pancreas, the stomach close to the splenic flexure and ligament of Treitz to avoid accidental injury. This completes mobilization of the transverse colon.

Troubleshooting. In obese patients, the large omentum might make the mobilization of the transverse colon more challenging. If it cannot be retracted cephalad, then transect it off the stomach and excise it en-bloc with the remainder of the colon.

4. **Mobilization of right colon & hepatic flexure**

During the next stage of the operation, attention is addressed towards mobilization of the right colon. The patient is first placed in *Trendelenburg position with the right side up*. The ascending colon is mobilized off of the lateral abdominal wall by using atraumatic bowel graspers for retraction and the energy device for blunt dissection. It is important that dissection continues along the avascular *white line of Toldt* in order to minimize bleeding and damage to nearby structures.The ureter is also identified and protected. As you ascend from the cecum, the colon is lifted away from Gerotas fascia by medializing the dissection in order to avoid injury to the kidney. The duodenum is also seen at this point and attachments to the colon are divided.

Attention is also drawn to the ileocolic vessels, which are identified by lifting the mesentery at the ileocolic junction. At the base of the mesentery, the origin of the ileocolic vessels is seen right next to the duodenum. Once identified, the ileocolic vessels are divided. A stapler device such as the Endo-GIA® device is also used to divide the terminal ileum at this stage. We then proceed with mobilization of the left colon.

5. **Mobilization of left colon & hepatic flexure**

Similar to the right colon, we proceed with mobilization of the left colon in a lateral-to-medial direction. The patient is placed in *Trendelenburg position with the left side up*. The lateral peritoneal attachments to the sigmoid colon are again incised and dissection proceeds in a cephalad direction along the White line of Toldt. The ureter is again identified and protected. This dissection is extended up to the previously mobilized splenic flexure.

If the operation is done for purposes of dysplasia or malignancy, high ligation of the inferior mesenteric vessels is accomplished by identifying the vascular pedicle near its origin close to the aortic bifurcation. Division is accomplished using the themal energy device. If a high ligation is not necessary the sigmoidal branches of the colicvessels are ligated near the wall of the sigmoidusing the energy device. It is important in this scenario to the preserve the superior rectal vessels. This step is repeated for the left colic artery and inferior mesenteric vein.

The mesosigmoid is then incised and dissection proceeds down to the upper rectum with appropriate retraction. At the level of the upper rectum, a stapler device such as the Endo-GIA®stapler is used to transect at the rectosigmoid junction (Fig. 28.4a, b). Preferrably one load of the stapler should use to complete the transection. The use of multiple consecutive staple lines for transection is associated with increased risk for staple line breakdown (Fig. 28.4a, b).

6. **Specimen retrieval**

At this step of the operation, the entire colon from the ascending colon, hepatic flexure, transverse colon, splenic flexure, descending and sigmoid colon should be mobilized. The major vessels including the ileocolic, middle colic and inferior mesenteric vessels should be divided. Appropriate hemostasis is confirmed, and all solid and hollow viscus organs are inspected for missed injury. Using a grasper, the

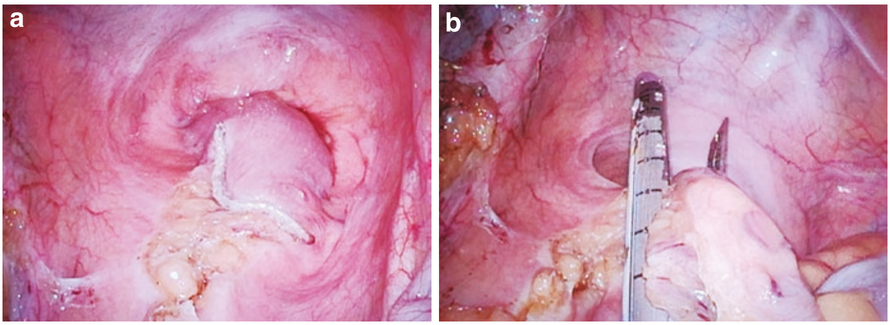

Fig. 28.4 (**a**, **b**) Use of stapler device to transect the large intestine at the rectum sigmoid junction in the pelvis

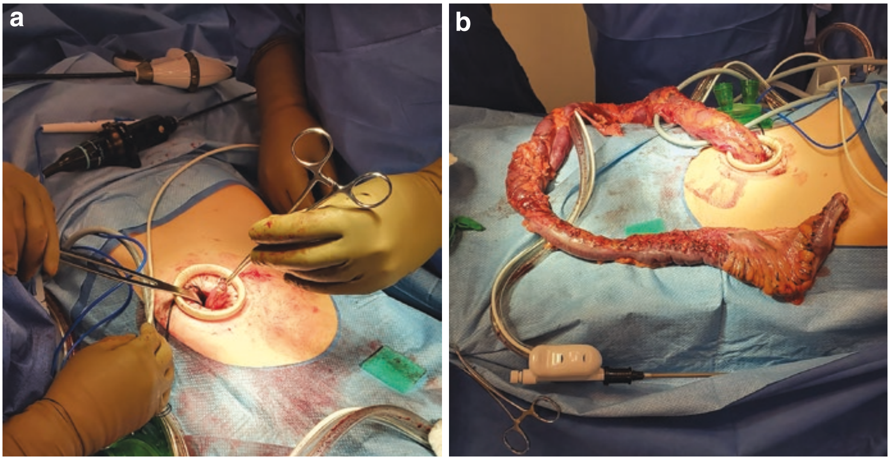

Fig. 28.5 (**a**, **b**) Final specimen retrieval through the single incision port access site

surgeon handles the colonic staple line and brings it into the forceps. The abdomen is desufflated and the colon is removed through the single port (Fig. 28.5a, b).

An alternative approach would be to open the rectal stump and perform a transrectal specimen extraction and then staple the rectum closed. With single site laparoscopy this is rarely needed since the port is large enough for the specimen extraction.

End ileostomy

If an end ileostomy is planned, the terminal ileum is brought up to the level of the port site or the proposed ostomy site, depending on whether the ostomy site is used as an entry point. In any event, appropriate orientation of the small bowel should be confirmed. The ileostomy is then matured in the standard Brooke's fashion (Fig. 28.6).

7. **Ileorectal anastomosis**

The principles of performing an ileorectal anastomosis using the SPS approach are the same as that of the open procedure. The single port device is removed and the terminal ileum is exteriorized through the wound. Prior to doing this, it is important to ensure that there is sufficient length of ileum to reach the rectum easily (See Troubleshooting).

We utilize an end-to-end stapled anastomosis in our practice but a side-to-end stapled anastomosis yields similar results in experienced hands. To perform the anastomosis, the terminal ileum is opened and a purse-string suture is placed at the cut edge. The anvil device is then inserted into the opened ileum and secured in place using the purse string suture. For a side-to-end anastomosis, the anvil is inserted in the bowel through the small bowel opening and using the spike it penetrates the antimesenteric side of the small bowel 5 cm proximal to the entry site. Then the entry site is stapled closed.

Fig. 28.6 Final endileostomy maturation utilizing the port site. No incisions are visible through the abdominal cavity

For the SPS approach, the ileum is then re-inserted into the abdominal cavity and the SPS port is placed into the wound. Following insufflation, the ileum is positioned near the rectum. The assistant then inserts several dilators through the rectum followed by the end-to-end stapler device. The stapler is advanced transrectally under direct guidance with the laparoscopic camera. The stapler should be positioned so that its head is aligned at the middle of the rectal stump staple line. Once satisfied, the trocar of the stapler is advanced to pierce the staple line. A laparoscopic grasper is then used to align and engage the anvil with the stapler. It is essential to verify proper orientation of the small bowel and ensure that it has not twisted on itself. *The small bowel should lie on the left side of the abdomen and the cut edge of the mesentery should be longitudinally oriented to the right of the patient.*

The stapler is then closed ensuring proper mesenteric orientation (i.e. no twisting of the ileum). Once satisfied, the stapler is fired and removed under direct guidance from the rectum. The two donuts should be verified that they are intact. We ensure the integrity of our anastomosis by instilling the pelvis with saline followed by insertion of a flexible sigmoidoscope through the anus and insufflation of the rectum with air under direct visualization of the anastomosis. The absence of air bubbles in the pelvis confirms that our anastomosis is intact. We do not routinely use drains or perform a diverting loop ileostomy in the elective setting.

Troubleshooting: If you do not have enough length of small intestine to reach the rectum easily without putting tension on your anastomosis there are a number of strategies you can employ. First of all, ensure lysis of all adhesions from the ligament of Treitz to the terminal ileum. If further length is needed, relaxing incisions can also be made along the small intestine mesentery. These are done by exteriorizing the mesentery and identifying vessel-free windows upon transillumination. If the terminal ileum cannot reach the pelvis, then mobilization of the duodenum (kocher maneuver) will be needed to gain additional length.

28.7 Post-operative Management

Our patients undergoing SPS for a total abdominal colectomy recover through our accelerated recovery after surgery pathway [11]. This pathway starts with preoperative education, prescription of oral gabapentin and a carbohydrate load just before surgery. We also emphasize early post-operative mobilization, optimal pain management with minimal opioid use, early diet advancement, and minimizing postoperative fluids. Patients are encouraged to get out of bed and ambulate on post-operative day zero.

For pain management, we focus on using non-opioid analgesics (acetaminophen and nonsteroid anti-inflammatory drugs) in the post-operative setting. In the immediate post-operative period these are given in an intravenous formulation and changed to an oral form when the patient is tolerating a diet. Intraoperatively the surgeon will also routinely administer a transversus abdominis plane (TAP) block. The combination of these approaches minimizes narcotic use in the postoperative setting.

In terms of fluid management, we limit the use of intraoperative intravenous crystalloid fluids to 3 cc/kg/hr. Before the patient is able to tolerate oral intake we keep resuscitative fluid to a maximum of 40 cc/hr. Typically patients are allowed to resume a regular diet in the post-anesthesia recovery unit. We do not routinely use nasogastric tubes or drains in our elective surgeries. Finally, urinary catheters are removed in the operating roomto reduce the risk of a urinary tract infection and assists in overall mobilization.

Our patients typically recover within a couple days and patients without any complications are typically discharged within 1–3 days. Patients who underwent surgery for an underlying malignancy or IBD are also given a 28-day prescription of enoxaparin for deep venous thrombosis prophylaxis. If the patient has a new stoma, they also receive extensive teaching with the assistance of our stoma nurses and they are not discharged until they have demonstrated basic stoma skills. The presence of an ostomy is the single factor that determines the time to discharge in an accelerated pathway.

28.8 Conclusion

Single port laparoscopic total abdominal colectomy is a safe and feasible alternative to traditional laparoscopy. It arguably provides better aesthetics which is an important consideration for many patients. Furthermore, with the appropriate equipment and a small technical adjustment, the transition from traditional laparoscopy to single port is feasible for the experienced surgeon. Our goal with this chapter is to increase the readers familiarity with our approach to this minimally invasive procedure.

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Chapter 29
Robotic Abdominal Perineal Resection

Y. Nancy You, Syed Nabeel Zafar, and Brian Bednarski

29.1 Introduction

An estimated 700,000 new cases of rectal cancer are diagnosed each year globally. Rectal cancer is the 10th most lethal malignancy worldwide, accounting for 310,000 deaths annually [1]. In the United States, over 43,000 patients each year will have rectal cancer and the 5-year overall survival for rectal cancer is approximately 67%, ranging from 15.8% in those presenting with distant metastatic disease to 89.4% in those with localized disease [2]. Despite increased screening, only about 40% of the patients present with localized disease. While most patients presenting with rectal cancer are older than age 65, the incidence of rectal cancer is rising by approximately 2% each year among young adults aged 18 to 50 [2, 3]. By 2030, an estimated 25% of all rectal cancers would be diagnosed under age 50 if current trends continued [4].

29.2 Clinical Presentation and Evaluation

Patients with rectal cancer often present with symptoms such as bleeding per rectum, change in bowel habits, tenesmus, rectal pain, and/or signs of malignant fistulizing disease. Those diagnosed from screening may present without significant symptoms. Once a patient presents with a biopsy-proven adenocarcinoma, a thorough evaluation is required is determine the appropriate treatment.

Evaluation begins with a thorough history and physical examination with particular attention to symptoms that may warrant urgent intervention, particularly

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pain, tenesmus or obstruction. Evaluations of baseline bowel pattern, continence, sexual and urinary functions are equally important. Assessing the overall functional status,and support structure available to the patient are other vital questions to ask to inform preoperative planning.

Staging work up includes a full colonoscopy and biopsies if not previously performed, laboratory investigations including carcinoembryonic antigen (CEA), and cross sectional imaging. Computed tomography (CT) scans and Magnetic Resonance Imaging (MRI) of the pelvis are used to determine the clinical stage of the disease and inform the course of treatment, but they also are beneficial inassessing candidacy for a minimally-invasive surgical (MIS) approach. A triple-phase contrast-enhanced CT scan of the chest, abdomen, and pelvis assess for distant disease, adjacent organ involvement, overall body habitus, and evidence of prior operations. A rectal MRI is typically performed to determine tumor T and N staging as well as identify any other high risk features such as involvement of the circumferential resection margin (CRM), presence of extramural venous invasion (EMVI), and lateral pelvic nodes. MRI aids in surgical planning by delineating the relationship of the tumor to the mesorectal fascia and the surrounding structures (Fig. 29.1). Endoscopic ultrasound (EUS), less frequently performed now, provides for better T staging, particularly in early T stage lesions, and allows for the possibility of EUS guided biopsy of nodes. We favor the addition of EUS for tumors anticipated to be of low T stage.

The operative surgeon should ideally assess the tumor prior to any treatment through a digital rectal examination (DRE) as well as an endoscopic assessment (either rigid proctoscopy or flexible sigmoidoscopy). The size of the tumor, its degree of circumferential involvement, distance from the anal verge, sphincter tone, and relationship of the tumor to the dentate line, levators and sphincter complex

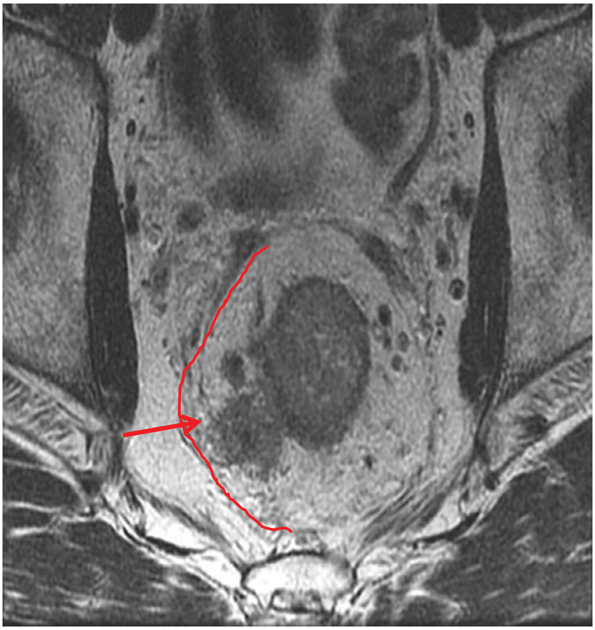

Fig. 29.1 High resolution pelvic MRI for locally advanced rectal cancer. The axial images demonstrate the involvement of the circumferential resection margin (red line denotes the mesorectal fascia) by direct extension of the tumor (red arrow)

must be noted. These factors play an essential role in the surgical decision-makingfor whether the patient is a suitable candidate for sphincter sparing surgery or not.

Goals of a thorough preoperative assessment should include:

1. Determine candidacy for sphincter preservation vs. permanent colostomy. Both anatomic and clinical factors must be considered including the location of the tumor, sphincter muscle and levator muscle involvement, body habitus, occupation, and physical and psychosocial ability to manage a permanent stoma. An APR is oncologically indicated for curative intent resection, if the sphincter complex and/or the levator muscles are either directly involved or is threatened without an adequate distal or radial margin. Preoperative ostomy education and marking must be performed when a permanent ostomy is planned. Goals and expectations should be clear and discussed in detail with the patient.
2. Consider conventional vs. intersphincteric APR. In the conventional APR the complete sphincter complexis removed and wide resection of the levator is performed. However, in certain cases, a patient with a low-lying tumor is being considered for a permanent ostomy because of poor candidacy for sphincter preservation due to expected poor functional outcomes. In these patients, resection of the entire sphincter complex, particularly the external sphincter muscles, is not necessary for adequate oncologic margin. An intersphincteric APR, where the internal anal sphincter is removed while the levator complex and external sphincters remain in place, can be performed. This approach offers the advantage of sparing the patient the morbidity of a perineal wound.
3. Determine the plane of dissection: TME vs. beyond-TME plane. A careful study of the rectal MRI including axial, sagittal and coronal views should be completed with an expert radiologist. Attention should be paid to radial margins of the tumor, malignant nodes, and EMVI. This can result in involvement of adjacent organs or structures including adjacent internal iliac vessels, obturator nerve and vessels, sacral nerve roots, and any pelvic viscera.The operative surgeon should assess whether adequate MIS skills are available in complex cases to ensure adequate margin negative resections including en bloc resections of involved structures.
4. Plan perineal wound closure. Depending on the planned operation and body habitus, several perineal wound closures options exist, as discussed below. Each has its indications, benefits and risks which need to considered and planned for. Coordination with plastic surgery teams if needed should be done in advance.
5. Assess the need for intraoperative aids. An example is ureteric stents, which may aid in identifying the ureters and their proximity to extended operative planes.

29.3 Operative Planning

29.3.1 Equipment

Robotic APR can be performed on various available platforms, most commonly the daVinci Si or Xi robotic system (Intuitive Surgical Inc., Sunnyvale, CA, USA).

29.3.2 Positioning and Preparation

The patient is placed in a lithotomy position.The legs are placed in stirrups with comfortable flexion at the hips and knees, and knees and feet are kept inline. The patient is secured to the bed through firmly secured foam padding or a beanbag, as well as Velcro bands across the chest. Both arms are well padded and tucked. Care must be taken to avoid compression injuries. Padding of the knee and lower leg is critical to prevent peroneal nerve injury. Padding of the arm, elbow and hand is necessary to prevent medial or ulnar nerve injuries. We routinely irrigate the rectum with dilute Povidone-iodine solution. The marked site for the end colostomy must be confirmed. Finally, the abdomen and perineum are prepped and draped. Prophylactic antibiotics and venous thromboembolism (VTE) prophylaxis are given per routine.

29.4 Operative Technique

Step 1: Trocar placement, Exploration, Exposure, and Docking

Pneumoperitoneum is established using a 5 mm port that allows direct camera visualization during trocar insertion through the tissue layers in the right upper quadrant. Once insufflated, we introduce a laparoscopic camera and the abdomen is explored with particular attention to the pelvis, as well as to the liver and the peritoneum. The goals of the exploration are to rule out metastatic disease and to assess the feasibility of a robotic approach.

Once the decision to proceed to robotic APR is made, additional ports are placed. Port sites are marked out as demonstrated in Fig. 29.2. A peri-umbilical 8 mm port is placed as the robotic camera port (port C), freeing the initial 5 mm port as a

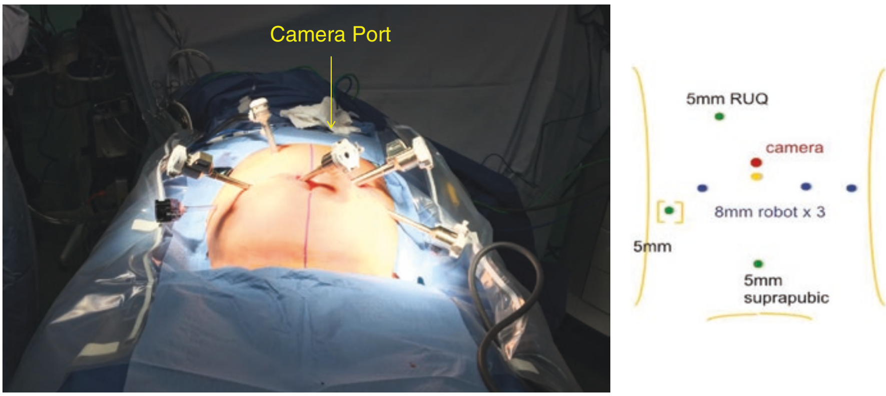

Fig. 29.2 Operative set up depicting port placement for robotic abdominoperineal resection. The image shows the port placement for an Xi robotic APR. Options include upsizing the assistant port in the right lower quadrant to accommodate a stapler and placing a suprapubic port as depicted in the drawing

laparoscopic assistant port. Additional 8 mm robotic ports are placed at the same level as the periumbilical port, with one on the right side (A1) and two on the left side (A3 and A4) of the abdomen, while ensuring a distance of approximately 8 cm between all ports. The colostomy site is used a port site whenever possible. An additiona 5 mm laparoscopic working port is typically placed to the right of A1 to facilitate retraction. Finally, an additional suprapubicmidline laparoscopic port may be helpful in patients with deep and narrow pelvis where the reach from other assistant ports may be difficult. An AirSeal port (CONMED AirSeal System, Utica NY) can be utilized at any of the laparoscopic ports.

Once port placement is complete, the patient is positioned in Trendelenburg position at a 10–15-degree angle as tolerated and with left side up, to facilitate exposure of the pelvis and the sigmoid colon. The small bowel is moved out of the pelvis and to the right upper quadrant exposing the mesentery overlying the sacral promontory.

The robot is typically docked at a 45-degree angle over the left leg. The camera is placed through the peri-umbilical robot port and targeted to the pelvis slightly toward the left sidewall. Instruments are introduced under direct visualization and parked in the operative field. We typically utilize curved scissors with monopolar power in robotic arm 4 introduced through port A1, atraumatic grasping forceps with bipolar power in robotic arm 2 introduced through port A3, and the tip-up or a similar instrument introduced through port A4 and used as the third/retracting arm. The bedside assistant can utilize any of the 5 mm laparoscopic ports, as needed. If the use of a robotic stapler is anticipated for proximal transection of the colon, then consideration should be given to placing a 12 mm robotic port that can accommodate the stapler but can also be downsized to a 8 mm robotic port for dissection.

A visual check is performed at this time to ensure safety, exposure and mobility through the remainder of the case. Care is taken to ensure that all robot ports are adequately cleared from the abdominal wall without exerting excessive pressure or distortion, that adequate spatial clearance exists between adjacent robotic arms, and that the entire length of the robotics arms are cleared from the patient's body or extremities. Maximizing the patient clearance option further decreases arm clashes.

Troubleshooting

- Safe entry into the abdominal cavity to establish pneumoperitoneum can pose a challenge depending on body habitus, prior surgery, and/or surgeon preference. Veress Needle offers an alternative to the Optiview technique, but Hasson (open) technique can be utilized if a 12 mm port is used for the stapler.
- Obesity can pose several challenges. Extra care should be taken to ensure that Trendelenburg position does not compromise respiratory status of the patient and that all extremities are free from external pressure. The small bowel mesentery can be thick and foreshortened, making exposure of the vasculature difficult. Taking time to adequately move all of the small bowel out of the pelvis and to the right of the patient can facilitate the remainder of the case and inserting a moist radiopaque gauze can aid in retraction.
- In the female pelvis, a bulky uterus can obstruct the view to the pelvis and it can be elevated towards the anterior abdominal wall using retracting sutures placed transabdominally.

Step 2: Vascular Dissection and Identification of the inferior mesenteric artery

A medial to lateral approach is utilized. The sigmoid colon is retracted laterally and lifted away from the retroperitoneum utilizing the retracting robotic arm. With the medial aspect of the sigmoid mesentery on stretch, we incise the peritoneum at the junction of the sigmoid mesentery and the retroperitoneum using the monopolar shears. This area is typically just cephalad to the sacral promontory and the proper plane can be identified by relaxing and stretching the sigmoid mesentery and noticing the tension on the tissues and the difference in hue between the fatty layers. Gentle dissection is begun as the division of the peritoneum is carried cephalad and caudad. The posterior wall of the superior rectal artery (SRA) is identified by its arterial pulsations and followed cephalad. In a plane that is more lateral and retroperitoneal, the location of the iliac artery can be identified along with the left ureter (Fig. 29.3). The left hand at this time holds a bipolar grasper device for more accurate dissection and hemostasis. Dissection of the SRA is continued cephalad until the origin of the inferior mesenteric artery (IMA) from the aorta is encountered. There are several approaches to adequate regional lymphadenectomy around the IMA during an APR [5]. The authors favor performing a complete lymphadenectomy surrounding the origin of the IMA, skeletonizingits branches while dissect the nodal tissue away from the ascending branch to the splenic flexure and the left colonic branch. After this, the SRA and the sigmoidal branches are isolated and controlled just after the takeoff of the left colonic branch; vessels are ligated individually using Hem-o-lock clips and divided using the shears. Prior to ligating the vessels, the location of the ureter in the retroperitoneum and the location of the IMV are confirmed. This approach allows preservation of the left colonic artery without compromising lymphadenectomy. An alternative approach of regional lymphadenectomy is performing a high ligation of the IMA and resection of the associated nodal-bearing mesentery (Fig. 29.4). Ligating the IMA at the aortic take off will typically provide significant colonic length and allow for a tension-free reach to the

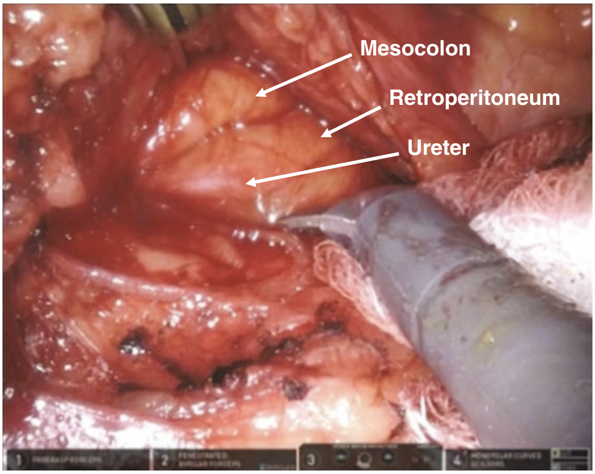

Fig. 29.3 Demonstration of identification of the left ureter. As the sigmoid mesocolon is elevated off of the retroperitoneum, the ureter can be identified as it crosses over the iliac vessels. Identification of the left ureter helps to ensure the proper plane is dissected and protects the ureter during further mobilization of the mesocolon and completion of the lymphovascular dissection

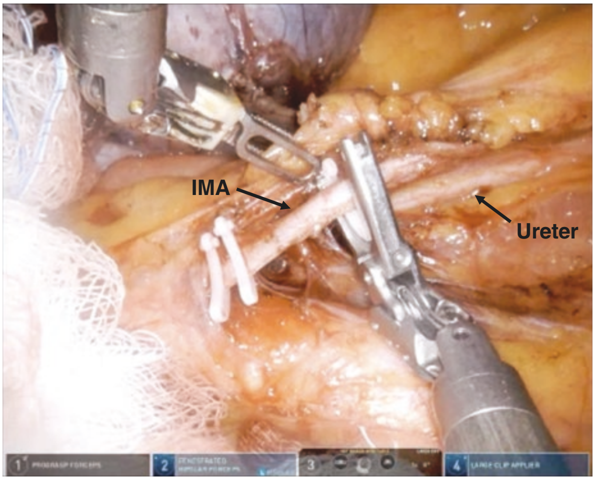

Fig. 29.4 High Ligation of inferior mesenteric artery (IMA). Careful dissection along the superior hemorrhoidal vessels up to the origin of the IMA yields a complete lymphadenectomy of at risk lymph nodes for locally advanced rectal cancer. The ureter is identified prior to division of the vessel

abdominal wall for an end colostomy. This may be particularly suitable for patients with a low IMA take off, with truncal obesity, or in whom extra colonic length and mobility is needed.

Troubleshooting

- While not typically required for an APR, ligation of the IMA and inferior mesenteric vein (IMV) can be performed to provide additional length of the colon mesentery if needed.

Step 3: Colonic Mobilization

After vascular dissection and ligation, space is created for medial to lateral mobilization of the colonic mesentery. This dissection is carried also cephalad toward the splenic flexure in case its mobilization is needed. Care should be taken to stay within the correct tissue plane and avoid violating the Gerota's fat or the pancreas. Then circumferential mobilization is completed with lateral dissection, by scoring just medial to the white line of Toldtusing monopolar shears. Gentle blunt dissection will establish the plane separating the colonic mesentery from the retroperitoneum. By adjusting the tension on the medial retraction of the colon, this alveolar plane of dissection is carried cephalad and caudad. Care is taken to avoid injury to adnexal structures and the ureter when dissecting along the left lower quadrant. As this dissection meets the prior dissection plane achieved through the medial approach, the colon is circumferentially mobilized. After this, the putative point of proximal transection is assessed based on prior vascular dissection, the adequacy of oncologic margin, and the quality of the colonic tissue and of vascular supply.

Full mobilization of the splenic flexure may or may not be necessary during an APR and should be determined by assessing whether the colon, after proximal transection, can reach the pre-marked colostomy site. If splenic flexure mobilization were needed, it can be accomplished by taking down the spleno-colic, gastro-colic, and omento-colic attachments.

Whether proximal division of the colon is completed here or later after rectal mobilization can be decided based on surgeon preference and patient anatomy. If mesenteric division were performed, then mesentery is divided after ensuring resection of relevant nodal tissue, typically just distal to the left colic vessel utilizing a robotic or a laparoscopic vessel sealing device. The marginal artery is dissected out and separately controlled with additional vascular clips. Finally, the colon is then divided using a robotic linear stapler.

Troubleshooting

- In patients with a highly redundant sigmoid colon, the natural colonic attachments tethering it toward the left abdominal wall can help with exposure. A 'pelvis first approach' can be considered, where the colonic attachments are left in place, and the proctectomy portion of the case (step 4 below) is started prior to completing colonic mobilization (step 3 above). This avoids the need to maneuver and retract a highly redundant colon [6].
- If splenic flexure mobilization is necessary but difficult, the patient can be moved into to a slight reverse Trendelenburg position. This can be achieved without undocking if the robotic table is paired with the robotic platform. To avoid the need to redock, an alternative approach is to leave this portion to the end of the proctectomy portion of the procedure, where it can be completed either robotically or laparoscopically.

Step 4: Proctectomy

a. **Rectal mobilization and Total Mesorectal Excision (TME)**

Rectal mobilization preserving the integrity of the total mesorectum is oncologically critical. The sigmoid colon is grasped by the laparoscopic assistant and retracted up and out of the pelvis. The dissection begins by following the areolar plane just posterior to the superior rectal artery previously started at the sacral promontory. This plane is carefully followed into the presacral space using a monopolar energy device. We prefer to use the monopolar shears through port A1,as it does not collapse tissue planes but rather allows areolar planes to manifest. The left hand in A3 actively provides counter retraction close to the point of dissection. We prefer to use a bipolar device to allow control of any bleeding if necessary. The posterior dissection is continued caudally down to the pelvic floor (Fig. 29.5). The posterior dissection plane is then carried to the left and right for lateral dissection. It is important to be vigilant about the course of the inferior hypogastric and the sacral nerve plexus to avoid injury. Gaining adequate retraction and counter-retraction, and maintaining a dry operating field clear of smoke, aid visualization and reduce the risks of injury.

For the anterior dissection, the rectosigmoid is retracted out of the pelvis and pushed posterior. The anterior peritoneal reflection at the rectovesicular or rectouterine pouch is identified by using a retracting instrument from A4, and a counter-retracting instrument from A2 (Fig. 29.6). The demonstrated alveolar plane can be incised using the dissecting instrument from A1. If the tumor is anterior, then dissection is carried anterior to Denonvilliers' fascia. Care should be taken to avoid

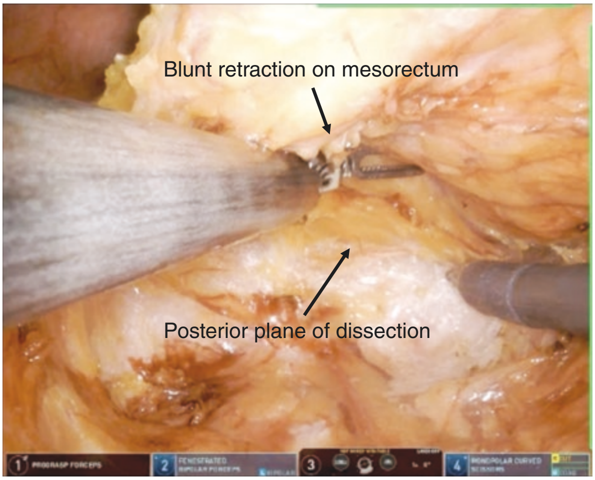

Fig. 29.5 Posterior dissection for total mesorectal excision for abdominoperineal resection. The posterior dissection is typically the safest place to start the pelvic dissection. Gentle retraction of the mesorectum anteriorly is important to maintain the completeness of the mesorectum and avoid disruption

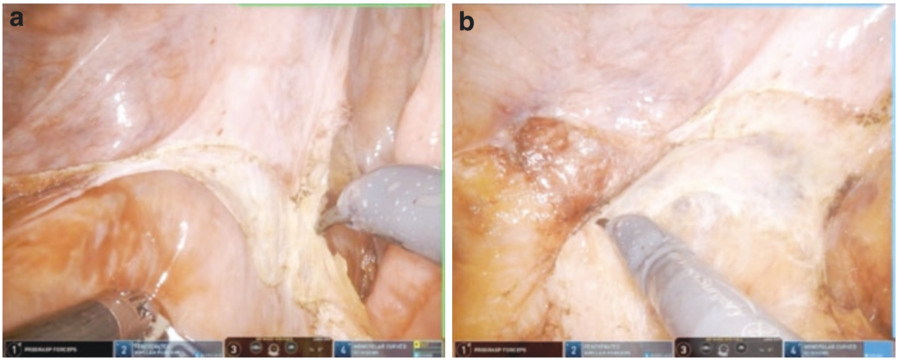

Fig. 29.6 Anterior total mesorectal excision dissection for abdominoperineal resection. The anterior dissection can be challenging, but identifying the planes posteriorly and laterally can help. Depicted in part A is the initial dissection of the rectouterine peritoneum and then in part B, further distal dissection in the anterior mesorectal plane posterior to the vagina is demonstrated

injury to the sympathetic plexus along the seminal vesicles in the male and to the vaginal wall in the female.

b. **Division of levator ani**

The final portion of the low pelvic dissection toward the top of the sphincter complex and the division of levator ani should be performed with the configuration of the specific tumor in mind. The operative surgeon should understand if there is tumor involvement along the central axis of the sphincter complex, or if there is tumor involvement radially and laterally along the levator ani muscle, or if there is a combination of these. In order to avoid breaching the malignant tissue planes and to ensure adequate oncologic resection margins, dissection along the normal TME

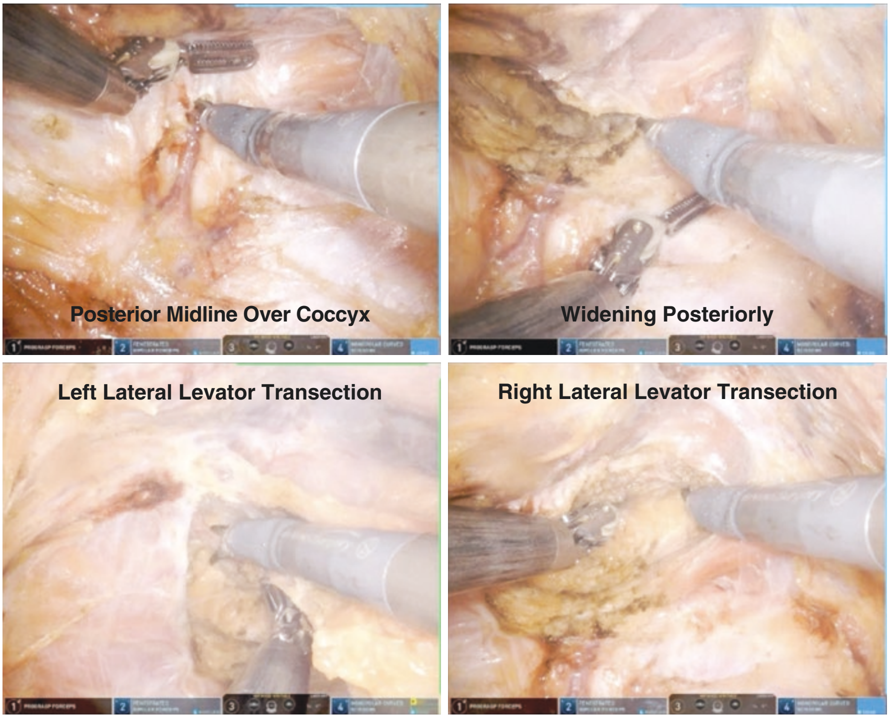

Fig. 29.7 Robotic laparoscopic division of the levator ani muscles transabdominally. With adequate retraction and exposure, the levator ani muscles can be identified transabdominally. The division typically starts posteriorly after "palpating" the coccyx with the scissors. The muscles can then be divided exposing the ischiorectal fat. The transection can then be extended bilaterally

plane should be halted without disturbing areas of sphincter complex or of levator involvement. Once circumferential dissection to the appropriate level is complete, then the levator ani is incised widely. This can be accomplished transabdominally if visualization allows (Fig. 29.7), or transperineally. Halting the TME dissection at appropriate location and dividing the levator widely are critical for preventing "coning" of the specimen (Fig. 29.8)

Troubleshooting

- The most common challenges relate to exposure, due to unfavorable body habitus or significant redundancy of pelvic organs. Redundant pelvic organs can be mitigated by retraction options including leaving sigmoid mobilization until after the pelvic dissection or using transabdominal sutures for gynecologic organs as described above. Another technique is to wrap a Ray-Tec gauze around the rectosigmoid junction or upper rectum which can be used by the bedside assistant as a handle for retraction. Countertraction on the rectum or pelvic side wall by the assistant should be maximized, and a laparoscopic suction device can be used for this. It would also enable intermittent suction of smoke or blood.

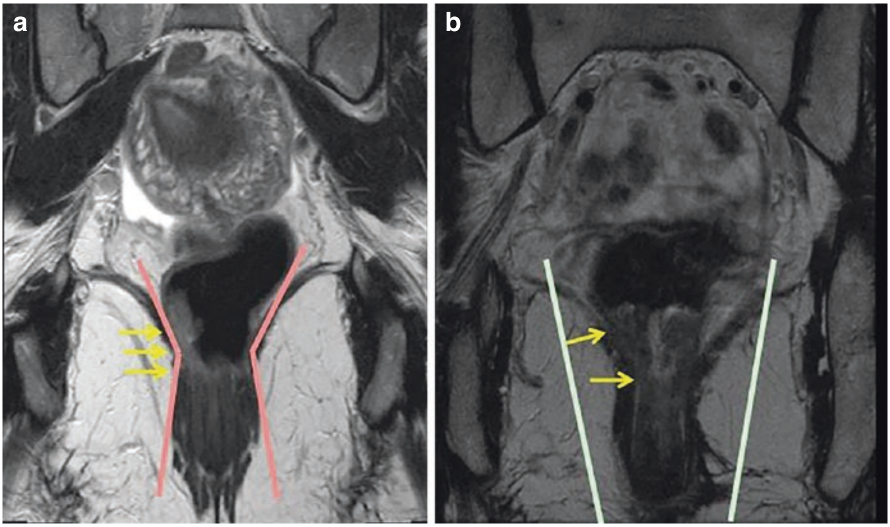

Fig. 29.8 Wide division of the levator ani muscles to avoid positive margin resection. Approaching the levator ani muscles for a wide resection (**b**) to avoid coning or waisting (**a**) of the specimen at the level of the anal canal can help avoid a positive margin during resection of distal rectal cancers

Step 5: Siting of the end colostomy

The proximal division of the colon can be completed at this point using the robotic stapler if not previously completed already. The cut end is identified and grasped using a laparoscopic instrument. The authors typically undock the robot at this time and utilize a laparoscopic camera. Externally, the pre-marked site on the abdominal wall is prepared. A circular incision is made on the skin and carried down to the fascia. After incising the anterior rectus fascia, the muscle is split and the posterior fascia and peritoneum are incised and the defect enlarged. The colon is delivered under laparoscopic vision and sited to the appropriate length to be matured at completion of the case. The pneumoperitoneum can be re-established to re-assure that the mesentery is not twisted.

Troubleshooting

- If the colon is discovered to have been inadequately mobilized for tension-free reach to the colostomy site at this time, then laparoscopic assisted splenic flexure mobilization can be accomplished at this point.

Step 6: Perineal Resection

The perineal resection can be accomplished with the patient in lithotomy position or in prone position. The authors typically perform the perineal dissection in high lithotomy position. But the prone position offers superior visualization of the anterior dissection plane along the prostate and may be particularly advantageous for bulky, locally-invasive anterior tumors; however, careful coordination with anesthesia and nursing teams is required for safe position change of the patient under anesthesia.

An elliptical perianal incision is made outside of the sphincter complex. Soft tissue is dissected until bilateral ischiorectal fossa are entered. After further dissection, the tip of the coccyx is palpated posteriorly. Further dissection is carried out bilaterally. A perineal St. Marks retractor is often used to aid exposure. The levator ani musclesare typically divided just anterior to the coccyx if this was not completed transabdominally. After full thickness muscle division, the empty retrorectal and presacral space is palpated to confirm that the transabdominal and the perineal dissection planes are connected. The levator ani is then divided widely; this is typically greatly facilitated by transabdominal levator division if it had been able to be completed. Anterior dissection is typically left to the end as it is the most challenging. Care should be taken to not violate the posterior vaginal wall, the prostate, or the urethra.

Removal of the specimen from the operative field can be accomplished through the perineal wound or through a separate low transverse abdominal wound. A separate incision is favored in patients with bulky mesorectum, large tumor, narrow pelvis, or had an intersphincteric resection. In those cases, negotiating the specimen through a narrow pelvis may risk mesorectal disruption and inadvertent tumor spillage. Finally, the pelvis is inspected and hemostasis is achieved. We typically place a 19Fr Blake drain through a left lateral port into the deep pelvis.

Troubleshooting

- Anterior dissection can be challenging due to obliteration of the normal tissue planes by radiation and by tissue inflammation. The operative surgeon must be cognizant of the extent of the malignant tumor and take extra care if the tumor is anterior. Frequent palpation, maintaining hemostasis and adequate visual fields are critical. Inadvertent perforation of the rectum during this portion of the dissection has been shown to be associated with risks for inferior oncologic outcomes.
- Bleeding during perineal dissection can occur from muscular, peri-prostatic or peri-vaginal soft tissues. When direct electrocautery is ineffective for hemostasis, figure of 8 suture ligature should be utilized to avoid thermal injury to vaginal wall or the prostate.

Step 7: Management of the perineal wound

Plans and options for management of the perineal wound should be established preoperatively in collaboration with Plastic and Reconstructive surgery. In most oncologic cases that required wide division of the levator ani, primary closure is no longer an option. When preoperative radiation had taken place, advancing non-radiated soft tissue for closure aids healing. Options include omental advancement flap, myofascial flap, or myocutaneous flap. The most common scenario encountered is a patient who needs soft tissue filling of the hollow presacral space. Omental flaps are suitable for patients with a bulky omentum and robust blood supply, while myofascial flaps can be used when omentum is not suitable [7]. Commonly utilized muscles include the rectus, the vastus lateralis, and the gluteus. Those patients who had a wide incision at the perineal skin level benefit from pedicled myocutaneous flaps. The most commonly used is the vertical rectus abdominus myocutaneous (VRAM) flap with attached abdominal wall skin pedicle [8]. Finally, in patients where an intersphincteric APR had been performed, the external sphincter musculature and the levator ani have remained largely intact. In these cases, the perineal wound is likely amendable for primary closure. This is typically accomplished with figure-of-eight sutures from posterior to anterior in layers using 0-vicryl and then 2-0 Vicryl.

Troubleshooting

- We emphasize here that the management plan of the perineal wound must be established preoperatively. We favor a plan that includes multiple options. For example, if omentum is recognized intraoperatively as inadequate, we favor to have already established secondary options for myofascial flaps. Expertise in harvesting and siting reconstruction flaps minimally-invasively can be limited. Therefore, coordination for incision and port placements, transitioning into and out of pneumoperitoneum, and sequence of procedure components should be discussed preoperatively. For example, an omental flap would typically be harvested prior to perineal resection when the pneumoperitoneum is still maintained. It can be accomplished robotically by rotating and redocking the robot toward the LUQ, or laparoscopically after the robot is undocked. Similarly, minimally-invasive harvesting of a soft tissue flap is typically performed prior to completion of perineal resection.

Step 8: Closure and colostomy maturation

The abdomen is inspected and the ports are removed. If an incision had been made for specimen removal, then it should be closed in the usual fashion. We do not close 8 mm or smaller minimal access port sites.

The end colostomy is typically matured with a slight height protruding from skin. This is accomplished using three to four Brooke sutures (3-0 Vicryl) placed circumferentially while avoiding the colonic mesentery. Additional sutures are placed to fill any gaps to the mucocutaneous junction. A colostomy appliance is then placed.

29.5 Postoperative Management

Routine postoperative care includes opioid-sparing analgesia, sensible dietary progression, and early ambulation. Thromboembolic prophylaxis is routine and is typically continued for 28 days postoperatively. Urinary catheter is removed typically on postoperative day 3. Wound ostomy teaching is commenced on postoperative day 2 to 3 and continued to discharge. Patient and family members should demonstrate proficiency in ostomy care prior to discharge.

Perineal wound complications, most commonly infectious, can occur in up to 30% of the patients. Daily inspection of the perineal wound is required. When a myocutaneous flap has been performed, daily inspection of the visible pedicled skin is critical for assessing the status of the flap perfusion. Signs that may be consistent with a superficial or deep wound infection should prompt early re-opening and debridement of the wound. We typically limit direct sitting to no more than 20 minutes at a time and encourage the use of a well-padded flat cushion as opposed to a donut shaped cushion.

Conflict of Interest The authors have no conflict of interest to disclose.

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Chapter 30
Transanal Total Mesorectal Excision

Allison A. Aka, Jesse P. Wright, and John R. T. Monson

30.1 Introduction

The surgical management of rectal cancer has evolved significantly over the last several decades. From invasive, radical resection, to minimally invasive local excision (TEMS, TAMIS, etc.) and even nonoperative management of lesions treated in the neoadjuvant setting (watch and wait), rectal surgeons of the twenty-first century are required to be fluentina myriad of surgical and medical management strategies and approaches. Most recently, transanal total mesorectal excision, or taTME, has been developed to provide a minimally invasive transanal approach for mid to low rectal cancer that would otherwise be difficult to manage from a routine transabdominal approach. Despite encouraging outcomes from initial studies [1–3], the approach-specific complication profile and increasing concern for inferior oncologic outcomes, specifically increased rates of local recurrence, have kept taTME from being universally adopted. In 2019, taTME data from Norway showed a 9.5% local recurrence rate, with a short median of 11 months after surgery, which led to the Norwegian moratorium on taTME pending a national audit [4–6]. With new instrumentation, setup, and decreased familiarity with non-traditional dissection planes, there are several different variables that contribute to the steep learning curve for the unfamiliar surgeon. Understanding basic principles of transanal surgical platforms, a bottom-up anatomic perspective and the effects of pneumodissection on surgical planes are key components to success. Hesitancy for universal adoption is to be expected when possible perioperative morbidities include

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anastomotic failure, urethral injury, bleeding, splanchnic and inferior hypogastric plexus injury, obturator neurovascular injury, and failure to obtain TME. As such, simulation, proctored courses, intense video review, and personal feedback are essential to overcome the steep learning curve and to minimize common pitfalls and complications. This chapter aims to provide step-by-step instruction for safe, effective, and efficient taTME dissection for surgeons learning this new approach.

30.2 Clinical Presentation

Rectal cancer can present in a variety of ways, from the asymptomatic tumors found on screening colonoscopy to the patient who presents with a complete large bowel obstruction. Signs and symptoms that may prompt endoscopic evaluation include blood per rectum, change in stool caliber, constipation, or abdominal pain. Patients may only be referred for colonoscopy after a positive fecal occult blood test or anemia is noted on routine labs.

30.3 Preoperative Evaluation

Patient selection and preoperative workup play a key role in successful taTME. While this technique may be utilized in both benign and malignant conditions, certain patient and tumor characteristics make the taTME approach more advantageous: (1) male gender, (2) narrow and/or deep pelvis, (3) BMI > 30, (4) tumor < 12 cm from the anal verge, (5) tumor diameter > 4 cm, (6) prostatic hypertrophy, (7) impalpable rectal tumor that necessitates choosing a precise distal resection margin, and (8) neoadjuvant radiotherapy resulting in unclear dissection planes [7, 8]. Just as with all rectal cancer cases, proper oncologic workup and staging are essential, including a full history and physical exam, basic laboratory evaluation, complete colonoscopy, carcinoembryonic antigen (CEA) level, rectal cancer protocol MRI or endorectal ultrasound (EUS),and computed tomography (CT) of the chest, abdomen, and pelvis, as recommended by the American Society of Colon and Rectal Surgeons (ASCRS) [9]. Preoperative stoma marking andeducation is recommended when an ostomy is being considered, as this has been shown to decrease hospital length of stay, decrease the time needed for patient competency in ostomy management, and decrease medical costs by reducing stoma-related interventions [9, 10].

30.3.1 Endoscopic Evaluation

Colonoscopy remains the gold standard for colorectal cancer screening. In 2018, data from the American Cancer Society emerged detailing the increased incidence of colon and rectal cancer in the United States. In response to these data, screening colonoscopy is now recommended to begin at age 45 in average-risk patient [11, 12]. Colonoscopy permitse valuation for synchronous tumors that may alter treatment planning, tissue sampling, and have the potential for therapeutic intervention. Rigid proctoscopy is an important tool to confirm the tumor distance from the anal verge, which may vary when a flexible endoscope is used.

30.3.2 Rectal MRI

Depth of tumor invasion, involvement of adjacent pelvic organs, assessment of circumferential resection margin (CRM), tumor relationship to the mesorectal fascia (MRF), and regional lymphadenopathy arebest evaluated with rectal MRI, both in the pretreatment and posttreatment settings [13–17]. While endorectal ultrasound is still utilized, especially in the absence of high resolution MRI, results and interpretation still remain operator dependent [15]. Furthermore, MRI in conjunction with endoscopic and physical examination results in the most accurate estimate of tumor height/distance from the anal verge and isa critical factor when determining the appropriate candidate for a taTME approach [18].

30.3.3 Computed Tomography Chest, Abdomen, Pelvis

In the setting of colorectal cancer, appropriate staging includes a complete computed tomography (CT) scan. A non-contrast CT of the chest evaluates the chest for pulmonary metastases which are present in 4–9% of patients [19, 20]. An intravenously contrasted CT of the abdomen and pelvis helps delineate anatomy and assess for distant disease. It is not as accurate as rectal MRI or endoscopic ultrasound in determining tumor penetration and lymph node involvement [15, 17].

30.4 Operative Technique

1. **Position of the patient and OR setup**

The patient should be placed in the Lloyd-Davies position on the operating table on a non-slide foam panel or bean bag, as both steep Trendelenburg and reverse Trendelenburg will be used during the procedure. After induction of general endotracheal anesthesia, the arms are tucked and a Foley catheter is placed. The surgeon and assistant will mostly stand on the patient's right and in between the legs, depending on the phase of the procedure.

Two sets of laparoscopic instruments and monitors are necessary. Two back table set-ups are necessary as well—one for the transabdominal equipment (to remain sterile) and the second table for the transanal equipment (remain contaminated). Care should be taken to minimize cross contamination between the different setups. Ideally two teams can work simultaneously, one from above, intra abdominally, and the other from below, trans-anally, to decrease operative time and to help retract for each other once the dissection planes begin tojoin. It is most efficient to allow the abdominal team to start with splenic flexure mobilization as the steep Trendelenburg and right tilt position makes a simultaneous trans-anal approach very challenging. Once the abdominal team begins the pelvic dissection, then the right tilt can be removed and the trans-anal dissection can begin with the second team. The two-team approach also aids mutual learning between several surgeons, which is an important component when introducing such technology (Fig. 30.1).

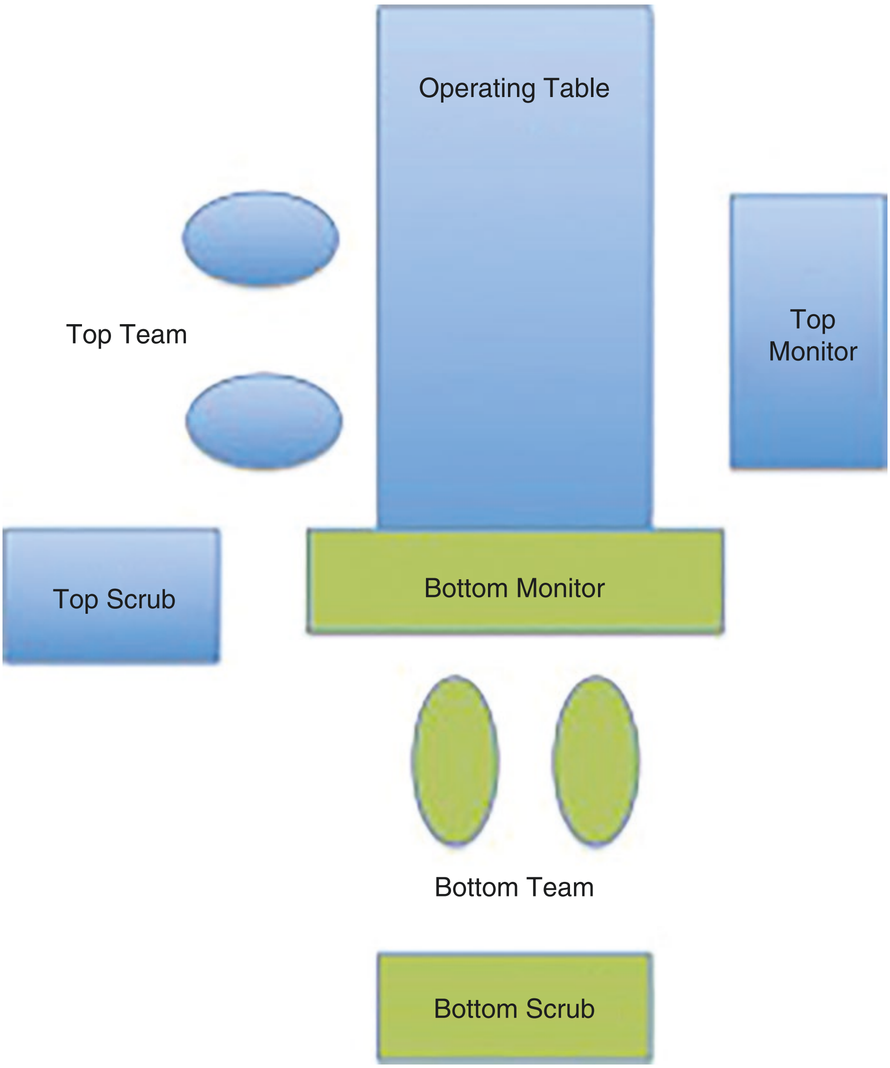

Fig. 30.1 Operating room setup

30.5 Transabdominal Steps

2. **Trocar placement**

We usefour, 5-mm ports for the transabdominal portion of the procedure.Thefirst port is placed through the umbilicus, pneumoperitoneum is established and the abdomen is insufflated to 15 mmHg using CO2. A 5 mm-30° laparoscope is inserted and the abdomen is thoroughly inspected for initial trocar injury to the underlying viscera or any evidence of metastatic disease. Two 5-mm working ports are placed in the right upper quadrant and right lower quadrant, in such a way to maximize access to the left colon. A third working 5-mm port may be placed in the left flank if need be. Our preference is to use the AirSeal insufflation system (Conmed, Utica, NY) for both components of the surgery and one of the 5 mm port locations is chosen—usually the right flank (Fig. 30.2).

Troubleshooting: Trocars should be placed at least a hands breadth apart to avoid collision and appropriate triangularization of the left-colon and rectum.

3. **Medial to lateral mobilization of the splenic flexure with ligation of the inferior mesenteric vein and inferior mesentery artery**

The patient is placed in steep Trendelenburg and left side up. The omentum is flipped cephalad over the colon and the small bowel swept to the right upper

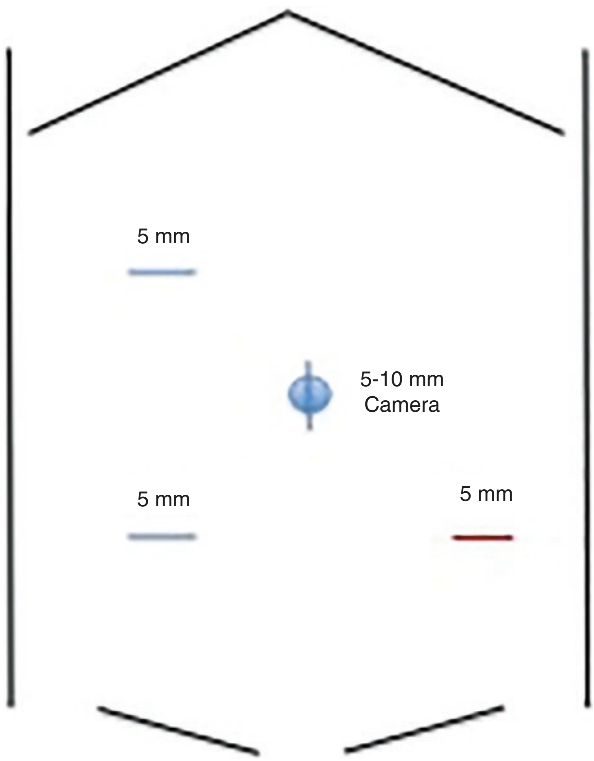

Fig. 30.2 Trocar placement—Blue trocars are standard, red trocar is optional

quadrant, giving an unimpeded view of the colonic and small bowel mesentery. The ligament of Treitz is visualized, and the origin of the IMV pedicle is identified as it emerges from the duodenal-jejunal flexure. The proximal most-IMV pedicle is gently elevated anteriorly, and peritoneum is incised posterior to and in parallel with the vein using monopolar cautery. The embryologic plane between the colonic mesentery (anterior) and retroperitoneum (posterior) is developed bluntly in a medial to lateral direction, heading over Gerota's fascia and towards the abdominal sidewall. The dissection extends superiorly over the pancreas and into the lesser sac. The IMV can be ligated between clips at its origin (Fig. 30.3).

As the dissection is carried inferiorly, the inferior mesenteric artery pedicle will be encountered. The sigmoid colon is elevated such that the IMA pedicle is tented anteriorly. The peritoneum is scored parallel to the vessel, and a dissection plane is created beneath the IMA, aiming for the already completed medial dissection superiorly. Once the left ureter and other gonadal vessels have been identified and safely dissected away (posterior), the IMA is skeletonized, isolated and divided using the LigaSure (Medtronic Inc., Boulder, CO) device (Fig. 30.4).Once the medial dissection is complete, attention is turned to the lateral colonic dissection.

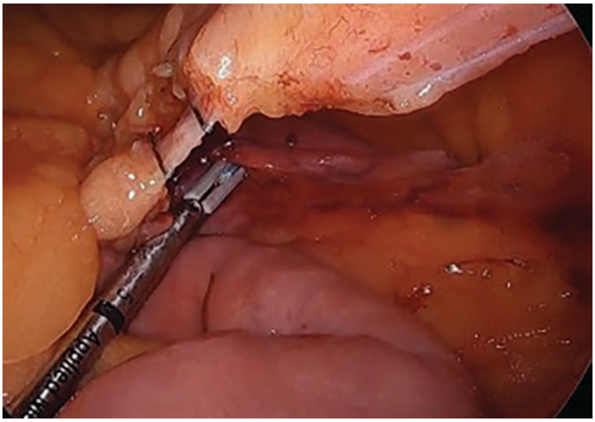

Fig. 30.3 Medial to lateral dissection for splenic flexure mobilization with IMV clipped

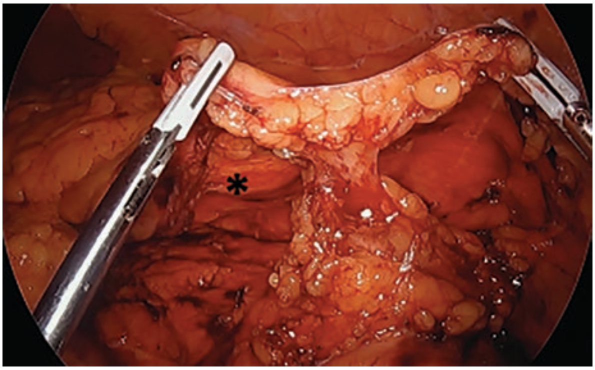

Fig. 30.4 Inferior mesenteric artery pedicle; * = splenic flexure medial to lateral dissection

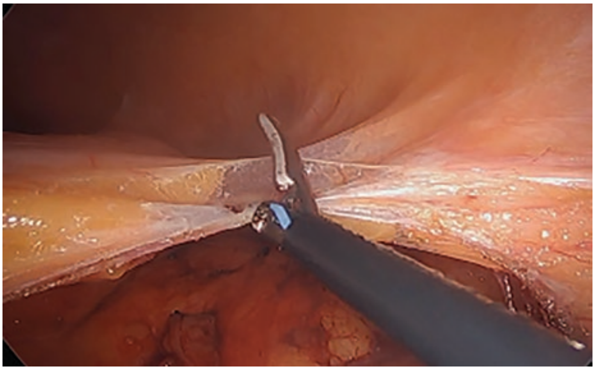

Fig. 30.5 Dissection of lateral peritoneal attachments (white line of Toldt). The medial to lateral dissection can be seen deep to the colon

The sigmoid colon is grasped and retracted medially. The lateral colonic peritoneal attachments (white line of Toldt) can be divided sharply and taken superiorly towards the splenic flexure, again taking care to identify and preserve the left ureter as it courses over the pelvic brim and down to the bladder (Fig. 30.5).As dissection is carried around the splenic flexure, a plane is developed between the omentum and transverse colon. If anatomy prevents visualization from this angle, then dissection can be switched to the mid transverse colon by entering the lesser sac and progressing towards the splenic flexure.

Troubleshooting: The distance of omental dissection along the transverse colon is dependent on how much mobility is necessary to complete a tension-free anastomosis. Proximal ligation of the IMV earlier in the dissection can offer considerable length. Indocyanine green fluorescence angiography can be utilized later in the procedure to confirm perfusion of the conduit prior to anastomosis.

4. **Division of the pelvic peritoneum**

The sigmoid is retracted anteriorly and medially and the peritoneal attachments that anchor the sigmoid to the peritoneal reflection of the left pelvic wall are divided. The peritoneum is incised down to the cul-de-sac. A similar technique is used for the right side of the rectosigmoid colon after swinging the retracted sigmoid anteriorly and laterally to the left, with the peritoneum being incised lateral to the inferior mesenteric and superior hemorrhoidal vessels, carried down to the pouch of Douglas. The right ureter is identified and preserved. Continued TME dissection of the avascular, areolar Holy Planeseparating the parietal and visceral layers of the endopelvic fasciaand is taken as low as possible prior to proceeding to the transanal portion (Fig. 30.6a–c) [21].

Troubleshooting: The correct dissection plane is identified by wispy areolar tissue that has minimal bleeding. Dissection in this avascular "Holy Plane" allows for the removal of the mesorectum en bloc with the rectum, with the fatty tissues containing the neurovascular structures and lymph nodes of the rectum. Removal of an intact mesorectum is necessary for a complete oncologic resection [22].Significant bleeding can be an indication of incorrect dissection planes.

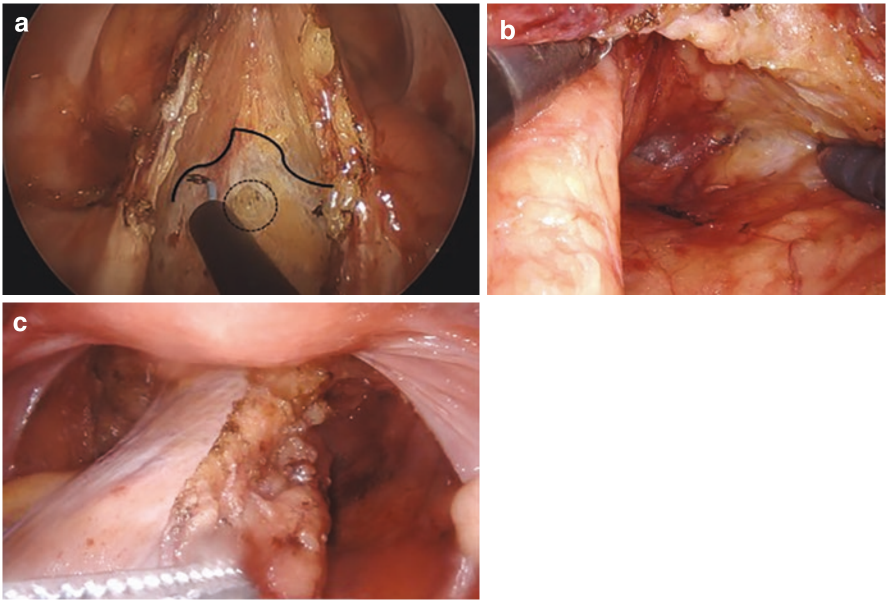

Fig. 30.6 (**a**) TME dissection—Solid line: Loose areolar tissue as the dissection landmark. Dashed circle: Wrong dissection plane (too deep) [21]. (**b**) Holy Plane. (**c**) Completed TME with the rectum being retracted out of the pelvis

30.6 Transanal Steps

5. **Introduction of TAMIS port**

Exposure is critical during any transanal approach. As such, we utilize the Lone Star retractor (Cooper Surgical, Inc., Trumbull, CT) to aid in the effacement of the anal verge. We then place a GelPointe anal access retractor (Applied Medical, Rancho Santa Margarita, CA) (available in 4 cm × 4 cm, 4 cm × 5.5 cm, and 4 cm × 9 cm sizes), which is best placed by folding the canal portion of the retractor and clamping it with a ringed grasper (i.e. Kelly-clamp) in order to effectively maneuver it into the anal canal. The obturator is then inserted to the trocar to fully deliver it circumferentially into the anal canal. Secure the trocar to the skin with a stitch. The cap of the access channel is prepared by placing the trocars and camera port prior to securing it to the retractor. A triangulated formation, with 5-mm AirSeal (Conmed, Utica, NY) trocar at the top and two GelPointe ports on the bottom (Fig. 30.7a and b). The next step is to activate the AirSeal and set pressures to 12 mm Hg. It is sometimes useful to clamp the colon proximally with a laparoscopic instrument in order to maintain pneumorectum until the pursestring is created.

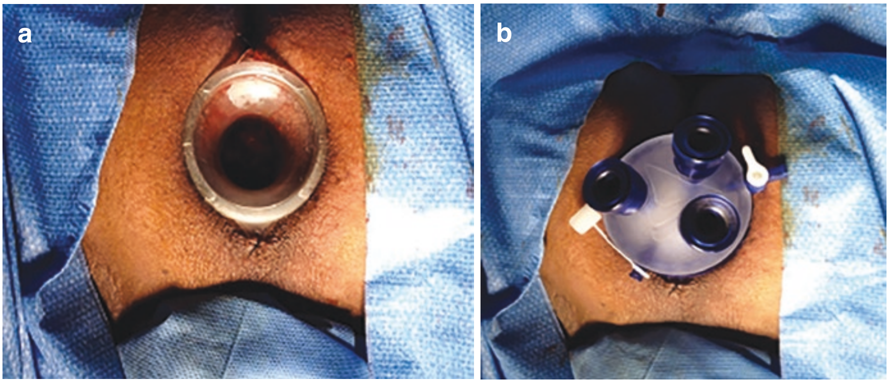

Fig. 30.7 (**a**) Transanal access channel. (**b**) Transanal access channel with ports. (Note: AirSeal port not utilized in this figure)

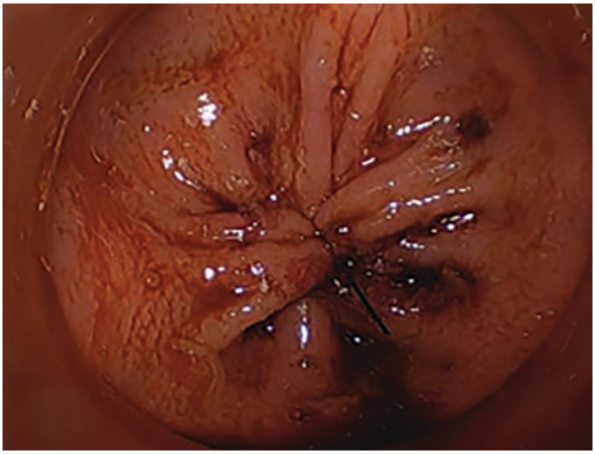

Fig. 30.8 Pursestring suture

6. **Pursestring suture**

One of the most important steps of successful taTME dissection is placement of a circumferential submucosal pursestring suture distal to the pathology. Acting as the distal-most margin for the oncologic resection, correct purse string placement is crucial. This purse string is also used to effectively maintain pneumorectum, prevent proximal colonic distension, augment pneumo-dissection, and prevent spillage of fecal material into the dissection field, which is critical to prevent tumor seeding and potential local recurrence. A 2-0 Prolene (Ethicon, Inc., Somerville, NJ) suture is used to create the pursestring via endoluminal suturing using laparoscopic instruments. Once the suture is in place, the transanal gel-cap can be removed so that the pursestring knot can be tightly secured. The closure should be tested by attempting to pass forceps through the center of the pursestring prior to re-insufflation. Any defect at this point should be corrected by either placing a figure of eight suture or redoing the pursestring altogether (Fig. 30.8).A washout of the distal anorectum with betadine should be performed after completing the pursestring. The cap is then replaced and pneumorectum re-established. The proximal colon can be unclamped at this point.

Troubleshooting: Electrocautery can be used to mark the area of chosen pursestring, as this helps prevent an insecure or asymmetric closure. Recognition of an incomplete pursestring once proctotomy and dissection has begun should be immediately addressed with defect closure and repeat betadine washout, again to minimize tumor or fecal contamination, as local recurrence after rectal perforation during abdominoperineal resections has been described, possibly secondary to tumor seeding [23]. An endoloop can be utilized to secure around the entire pursestring if dissection has already started. Excessive manipulation of the suture or insufficient suture depth with subsequent avulsion through the mucosa can lead to pursestring failure.

7. **Full thickness proctotomy**

A circumferential margin is marked out using electrocautery distal to the pursestring that allows for adequate tissue to grasp as well as not disrupt the suture. Incision of the rectal wall is circumferentially deepened in a sequential manner to allow for symmetric dissection. This is continued until the perirectal fat is reached, thus creating a full-thickness proctectomy (Fig. 30.9a, b). At this point, the effects of pneumodissection can be better appreciated as dissection in the TME plane is next.

8. **Dissection in the TME plane**

After a full thickness proctotomy, TME dissection should be done in a purposeful, stepwise manner. Circumferential dissection should progress evenly so as to prevent anatomical distortion. When not done in an intentionally ordered fashion, pneumopelvis will tend to push the rectum towards the side of least dissection, which may lead to entry into the wrong plane. Bleeding or visualization of striated muscle must be recognized as intraoperative markers of wrong dissection planes and guarded against at all times. Bipolar energy devices should be minimized so as not to erroneously injure vital structures, especially when one is unsure of the

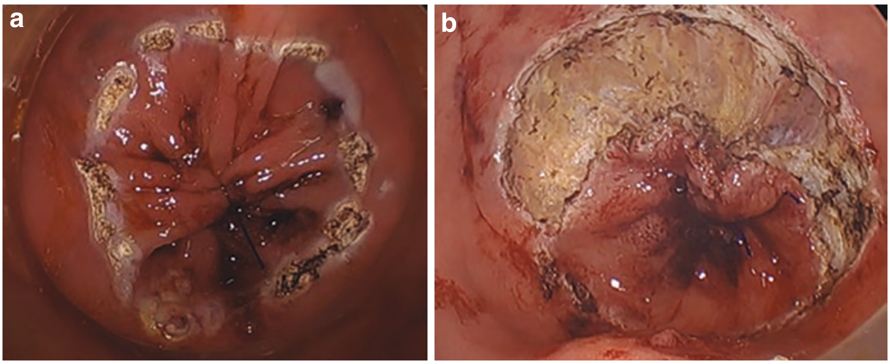

Fig. 30.9 (**a**) Marked out pursestring for proctotomy. (**b**) Full thickness proctotomy

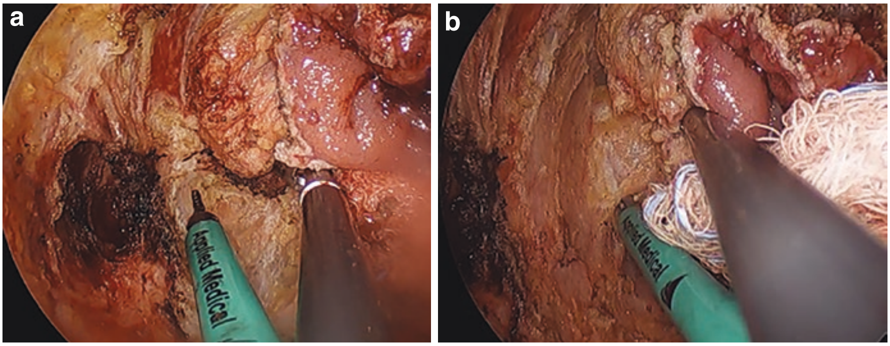

Fig. 30.10 (**a**) Lateral sidewall dissection on left. Correct dissection plane medial to char. (**b**) Transanal total mesorectal excision

dissection plane. The correct dissection plane is composed of loose areolar tissue that should easily be dissected bluntly with minimal electrocautery (Fig. 30.10a, b).

Troubleshooting: Visualization of bare muscle indicated that the dissection plane is too deep. A thin layer of endopelvic fascia will overlay the pelvic floor or muscles of the pelvic sidewall. Transanal surgery can lead to inadvertent pelvic sidewall injury as dissection is carried proximally. This is the most likely error in taTME and landmarks for guidance include the thin layer of endopelvic fascia that overlies the levator ani posterolaterally. Dissection too lateral may lead to injury of the distal branches of the internal iliac vein and artery, or even the inferior hypogastric plexus and S4 nerve root. Deep dissection medially may lead to injury of the obturator nerve, artery, and vein that is contained.

Posterior intramesorectal dissection may be encountered if the natural curvature of the mesorectum is underappreciated. Therefore, dissection should usually be started posterolaterally. Pneumo-dissection between the rectal wall and mesocolon may lead the surgeon into the wrong plane. Encountering the white outer wall of the rectum or any of the perforating blood vessels between the mesocolon and rectal wall should cause the immediate corrective maneuvers to return to the correct plane. It is important to remember that as dissection ascends in the pelvis, the sacrum abruptly curves, which can lead to dissection through the presacral fascia and injury to the presacral venous plexus. Dissection directly on the mesorectal envelope helps to avoid this occurrence but any bleeding during the TME dissection should alert the surgeon of possible wrong plane dissection.

Urethral injury is one of the most feared complications of taTME. While the ureters are not exposed during extraperitoneal rectal dissection, both the bladder and urethra are at risk for injury. Intersphincteric dissection can increase the possibility of urethral injury due to the higher risk of dissection too deep and too lateral, especially when dissection planes are obliterated by radiation, severe proctitis or an anterior tumor. In men, injury to the urethra is the result of improper dissection anterior to the prostate, which is where the urethra lies. Therefore, an initial anterior approach may help improve identification of the rectoprostatic plane and decrease the anatomical distortion that may occur if one were to start the TME dissection in a

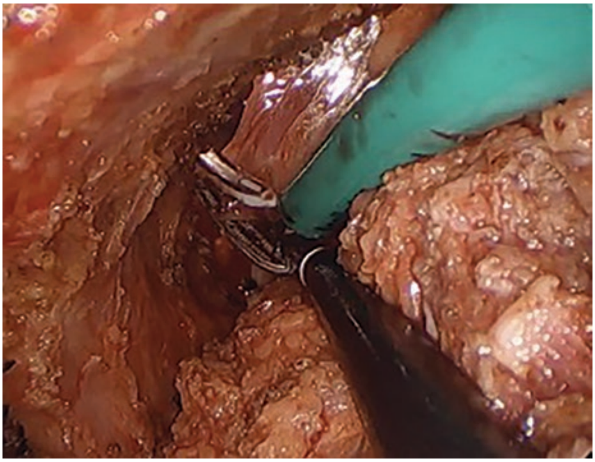

Fig. 30.11 Trans-abdominal and transanal dissections connect

posterior to lateral approach. Encountering a bulky midline structure should prompt immediate reevaluation. Techniques utilized to avoid urethral injuries that have been described include frequent manipulation of the urinary catheter, the use of illuminated ureteral catheters, indocyanine green fluorescence angiography [24–27].

9. **Connection of the transabdominal and transanal dissection planes**

Eventually, the transabdominal and transanal dissection planes will meet. When there are two teams working simultaneously, they can provide improved retraction and dissection for each other as pneumoperitoneum and pneumorectum is compromised once the dissection planes connect. By far the commonest sequence is the taTME surgeon entering through the anterior peritoneal reflection (Fig. 30.11).

10. **Extraction and anastomosis**

Once the rectum is dissected completely free, the specimen can either be extracted transabdominally or transanally. We often extract through a Pfannenstiel incision, utilizing a small Alexis wound protector (Applied Medical, Rancho Santa Margarita, CA) to minimize incision size and contamination. However, other options including trans-anal extraction are entirely reasonable depending upon the specimen size.

We routinely utilize indocyanine green (ICG) fluorescence angiography to better identify bowel perfusion and to guide proximal colonic division. The bowel is then transected using heavy scissors, the cut edge is inspected for adequate blood supply, and the specimen is passed off the table for submission to pathology. The anvil of an EEA-DST (Medtronic Inc) stapler—28 mm is the commonest size employed—is placed into the proximal colon and the pursestring is tied down. The open anorectal cuff is closed using a 2-0 Prolene pursestring handsewn through the transanal access port. Of note, unlike traditional colorectal anastomosis, in which the distal rectal stump is completely closed with a linear stapler, this pursestring will always have a small defect at its center (Fig. 30.12). It is through this defect that the spike of the

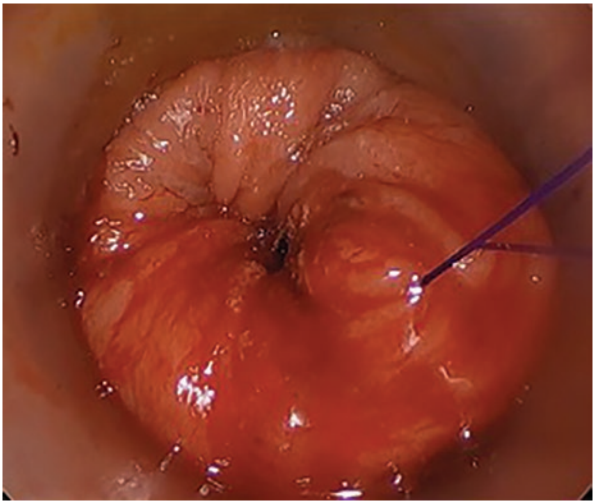

Fig. 30.12 Creation of anorectal cuff pursestring—Small central defect is always the result

EEA stapler is passed. The anvil is mated with the spike, and the stapler is closed and fired. Creating this pursestring and passing the EEA stapler spike directing through the central defect is a critical portion of the procedure, as anastomotic leaks have been attributed to this portion of the procedure [28]. Proctosigmoidoscopy can be used to confirm viability of the proximal colonic mucosa and to interrogate the anastomosis with a leak test.

11. **Diverting loop ileostomy**

Due to the low pelvic anastomosis, and some patients having received preoperative radiation, a temporary diverting loop ileostomy is routinely performed. A circular incision is made in the right hemiabdomen anterior to the rectus abdominus muscle, carried down until the anterior fascia is reached. The fascia is incised in a cruciate fashion, the rectus muscle is bluntly split, and the posterior rectus sheath is incised. The fascial defect should be large enough to pass two fingers through. The chosen loop of terminal ileum is brought up through the incision, making sure that the mesentery is not twisted or under any undue tension. The loop should be oriented such that the afferent limb is superior and the efferent limb is inferior. A transverse incision is made in the bowel, and the afferent limb is matured in the standard Brooke fashion, using 3-0 Vicryl sutures. An ostomy appliance is placed, making sure that the wafer is cut such that adjacent skin is covered.

30.7 Postoperative Course

The enhanced recovery after surgery (ERAS) protocol is utilized [29, 30]. This includes starting a full liquid diet immediately post-op, multimodal analgesia and minimizing narcotic use, and early ambulation. The foley catheter is discontinued postoperative day 1 or 2.Diet is advanced to a low fiber, soft diet as tolerated. Ostomy teaching is conducted with certified ostomy nurses until the patient is comfortable to personally manage their new ostomy. Patients are typically discharged on postoperative days 3–5.

30.8 Conclusion

TaTME is an excellent example of the progression of minimally invasive colorectal surgery. Oncologic and functional outcomes can be improved in the right surgeon's hands, but results have shown that there is a steep learning curve, during which there is the potential for devastating complications. The TME plane from a transanal approach is less familiar to most surgeons. Therefore, preoperative studying of videos, proctored courses, and formal training is important before undertaking taTME independently. In this piece we have reviewed the key steps, their associated difficulties, and how they can be avoided. However, in no way can a short chapter suffice as a complete guide to the surgeon interested in adopting taTME and the authors want to stress the importance of formal proctoring and simulation during the educational process.

Conflict of Interest The authors have no conflict of interest to declare.

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Part VI
Miscellaneous

Chapter 31
Laparoscopic Appendectomy

María Agustina Casas, Francisco Laxague, and Francisco Schlottmann

31.1 Introduction

Acute appendicitis (AA) is one of the most common surgical emergencies worldwide. The peak incidence occurs between 10–19 years, being less common at extremes of ages. In the United States, there is an overall incidence of approximately 9 cases per 10,000 population per year and an overall lifetime risk of 15% [1].

Luminal obstruction (usually due to a fecalith) with subsequent ischemia, mucosal disruption, and invasive bacterial infection is the typical pathophysiology of AA [2]. Other causes include hyperplasic lymphoid tissue, parasitic infections, or tumoral compressions among others.

31.2 Clinical Presentation

Classic presentation is diffuse, periumbilical abdominal discomfort than later becomes localized to the right lower quadrant. Nausea and anorexia are usually present. Several clinical risk scores have been proposed for its diagnosis. The most widely used is the Alvarado score, which uses a combination of patients' symptoms, physical signs, and laboratory values to determine the diagnosis of AA [3] (Table 31.1). Clinical diagnosis can be challenging in children, elderly patients, pregnant, and obese patients.

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Table 31.1 Alvarado Score for the diagnosis of acute appendicitis

Alvarado Score		Score
Symptoms		
Migration of pain		1
Anorexia		1
Nauseas/Vomiting		1
Signs		
Tenderness in right lower quadrant		2
Rebound pain		1
Elevated temperature		1
Laboratory findings		
Leukocytosis		2
Shift to the left of neutrophils		1
Total		*10*
Score 1–4	Score 5–6	Score 7–10
Discharge	Observation/Admission	Surgery

31.3 Preoperative Evaluation

Imaging modalities such as ultrasound and computed tomography (CT) are often used to confirm the diagnosis. While an abdominal ultrasound is a very accurate and cost-effective study, a CT scan has higher sensitivity and specificity for the diagnosis of AA and can help ruling out other causes of abdominal pain when the clinical presentation is unclear [4]. Radiation exposure and costs, however, are important drawbacks of the CT that should be considered [5, 6]. The American College of Radiology currently recommends the CT scan as the initial image modality for AA in nonpregnant adults [7].

31.4 Laparoscopic Appendectomy

Laparoscopic appendectomy was first described in 1983 by Semm [8]. This approach shows several advantages: reduced rate of wound infections, shorter length of hospital stay, earlier return to normal activities, and better quality of life scores in adults [9–11]. A properly executed operation is key for its success.

31.4.1 Antibiotic Prophylaxis

A single preoperative dose of antibiotics 30 min before surgical incision is administered in all patients. It is important to cover gram negative and anaerobic microorganisms with the antibiotic therapy adjusted to each institution flora.

Troubleshooting: Allergies towards antibiotics should always be asked in order to avoid adverse reactions.

31.4.2 Position of the Patient and Surgical Team

After induction of general endotracheal anesthesia, the patient is positioned supine with lower extremities extended, left arm tucked, and right arm abducted. The patient should have a slightly left lateral and Trendelenburg position during the procedure. Surgeon and first assistant stand on the patient's left side and second assistant on the patient's right side. A single video monitor is used on the right side beside the patient's feet.

31.4.3 Pneumoperitoneum and Trocar Placement

A three-port technique is used. After an umbilical incision of 10-mm, pneumoperitoneum with Veress needle is performed at 12 mm Hg. Once adequate pneumoperitoneum is established, a 10-mm port is introduced and abdominal exploration is performed. A second 10-mm port is then placed in the suprapubic region. A 5-mm port is finally placed in the left iliac fossa, lateral to the inferior epigastric vessels (Fig. 31.1).

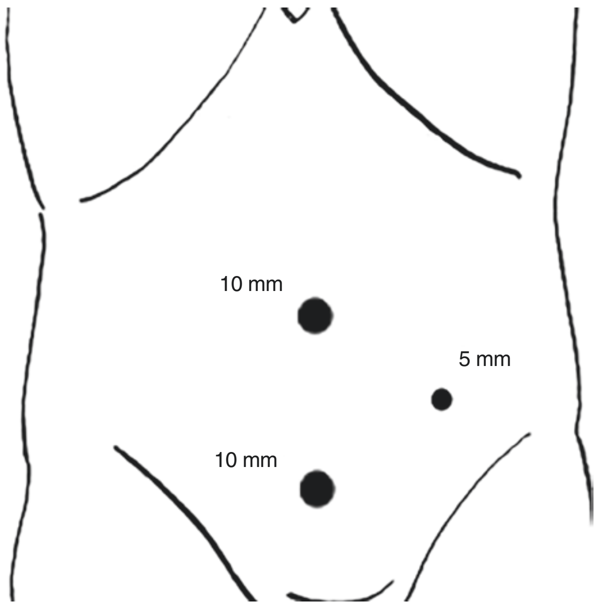

Fig. 31.1 Trocar placement

Troubleshooting: The abdominal cavity should be carefully entered to avoid injuring great vessels or bowel. The use of an open approach or another site for the Veress needle rather than the midline (i.e. Palmer's point, left upper quadrant of the abdomen) can be helpful in patients with multiple prior abdominal operations, bowel distention or obesity. The suprapubic port should be placed under direct visualization to avoid a bladder injury. It is recommended to ask patients to urinate immediately before the procedure or to place a urinary catheter. Visualization of the inferior epigastric vessels is critical to avoid injuring them with the third port.

31.4.4 Identification and Mobilization of the Appendix

A thorough exploration of the abdominal cavity is performed in order to confirm the diagnosis or rule out other causes of abdominal pain. With the patient in the adequate position (slightly left lateral and Trendelenburg position) the small intestine falls away from the operative field allowing the identification of the cecum. The identification of the base of the appendix is done by observing the site of confluence of the taenia. The appendix may be positioned adjacent to the ileocecal valve, retrocecal or intra-pelvic. Once the appendix is identified, it should be grabbed and lifted up towards the abdominal wall to expose the mesoappendix. Prior release of adhesions with gentle maneuvers may be required to adequately expose the mesoappendix (Fig. 31.2).

Troubleshooting: Complicated or necropurulent AA with peritonitis account for nearly 25% of the total cases [12]. In case of purulent fluid, culture swabs are often obtained with a laparoscopic needle in order to determine the pathogen and possible drug-resistance. Interestingly, previous studies have shown little or no benefit of this practice [13, 14].

31.4.5 Dissection of the Mesoappendix and Appendectomy

With cephalad traction of the appendix, the mesoappendix is identified. A window between the base of the appendix and the mesoappendix is initially performed (Figs. 31.3 and 31.4). The mesoappendix is then transected using electrocautery,

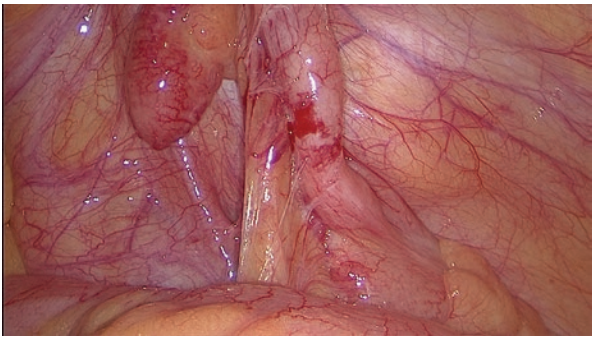

Fig. 31.2 Adequate exposure of the appendix

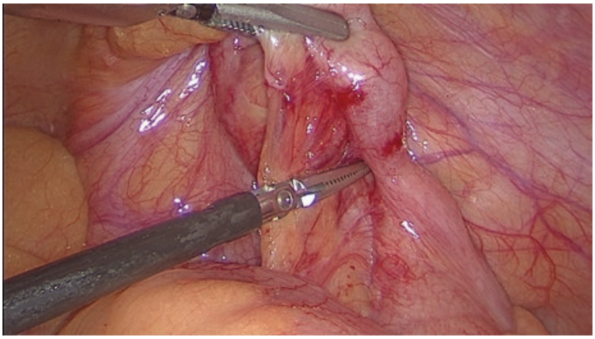

Fig. 31.3 Dissection of mesoappendix

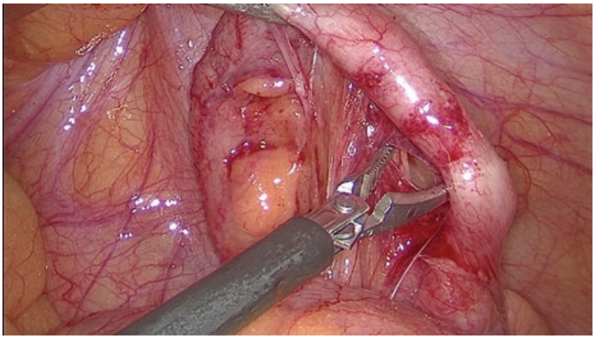

Fig. 31.4 Window between the base of the appendix and the mesoappendix

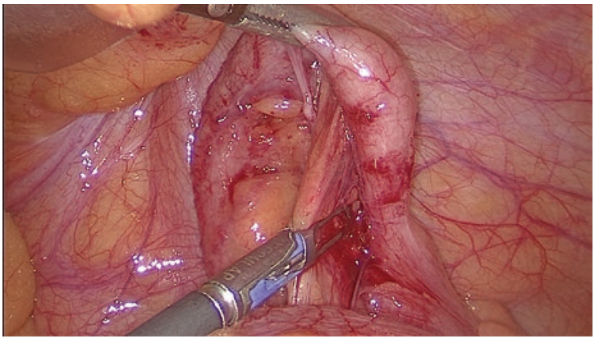

Fig. 31.5 Cauterization of the mesoappendix with bipolar forceps

harmonic scalpel, scissors between metallic clips, or linear stapler (Fig. 31.5). Once the base of the appendix is completely released, an endoloop is placed just above its implantation at the cecum (Figs. 31.6 and 31.7). The appendix is then sectioned with scissors approximately 5 mm above the endoloop (Fig. 31.8). The specimen is finally removed inside a protective bag through the suprapubic port.

Troubleshooting: Several instruments can be used for the mesoappendix transection such as monopolar electrocautery, harmonic scalpel, vessel sealing device, metallic clips, or linear stapler. Surgeon's preference and availability often determine the instrument used. Electrocautery should be used with caution in order to avoid thermic lesions of the small bowel or the cecum.

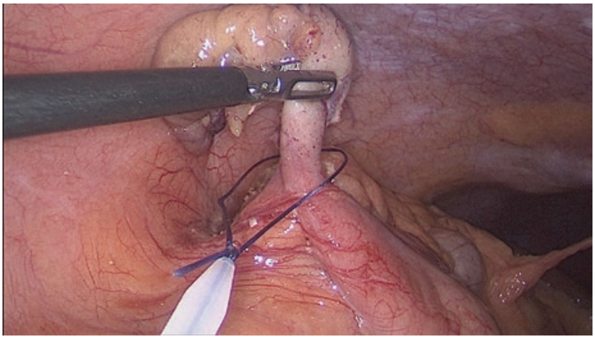

Fig. 31.6 Placement of the Endoloop

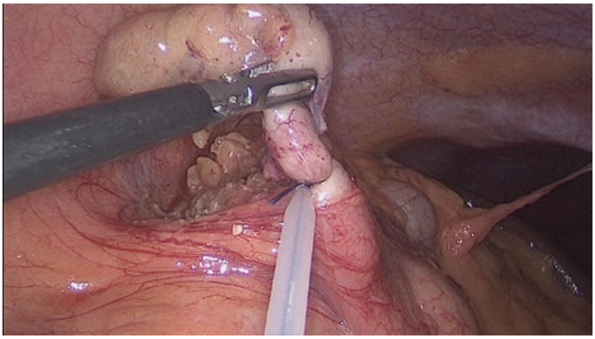

Fig. 31.7 Endoloop at the base of the appendix

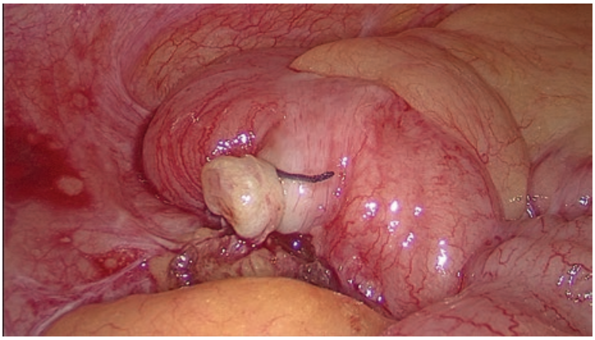

Fig. 31.8 Appendiceal stump

31.4.6 Final Abdominal Exploration

After removal of the appendix, the abdominal cavity should be further explored to verify adequate hemostasis and aspirate any remnant peritoneal fluid. Despite the lack of strong evidence, an abdominal drain can be placed in cases of perforated appendix with generalized purulent peritonitis [15].

Troubleshooting: Intra-abdominal abscess is the most feared complication after laparoscopic appendectomy for complicated AA [16, 17]. Multiple studies have failed to demonstrate the benefits of peritoneal irrigation (versus suction alone) to prevent this complication [18–20]. We recommend systematic suction of any remnant peritoneal fluid and use of irrigation only in cases where saline solution is needed for the proper lavage of purulent fluid.

31.4.7 Postoperative Course

Patients are usually fed with clear liquids and then soft diet after 6–8 h. Most patients are discharged within 24 h after the operation, and are able to resume their regular activity within two weeks. Hospital stay might be longer in patients with necropurulent appendicitis and peritonitis.

Postoperative follow-up in clinics is scheduled on postoperative day 7 and 30. Patients are advised to return to the hospital's emergency department in cases of fever, abdominal tenderness or purulent discharge from the surgical wounds.

31.5 Conclusions

A properly executed laparoscopic appendectomy should respect important technical elements to avoid troublesome surgical complications and obtain optimal postoperative outcomes.

Conflict of Interest The authors have no conflict of interest to declare.

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Chapter 32
Laparoscopic Splenectomy

Joseph A. Lin and Kimberly S. Kirkwood

32.1 Introduction

Splenectomy is an important tool in the management of certain complex autoimmune, hematologic, and oncologic disorders that result in medically refractory cytopenias, hypersplenism and/or splenomegaly. Splenectomy has successfully been used to reduce platelet sequestration as a bridge to stem cell transplant or targeted therapy, and it remains a therapeutic option for patients with thrombocytopenia, anemia, and certain hematologic malignancies [1]. These patients with severe systemic illnesses are at increased risk for both bleeding and venous thromboembolism, as well as infection and poor wound healing [2]. Thus, careful preoperative planning, intraoperative caution and skill, and thoughtful, multidisciplinary, perioperative management strategies are critical to the success of the procedure.

With recent improvements in systemic therapies for most non-malignant causes of thrombocytopenia, especially immune thrombocytopenic purpura, splenectomy has moved from second- to third- or fourth-line therapy for many patients [3, 4]. As a result, the proportion of spleens removed due to myeloproliferative or malignant conditions has increased [5]. These spleens are nearly all enlarged, frequently exceeding 25–30 cm, and are commonly adherent to the adjacent pancreas, stomach and/or colon [2, 6]. As a result, the resections are more complex and require specific technical adaptations to ensure safety.

Laparoscopic approaches to removal of the spleen were first reported in the 1990's as a potentially less morbid procedure, initially applied to normally sized spleens [7]. Laparoscopic approaches have proven advantages, including shorter lengths of hospital stay, reduced blood loss, fewer transfusions, and better patient-reported quality of life, typically at the cost of longer operating time [7–11].

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Historically, “massive” (>600 g or >17 cm craniocaudal length) or “supramassive“ (>1600 g or >22 cm craniocaudal length) spleens required open splenectomy. However, advances in laparoscopic techniques, including use of a handport, have allowed the successful application of minimally invasive approaches to the removal of massive and supramassive spleens. Rates of conversion to open splenectomy for large spleens are in the range of 15–23% in reported series, with the aforementioned outcome benefits [2, 12, 13]. Currently, the preferred approaches for elective splenectomy use minimally invasive techniques [5].

32.2 Clinical Presentation

Splenectomy plays a role in the treatment of a diverse array of autoimmune, hematologic and oncologic disorders. A splenectomy can be curative for lymphomas isolated to the spleen, or it may yield a tissue diagnosis when the cause of progressive splenomegaly is elusive. Factors such as the underlying diagnosis, number of prior transfusions, prior systemic therapies, extent of bone marrow suppression/infiltration, degree of thrombocytopenia, and responsiveness of the platelet count to transfusion, as well as health of the liver and coagulation pathways, all contribute to the risks of splenectomy.

Autoimmune conditions remain indications for splenectomy, but medical therapies have improved. In most cases, patients undergoing splenectomy for autoimmune disorders present with cytopenias and normal-sized spleens. The most common of these disorders, immune thrombocytopenic purpura (ITP), is caused by autoantibodies directed against platelets that lead to platelet phagocytosis by reticuloendothelial macrophages residing in the spleen. Primary ITP is a diagnosis of exclusion, since platelet sequestration can also be secondary to human immunodeficiency virus infection, hepatitis C virus infection, or certain medications. For primary ITP causing bleeding symptoms or significant thrombocytopenia (platelet count <30,000 per microliter), glucocorticoids are the first-line treatment, but only lead to long-term remission in 20% of patients [4]. Romiplostim or eltrombopag, both thrombopoietin receptor agonists, as well as rituximab, a monoclonal antibody against the B-cell surface protein CD-20, are second-line therapeutics that can provide short- or long-term recovery of platelet counts [4, 14–16]. Intravenous immunoglobulin (IVIG) can temporarily increase the platelet count for two to six weeks, serving as a bridge to splenectomy if needed. Splenectomy leads to long-term improvement in platelet counts in nearly 90% of patients and is typically recommended for medically refractory disease or for patients with intolerable side effects [4]. In autoimmune hemolytic anemia (AIHA), first-line therapy with glucocorticoids and rituximab, either as single agents or in combination, induces remission in most patients. In thrombotic thrombocytopenic purpura (TTP), plasma exchange and glucocorticoids are first-line therapies and splenectomy is reserved for failure of medical management [17].

Benign hematologic conditions such as hereditary spherocytosis and hereditary elliptocytosis, both autosomal dominant disorders of red blood cell membrane proteins, cause congenital anemia. Milder forms are typically asymptomatic or minimally symptomatic and can be managed nonoperatively, but severe forms with symptomatic, transfusion-dependent anemia and/or splenomegaly can be markedly improved with splenectomy [18]. We have noted that while these spleens are typically large, they are generally mobile and surrounded by minimal scar tissue formation. Thalassemias are autosomal dominant disorders of hemoglobin proteins that are typically managed with transfusions; for patients with an excessive burden of transfusions over time, splenectomy can significantly decrease the transfusion requirement [19]. It is important to note that the presence of chronic anemia in these patients leads to secondary hemochromatosis from excess enteral iron absorption, which can result in cirrhosis and cardiomyopathy. Preoperative testing of liver and cardiac function should be considered for these patients.

We have found that the most difficult spleens are typically those infiltrated by myelofibrosis or hematologic malignancies, as these are often dense, supramassive, immobile, and adherent. Supramassive splenomegaly may or may not present with left upper back or abdominal pain, and early satiety. In some cases, patients may be short of breath while supine due to diaphragmatic pressure from a spleen that fills the abdomen and pelvis with surprisingly little pain or difficulty eating. Hypersplenism leads to cytopenias including thrombocytopenia, anemia, and/or neutropenia, which can be profound. In many cases the cytopenias resulting from hypersplenism due to leukemias, lymphomas, and myeloproliferative disorders preclude administration of needed chemotherapy or confound planned stem cell transplantation by preventing transfused platelets from remaining in circulation. Splenectomy prior to stem cell transplant can, in these cases, facilitate the success of transfusion support during engraftment.

Notably, we have found the extent of thrombocytopenia is not always proportional to spleen size, making it difficult to predict the benefit of splenectomy for a given patient. Preoperative discussions with hematologists should consider the possible contribution to thrombocytopenia of factors such as impaired production from prior cytotoxic therapy or bone marrow replacement by fibrosis or an infiltrating hematologic malignancy. An up-to-date bone marrow biopsy and evaluation should be considered to help optimize timing and manage expectations of splenectomy.

Other uncommon indications for splenectomy include sepsis due to splenic abscess (for which percutaneous drainage and intravenous antibiotics are frequently adequate) and iatrogenic injury during another procedure.

32.3 Preoperative Evaluation and Preparation

Laboratory studies of blood counts and coagulation are necessary to determine correctable deficiencies. If not already done, we also check albumin, bilirubin, and liver enzymes to determine if liver synthetic function is impaired. Blood typing and preparation of blood products are necessary in case of significant intraoperative or postoperative bleeding. Imaging with computed tomography (CT), particularly for patients with palpable splenomegaly on physical examination, will help guide patient positioning and port placement.

Recent cross-sectional imaging is critical for patients with large spleens to clarify anatomy, particularly to define the geometry and guide placement of ports. Even for patients with "typical" ITP, we have a low threshold for obtaining at least an ultrasound to confirm absence of splenomegaly that would affect patient positioning. Imaging can also provide clues to the extent of adherence of the pancreatic tail, colon, stomach and left lateral segment of the liver, and to identify the vascular anatomy, including anomalies and splenic vein thrombosis with varices that may affect surgical planning.

Splenic artery embolization can be helpful as a means to decrease intraoperative blood loss for patients with profound thrombocytopenia unresponsive to transfusion and a supramassive spleen. We use this option rarely since it is typically unnecessary and tissue ischemia, especially for a huge spleen, can lead to a robust systemic inflammatory response, which increases perioperative fluid requirements, often dramatically, and affects anesthetic risk. When needed, embolization should be done immediately preoperatively, typically under the same general anesthetic, to minimize the ischemic time. We also consider embolization for cases in which preoperative imaging indicates that early surgical access to the splenic artery is impeded by the distorted anatomy from the bulky spleen.

Patients should receive vaccine series against *Haemophilus influenzae type B*, *Neisseria meningitidis*, and *Streptococcus pneumoniae* to be completed at least 14 days before splenectomy, to allow for a sufficient immune response [20]. We have found this approach to be the most reliable means of delivering vaccines, which have been proven to reduce the incidence of overwhelming post-splenectomy infection. If splenectomy is too urgent for preoperative vaccination, the vaccines can be administered starting 14 days after splenectomy, or once the immune system has sufficiently recovered from oncologic therapy [21].

Our preoperative transfusion goals are platelets at least 10,000 per microliter and hemoglobin at least 7.0 grams per deciliter. For patients with platelet counts less than 10,000 per microliter with minimal or no response to platelet transfusions, we avoid transfusions during the 24 hr preceding surgery, as we have noted that excessive platelet transfusions seem to engorge the spleen and lead to increased friability of the splenic capsule, further increasing the risk of hemorrhage with little or no benefit. Instead, starting just before incision, we trickle in platelets slowly until we have taken the short gastric vessels and splenic artery, then administer an additional unit of platelets. For all patients, we prepare packed red blood cells and platelets to be kept in the operating room until the conclusion of the operation.

32.4 Operative Technique

Per our Enhanced Recovery After Surgery (ERAS) protocol, the patient receives acetaminophen and gabapentin in the preoperative area. The patient is positioned on thick gel padding on top of a beanbag. After induction of general anesthesia, prophylactic antibiotics and dexamethasone are given to reduce surgical site infections and postoperative nausea and vomiting, respectively. The latter also compensates for adrenal insufficiency in patients on chronic steroids. We place an orogastric tube and a Foley catheter. We use pneumatic sequential compression devices (SCDs) on both legs to prevent deep vein thrombosis (DVT); for patients with a platelet count over 30,000 per microliter, we also give a dose of 5,000 units subcutaneous heparin (SCH). We sterilize and drape the skin from nipples to pubis. Recommended instruments and supplies are found in Table 32.1.

32.4.1 Patient Positioning

Normal Spleen. The patient is placed in right lateral decubitus position. Repositioning facilitates exposure as the spleen sits atop the viscera and omentum in plain view. Gravity serves to minimize bleeding related to retracting the splenic flexure in

Table 32.1 List of suggested instruments and supplies for laparoscopic splenectomy

Instruments for laparoscopic splenectomy
10 mm 45° laparoscope 5 mm 30° laparoscope
12 mm port for stapler
Additional ports: one 11 mm and two 5 mm
Rolled gauze (4 × 4 radiopaque gauze rolled and tied at each end)
Atraumatic graspers
Endoscopic monopolar hook cautery and bipolar or ultrasonic vessel sealer
Titanium clip applier
Locking hemoclip applier
Endoscopic stapler with vascular and regular loads
Argon beam coagulator
¼ inch Penrose drain, transfascial suture grasper, endoscopic suture loop
Fixed laparoscopic instrument retractor, paddle, and/or fan retractor
Suction/irrigator
Umbilical tape, 0 silk ties
Sturdy endoscopic specimen bag
Ring clamp and suction aspirator system with 14 and 16 Fr wands
If needed: laparoscopic handport

patients with very low platelet counts. A sub-axillary roll is used and a low-profile padded support holds the left arm level with the shoulder, with the arm extended cephalad as high as possible while minimizing traction on the brachial plexus. Pillows are placed between the knees and ankles with hips and knees gently flexed. The patient is secured to the table with padded wide tape across the chest and pelvis to prevent sliding during rotation and reverse Trendelenburg positioning. Both surgeon and assistant stand on the right side.

Enlarged Spleen (>17 cm). Since a large spleen will preclude access to the hilum with the patient in right lateral decubitus position, the patient remains supine on a thick foam mattress. Padded wide tape is used to secure the patient at the chest, pelvis and thighs, with right arm tucked. We have found that split leg configuration provides comfortable access for the surgeon with the assistant on the right.

32.4.2 Port Placement

Normal spleen. After insufflation using a Veress needle 2 cm below the costal margin at Palmer's point, we enter the abdomen using a 5 mm optical view trocar, then place a 12 mm radially expanding port medially and inferior (anticipating the angle needed for a stapler), a 5 mm port at the left midaxillary line over the inferior pole of the spleen, and a 5 mm port in the midline using a vertical incision about 4 cm below the xiphoid. The last port site can be incorporated within a 6 cm handport incision if needed. While this is rarely needed for a small spleen, the use of a handport can prevent conversion to an open approach.

Enlarged Spleen (>17 cm). The ports need to accommodate the spleen and the geometry of port placement anticipates a V, often with the apex shifting between the umbilicus and the right midepigastrium. Even with a spleen that nearly fills the abdomen, elevating the left liver nearly always provides access to the short gastric vessels and splenic artery (Fig. 32.1). A 12 mm port is placed within the umbilicus using Hasson technique unless the spleen comes within a few cm of the midline, in

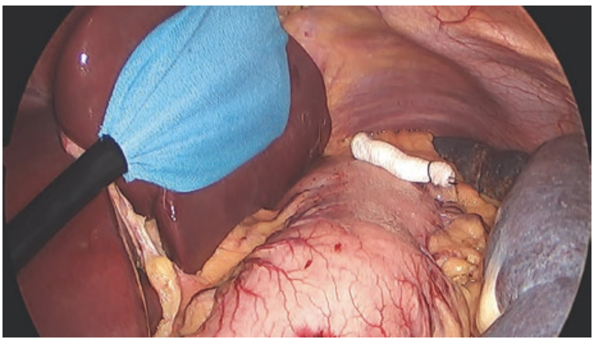

Fig. 32.1 Liver retraction and rolled gauze

which case we place this port in the right midabdomen. An additional 12 mm radially expanding port is sited to provide anticipated stapler access to the hilum. After the round ligament is taken down with a vessel sealer, a 5 mm port is placed in the midline vertically through the planned handport site, and another is placed in the left lower quadrant. All ports must be sited to provide safe working angles. Whenever possible these ports are placed so that instrument introduction does not overlie the spleen, to avoid unintentional injury. We typically mark out, but do not place, a handport before taking down the short gastric vessels as the handport can impede gastric retraction and it is usually not necessary before that step. If there are obvious adhesions of the omentum to the spleen, these are taken down with the vessel sealer to avoid traction injuries to the capsule.

**Tip*. While bleeding from capsular tears and even small fractures in fibrotic spleens can typically be controlled with argon/coagulation, this is challenging if the patient has received many recent transfusions and/or the platelet count remains less than 10,000, so avoidance of even small abrasions and avulsions is worth the extra effort.

32.4.3 Splenic Flexure Dissection

Normal spleen. With the patient in steep reverse Trendelenburg and right side down, we introduce two rolled 4 inch by 4 inch radiopaque gauze sponges secured at both ends with umbilical tape (rolled gauze) via the 11 mm port. We begin by mobilizing the proximal descending colon down to Gerota's fascia, and continue retracting it inferiorly as we dissect from lateral to medial. The lienocolic attachments to the inferior pole are carefully taken down with either the vessel sealer or hook cautery, leaving a small tuft of tissue on the spleen to avoid injury. The rolled gauze can gently elevate the inferior pole to allow better visualization of the proper tissue plane with the goal of identification of the tail of the pancreas medially.

**Tip*. If progress becomes slow in the multiple layers of omentum, gastrosplenic and lienocolic ligaments, pivoting to take the gastrosplenic ligament facilitates working from both sides to complete this dissection.

**Tip*. Most accessory spleens are located in the lienocolic and inferior gastrosplenic ligaments. For patients with autoimmune conditions, especially ITP, it is critical to identify these splenules and remove them as they can otherwise lead to persistent/recurrent cytopenic disease.

Enlarged spleen. Commonly, the risk of the procedure can be reduced by getting control of the splenic artery relatively early, so we often begin by taking down the short gastric vessels and deferring the inferior dissection until the spleen is devascularized. Commonly the same process that infiltrates and enlarges the spleen similarly affects the liver. Mobilization and retraction of the liver using a paddle can provide the needed space to retract the stomach (Fig. 32.1).

32.4.4 Gastrosplenic Dissection

For normal spleens this dissection begins at the level of the inferior pole and for large spleens it typically begins at the inferior body of the stomach. Using an atraumatic grasper, the stomach is retracted anteromedially and the gastrosplenic/gastrocolic ligament is retracted laterally. A spot lateral to the gastroepiploic artery is selected, and the vessel sealer or hook cautery is used to open the lesser sac, as confirmed by the view of the posterior gastric wall. The dissection proceeds staying just lateral to the gastroepiploic and then taking the posterior branches to fully mobilize the stomach medially (Fig. 32.2). The left gastroepiploic is typically taken posteriorly distal to its takeoff from the splenic artery during the posterior aspect of this dissection. Care must be taken to identify and preserve the left gastric artery, often seen adjacent to the more visible accompanying coronary vein. This pedicle is reliably just cephalad to the view of the caudate segment of the liver through pars flacida. The dissection proceeds cephalad around the cardia, where the superior short gastrics are carefully identified. Often working from posterior to anterior opens the space up to avoid injury to the superior pole of the spleen.

**Tip*. The superior short gastrics can be treacherous, short, and unpredictable in their trajectory depending on the degree of scarring of the cardia to the superior pole. In many cases, it is safer to leave them until the spleen is devascularized in order to minimize troublesome bleeding or gastric injury.

**Tip*. Rarely, the left lateral segment of the liver and/or the gastric cardia can be fused to the superior pole. The stomach is typically able to be freed once the spleen has been devascularized, however the left lateral segment of the liver can be inseparable from the spleen, in which case it can be divided using either the vessel sealer or stapler firings, depending on thickness, and subsequently removed with the specimen.

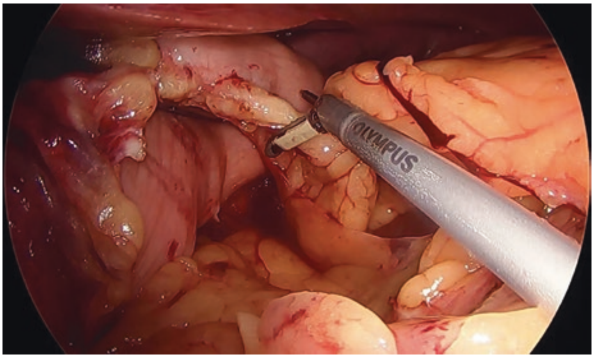

Fig. 32.2 Gastrosplenic dissection

32.4.5 Stomach Retraction

Occasionally, the stomach naturally falls medially providing sufficient exposure of the hilar structures and tail of the pancreas to proceed. With massive or supramassive spleens, however, some form of retraction is typically needed. If not already completed, mobilizing the left liver by taking the triangular and round ligaments can provide needed space. The stomach can be retracted by passing a ¼ inch Penrose drain around the gastric body, securing an endoscopic suture loop around the tails, externalizing the end of the suture loop using a transfascial suture grasper through a stab incision in the subxiphoid region, and securing it with a clamp at the level of the skin. This will provide adequate exposure in most cases. Occasionally, when liver enlargement or stiffness is encountered, a paddle or fan is needed, and can be brought in via a 12 mm port in the right anterior axillary line below the liver edge, secured with a fixed laparoscopic retractor system (Fig. 32.3).

32.4.6 Splenic Artery Division

Taking the artery before proceeding with further dissection reduces the chance of significant bleeding when isolating the hilum. While it is preferableto divide the artery and thereby provide time for autotransfusion of blood through the intact venous system, it is not always possible. In some patients with hematologic malignancies, the surrounding lymphadenopathy can preclude safe identification or dissection of the artery.

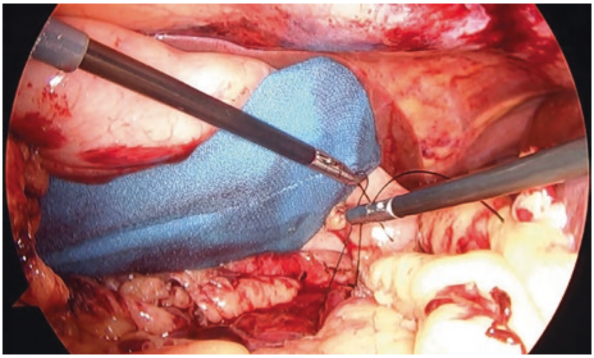

Fig. 32.3 Stomach retraction with a paddle

Depending on the configuration of the spleen, rolled gauze can be used to gently retract the anterior lip of the spleen laterally, with care being taken not to injure any of the delicate veins that may be found in this region. The splenic artery trajectory is typically visible at some point in its course along the cephalad border of the pancreas proximal to the artery's bifurcation. We look for a loop of artery, which usually denotes a spot not fixed to the pancreas by short troublesome branches (Fig. 32.4).

**Tip*. In some cases, marked enlargement and medial displacement of the inferior spleen forms a giant "boot" that precludes both visualization of and access to the splenic artery. In these cases, a handport placed transversely in the suprapubic position can allow an assistant to use a left hand from patient left to gently rock the boot laterally, thereby providing the needed exposure (Fig. 32.5).

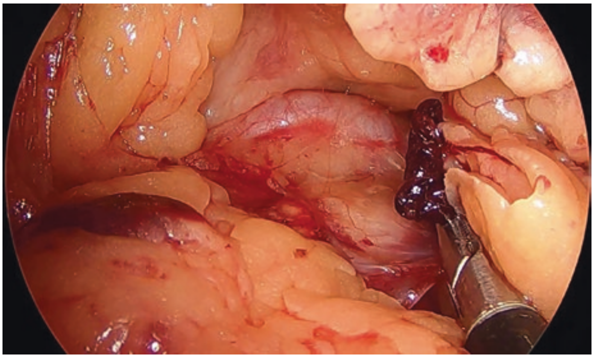

Fig. 32.4 Splenic artery loop superior to the pancreas

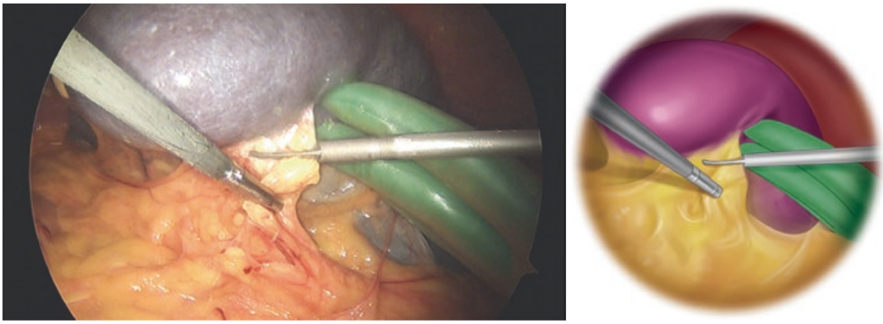

Fig. 32.5 Hand retraction of the inferior spleen

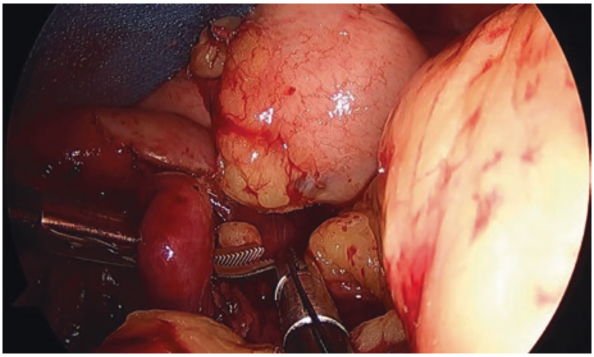

Fig. 32.6 Encircling the splenic artery with a silk tie

Dividing the tissue anterior to the artery, where there are no branches, then clearing a space cephalad, facilitates dissection under the arch of the vessel. Since the vein often is immediately posterior, the safest plane is right on the posterior wall of the artery where lymphatic channels can be divided to free up a path underneath. We encircle the artery with a 0 silk tie (Fig. 32.6) and, if it can be taken with a single large hemolock clip, that is placed. It is not necessary to transect the artery at this location, but it is helpful to allow the spleen to drain. If a clip will not comfortably take it, the vascular load of an articulating stapler is passed after a sufficient length of vessel has been cleared. For the rare patient with normal anatomy, both the artery and vein may be able to be taken with large hemolock clips and a stapler is not needed. The hemolock has the advantage that it provides clarity that the clip is across the vessel. In these cases, we reinforce the hemolock clip with a titanium clip to provide certainty that the vessel is ligated.

**Tip*. During dissection and control of the artery, it is critical that any clips placed near the hilum are far enough to the right to be out of the path for a potential subsequent firing of the stapler in order to avoid catastrophic stapler misfire across the vein. Use of the silk tie to encircle vessels instead of a vessel loop eliminates the worry of catching a piece of a foreign body in the staple line.

If there remains any portion of the lienocolic ligament, this dissection can now be efficiently completed working cephalad from an imaginary line drawn anteriorly from the inferior border of the pancreas, around the inferior pole.

32.4.7 Pancreatic Dissection

The pancreas can nearly always be teased away from the splenic hilum. The tissue anterior to the pancreatic tail is divided, staying several mm away from the spleen. Working back and forth from an inferoposterior to anteromedial approach at the retroperitoneal border of the spleen using hook cautery, vessel sealer, and gentle suction, will generally reveal the tail and allow division of the tuft of peripancreatic fat at the border with the splenic vein (Fig. 32.7).

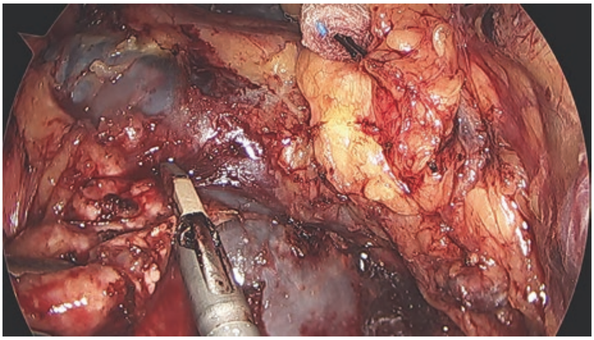

Fig. 32.7 Dissection of the pancreatic tail

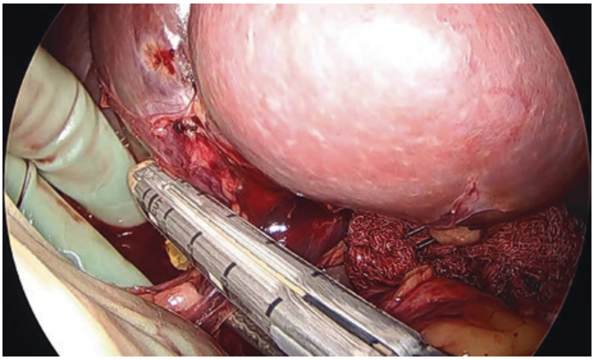

Fig. 32.8 Stapling the splenic vein

32.4.8 Hilar Dissection

Clearing the tissue cephalad and deep to the superior branch of the artery underneath the spleen facilitates emergence of the stapler when passed from below. The dissection then proceeds from inferior and posterior to the splenic vein, in a space that is usually avascular and is often deeper than expected, just anterior to the retroperitoneum. In some cases, this plane is fused and the dissection needs to be deep to the retroperitoneum. The goal is to encircle the hilar structures to the left of the pancreas so they can be looped with a ¼ inch penrose and/or a 0 silk tie.

**Tip*. Dense adhesions posterior to the hilum are uncommon but challenging. By mobilizing the inferolateral spleen anteromedially using rolled gauze to retract it atraumatically, essentially "standing" the spleen on its hilum, the necessary access can often be achieved by this "back door" approach.

Once the hilum is isolated, an articulating stapler is introduced inferior and parallel to the hilum, or rarely medial and perpendicular to the hilar structures. A vascular staple load can be used if the vessels are reasonably skeletonized, but if extensive fat, fibrosis and/or lymphadenopathy remain, longer staples will be needed. Great care must be taken to be sure any previously placed clips are out of the stapler trajectory, or removed, to avoid misfire. We close the stapler for 5 minutes before firing to improve hemostasis (Fig. 32.8).

**Tip*. When advancing the stapler past the hilum from an inferior approach, it is important to be aware of the natural curve of the spleen to avoid puncturing the superior pole parenchyma. Similarly, the posterior parenchyma is at risk with medial introduction of the stapler, a maneuver that can be made safer by elevation of both the superior and inferior poles with rolled gauzes held by graspers. For a bulky hilum, we use both the Penrose and the silk, and once we have clearly seen the stapler tip emerge, we remove the Penrose to avoid inadvertently incorporating it in the staple line. For smaller hilar bundles, a silk tie alone may suffice, or a stapler with a curved tip can provide clarity.

**Tip*. In patients with supramassive spleens, the vein is often overdistended and thin-walled. Including surrounding tissue in the staple line may buttress the staple line and improve integrity. Every effort should be made to avoid injury to the vein and its tributaries. If bleeding is encountered, direct pressure for 5 minutes is often effective, and provides time to assess options, including placing a handport, which will nearly always avoid conversion to open.

The pancreas is inspected to be sure the tail is intact. If there is any question of pancreatic injury, a soft drain is left. We prefer drains with a central lumen of sufficient caliber to facilitate exchange over a wire by interventional radiologists, such as a 19 Fr round soft silicone drain.

32.4.9 Diaphragmatic Dissection

Atraumatic retraction of the superior pole of the spleen will aid dissection along the diaphragm, as well as the retroperitoneum. It is important to recognize that the diaphragm can be folded onto the dome of the spleen and very densely adherent.

**Tip*. Adding a 5 mm port immediately subcostal, directed over the superior pole can greatly facilitate this plane of dissection, as well as moving the endoscope to the epigastric port.

If a hole in the diaphragm is made, we address it after the spleen is fully detached. We gently suction any blood from the pleural cavity, then place a figure-of-8 stitch of heavy silk and introduce a 10 Fr red Robinson tube connected to sterile tubing passed via the 12 mm port. As the anesthetist delivers and holds a large inspiration, we gently suction the air from the pleural cavity, remove the tube, and tie down the knot. A postoperative chest radiograph will typically confirm the absence of a pneumothorax.

If the diaphragmatic attachments are extensive, we defer this dissection until the rest of the retroperitoneal dissection is complete to provide maximal mobility of the spleen to better visualize the proper plane and minimize diaphragmatic injury. In some cases, some of the splenic capsule can be left on the diaphragm and argon beam coagulation can be used to desiccate this after detachment.

32.4.10 Retroperitoneal Dissection

For small spleens, a few minutes with the hook cautery is all that is needed, whereas for supermassive densely adherent spleens, the retroperitoneal and diaphragmatic dissection can be a prolonged endeavor. Working from all sides, using gains in mobility to provide improved exposure, and careful elevation using rolled gauze to avoid fracture are important strategies. Most of the dissection will be done working from inferior to cephalad with increasing elevation of the spleen, balancing it on rolled gauze sponges.

**Tip*. When the retroperitoneal attachments are dense and vascular, it is important to resist the temptation to avulse the spleen as it can be easy to underestimate the remaining time before it is fully detached. Even though the splenic artery has been taken, the spleen can receive a rich blood supply from the retroperitoneum, and losses can be considerable. This is generally avoidable by disciplined persistence, adapting and evolving the exposure needed to divide the vascularized attachments in a controlled fashion.

After the spleen is detached, any oozing points on the diaphragm, retroperitoneum, lienorenal, gastrosplenic or lienocolic ligaments can usually be controlled with argon beam coagulation. Bleeding from peripancreatic tissue or the short gastric stumps on the greater curve of the stomach may require clipping.

32.4.11 Use of the Handport

Conversion to an open procedure can nearly always be avoided by placing a handport. Anytime after the short gastric vessels are divided and the stomach is retracted, a handport may be placed to facilitate the dissection (Fig. 32.9). Prior to that time, it tends to be in the way. Insertion of a handport can be helpful if the colon is stuck to the spleen, if there has been severe pancreatitis or regional inflammation and the planes are unclear, or if troublesome bleeding is encountered. Insertion of the left hand provides immediate access to the hilum and anatomic clarity and vascular control is achieved (Fig. 32.10).

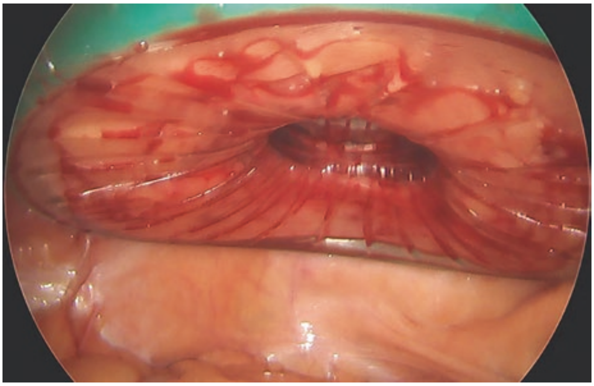

Fig. 32.9 Upper midline handport

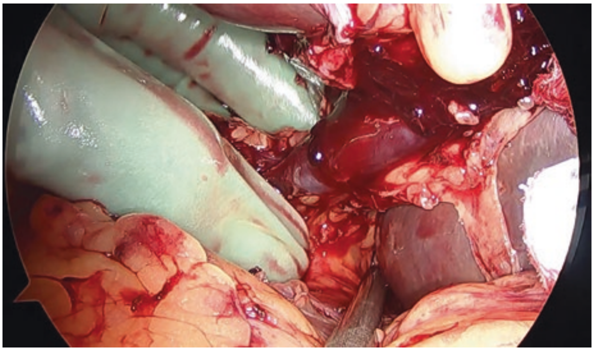

Fig. 32.10 Hand retraction in dissection of the splenic vein

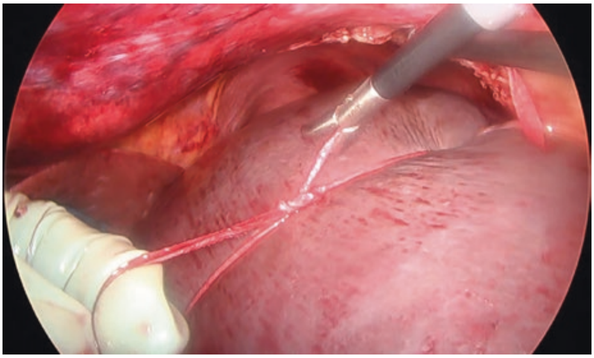

Fig. 32.11 Securing umbilical tape around the spleen

We virtually never use a handport for a normal spleen and commonly use it for a supramassive spleen. Not all supramassive spleens require a handport, but for those that are densely stuck, the left hand can provide atraumatic, dexterous, and steadily adapting retraction of the spleen to facilitate exposure. It is important to be aware that there is a tendency, nearly irresistible, for the left hand to bluntly dissect; this should be minimized as it leads to steady, although controllable, bleeding.

The handport can be created with a 6–8 cm incision fitted with a laparoscopic hand access device (Fig. 32.10). We typically place this in a vertical upper midline incision (replacing the epigastric 5 mm port) to avoid blocking the endoscope or other instruments. This incision subsequently serves as the spleen retrieval site. We found that use of the handport was associated with an extra postoperative day in the hospital, although a selection bias likely contributed to this finding [2].

32.4.12 Retrieval of the Spleen

Careful handling of the spleen during retrieval is key to avoiding spillage and resultant splenosis, especially for patients with autoimmune cytopenias. To avoid splenic disruption,especially for enlarged spleens, we introduce an umbilical tape and tie it

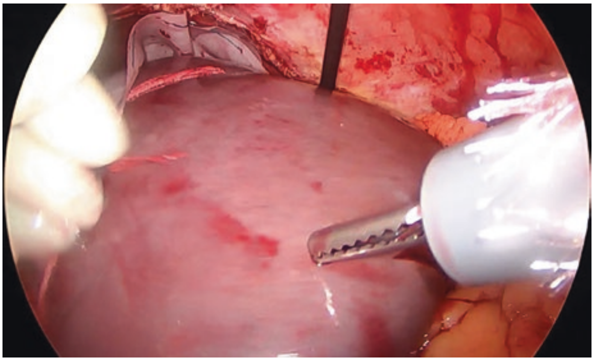

Fig. 32.12 Bagging the spleen

snugly around the narrowest part of the spleen to serve as an atraumatic laparoscopic handle (Fig. 32.11). This also provides an opportunity to size the spleen to select the appropriate specimen bag. We maneuver the spleen inferiorly with a grasper locked onto the knot, switch the endoscope to the most distant and inferior port on the right, and introduce a sturdy thick-walled specimen bag via the largest port. The bag is placed just below the diaphragm with the drawstring ties laterally, the closed end folded anteriorly along the curve of the diaphragm, and the mouth on the retroperitoneum facing the spleen. A grasper is securely locked onto the posterolateral lip of the bag to hold it against the retroperitoneum. We then position the patient in Trendelenburg with left side down and guide the spleen into the bag (Fig. 32.12).

**Tip*. The trick is to keep the posterior wall of the bag flush with the retroperitoneum so the spleen slides into the bag, rather than underneath it. Resist the temptation to pull the anterior wall of the bag over the spleen, which invariably extrudes the spleen. Rather, the maneuver is to shimmy the medial and lateral edges of the posterior wall of the bag under the spleen with steady cephalad force on the splenic tie while rolling it a bit side to side as needed.

Once the spleen is bagged, the patient is returned to a neutral position. We extract the mouth of the specimen bag through the largest port. Retracting the bag against the abdominal wall allows the maintenance of pneumoperitoneum, which is needed for continuous visualization with the endoscope to ensure there is no spillage or tearing of the bag during retrieval. Finally, we use a ring clamp and a suction aspirator with large blunt plastic wands to morcelate and extract the spleen in a piecemeal fashion.

**Tip*. The suction-powered plastic wands used by gynecologists for dilation and curettage are ideal for this purpose as they are blunt and do not risk perforation of the bag. A corkscrew motion allows them to morcellate the spleen while aspirating the contents. This accelerates extraction time by about two thirds, especially for very large spleens.

In the very rare case that the specimen must be retrieved intact for surgical margins, we use a Pfannenstiel incision for retrieval. This is generally not needed for hematologic malignancies.

We conclude by reestablishing pneumoperitoneum, irrigating and suctioning the splenectomy bed, and verifying hemostasis with special attention to the splenic vessels and short gastric vessels. We close the fascia for 10 mm or larger laparoscopic ports to prevent port site hernias.

32.4.13 Conversion to Open Splenectomy

Conversion to an open approach is an appropriate step when continuing with a minimally invasive approach is unsafe. If a hand port was used, that incision can be extended to a laparotomy incision. We have found this to be needed in <2% of patients.

32.5 Post-operative Management

We check baseline complete blood counts and coagulation studies in the postoperative recovery area, followed by daily counts if indicated to monitor for bleeding and recovery of cytopenias.

If there is no evidence of bleeding and the patient does not have contraindications, we start DVT prophylaxis with SCH immediately postoperatively; otherwise, we use SCDs. Many of patients with myelofibrosis and hematologic malignancies can be hypercoagulable, and if visceral thrombus is detected after splenectomy, we therapeutically anticoagulate in order to avoid propagation of thrombus into the portal venous system. This is an advantage afforded by the minimal blood loss and reduced risk of postoperative hemorrhage associated with a minimally invasive approach.

These patients are on an ERAS pathway that includes a multimodal opioid-sparing analgesic regimen including preoperative gabapentin, acetaminophen and scopolamine if under age 60, intraoperative dexamethasone, lidocaine, magnesium, local anesthetic, and minimal opioids. Postoperatively they receive scheduled gabapentin and acetaminophen to minimize opioid use. We avoid cyclooxygenase inhibitors given patients are typically thrombocytopenic.

Patients are given a regular diet the day after surgery and no activity restrictions. For some, frequent small meals are needed for a couple of weeks. The typical postoperative length of stay is one day for patients with a normal spleen. Patients with enlarged spleens are typically ready for either discharge or further hematologic treatment after 2–4 days.

If splenectomy vaccines were not completed preoperatively, we administer the series starting after postoperative day 14 (see Sect. 32.3). Overwhelming post-splenectomy infection (OPSI) is an uncommon but devastating long-term complication of splenectomy. Overwhelming sepsis due to encapsulated bacteria, most commonly *S. pneumoniae*, can occur years after surgery. Prior to the introduction of post-splenectomy vaccination, the incidence of OPSI was 3.2% and the mortality rate was 1.4% [22]. Adequate preoperative or postoperative vaccination significantly decreases the risk of OPSI [23].

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Chapter 33
Laparoscopic Adrenalectomy

Jina Kim, Claire E. Graves, and Sanziana A. Roman

33.1 Introduction

Laparoscopic adrenalectomy is a minimally invasive approach for resection of the adrenal gland that can be performed in one of two ways: transabdominally or via a posterior, retroperitoneal approach. In 1991, Snow et al. performed the first successful transabdominal laparoscopic adrenalectomy, which was soon followed by the first posterior, retroperitoneal laparoscopic adrenalectomy by Mercan et al. in 1995 [1, 2].

Since its introduction in the 1990s, laparoscopic adrenalectomy has since become the preferred approach for nonfunctional and functional benign lesions, as it has similar biochemical cure rates and fewer complications in comparison to open adrenalectomy [3, 4]. In cases of primary hyperaldosteronism, several single institutions studies have shown laparoscopic adrenalectomy to be associated with lower risk of postoperative complications and shorter hospital length of stay [5–7]. Nonfunctioning benign lesions with suspicious imaging findings or size between 4 to 10 cm should be considered for laparoscopic adrenalectomy. Because of the limited working space, the retroperitoneoscopic approach is typically not recommended for tumors larger than 7–8 cm [8]. Although there is no size limit to the laparoscopic transabdominal approach, tumors >10 cm may not be as amenable

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to laparoscopy due to technical difficulty or local invasion. However, the placement of a hand-assist port can help for resecting tumors >10 cm.

In addition to large tumor size, suspected adrenocortical carcinoma is considered a relative contraindication for laparoscopic resection. The use of laparoscopic adrenalectomy in adrenocortical carcinoma is controversial, as some studies have suggested that laparoscopic approach may increase risk of locoregional recurrence or mortality [9, 10].

33.2 Preoperative Management

Initial evaluation of an adrenal mass should rule out functional tumors: hyperaldosteronism, hypercortisolism, or pheochromocytoma. Initial laboratory studies therefore should include serum potassium levels, aldosterone, plasma renin activity, a low-dose dexamethasone test, and plasma fractionated metanephrines. If any of the initial biochemical evaluation is abnormal, consultation with an endocrinologist is recommended, and further confirmatory testing is necessary.

For patients with functional tumors, electrolyte or metabolic abnormalities should be corrected prior to surgery. Patients with primary hyperaldosteronism may need potassium supplementation, as they characteristically have hypokalemia. Patients with Cushing syndrome may require correction of hyperglycemia and electrolytes. Importantly, those with pheochromocytoma will need close preoperative management to manage their blood pressure. These patients first receive alpha blockade with doxazosin, prazosin, or phenoxybenzamine. Subsequent beta-blockade may be needed in patients with persistent tachycardia. Patients with pheochromocytoma also need volume repletion and increased salt intake to avoid postoperative hypotension [3].

Imaging evaluation of an adrenal mass may aid in distinguishing malignant and benign disease. If an adrenal mass with smooth borders measures less than 10 Hounsfield units (HU) on a noncontrast computed tomography (CT), it is likely to be a benign adenoma [3]. CT findings of a poorly defined tumor with high CT attenuation > 20 HU, delay in contrast washout, high standardized uptake value on FDG-PET, calcifications, necrosis and associated lymphadenopathy are suggestive of malignancy.

Troubleshooting: Pregnant patients merit special preoperative consideration. Ideally, surgery would be delayed until a few months after delivery, but if surgery is required during pregnancy, the second trimester is safest. Surgery during the first trimester carries risk of teratogenesis and spontaneous abortion, while the surgery in the third trimester poses greatest risk of preterm labor [12].

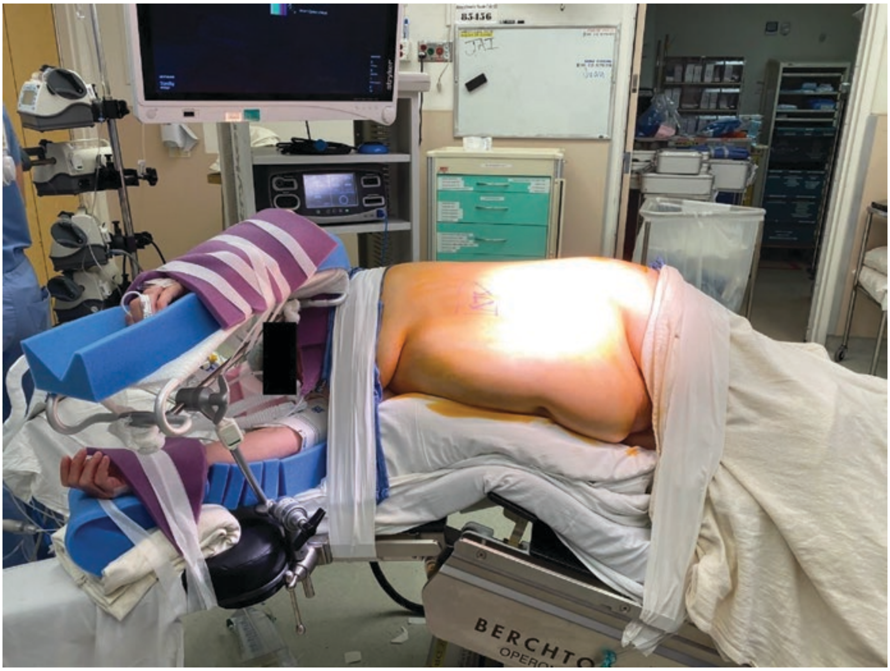


Fig. 33.1 Positioning for laparoscopic transabdominal left adrenalectomy

33.3 Left Adrenalectomy

33.3.1 Laparoscopic Transabdominal Left Adrenalectomy (TAA)

1. *Patient positioning*

   The patient is intubated, the urinary catheter placement and line placement are done in the supine position. An orograstric tube is indicated to keep the stomach decompressed during the procedure. Sequential compression devices are applied to the legs for venous thromboembolism prophylaxis. The patient is then placed on a padded bean bag in the right lateral decubitus position (left side up). The operating table is flexed at the waist with the kidney rest elevated to open up the area between the lower ribs and the iliac crest. The left arm should be secured forward, at the level of the patient's head using a padded armrest. The right leg is flexed while the left leg is left straightened, with padding between the legs and around them; this position opens the flank area more. The bean bag air is evacuated and hardened to secure this position. The surgeon and assistant both stand on the patient's right side. The laparoscopic tower and screen are placed on the patient's left, over the patient's left shoulder, for an in-line view (Fig. 33.1).

2. *Incisions/Trocar Placement*

Pneumoperitoneum to 12–15 mmHg can be achieved using a Veress needle. The Veress needle is inserted in the left anterior axillary line below the costal margin. Alternatives to the Veress needle are an optical trocar or muscle-splitting open technique with an 11mm Hasson cannula, by which the abdominal cavity can be entered with direct visualization.

Ports are placed along the left subcostal margin. Two additional 5 mm ports are placed: one in the mid-axillary line near the epigastrium, one in the mid-axillary line lateral to the 11 mm port. Most left TAA can be performed with three ports. If needed, a fourth 5 mm port can be placed slightly below the anterior axillary line port and the mid axillary line port in a triangular configuration. For patients who have thick abdominal walls, the lateral-most port in the mid axillary line can be converted to a 10 mm trocar.

Troubleshooting: A hand-assist port could be inserted in the medial most subcostal region by making a 6 cm incision in the subcostal area encompassing the medial-most 5 mm port site. A hand-assist port is valuable if an adrenal mass is large, friable, or concerning for malignancy and can avoid a full conversion to open surgery in most cases.

3. *Exposure*

A retractor is inserted through the medial-most port to retract the spleen. A 5 mm, 30-degree laparoscope is inserted through the lateral-most port. Dissecting instruments are placed in the middle (and the fourth, if needed) port. To expose the left adrenal gland, the splenic flexure of the colon is mobilized first by dividing the attachments to the spleen and pancreatic tail. This maneuver allows for the spleen and pancreatic tail to fall medially and the colon to be mobilized inferiorly (Fig. 33.2). The splenorenal ligament is then entered, and taken down circumferentially around the spleen all the way superiorly to the diaphragmatic crus and gastric cardia. This allows the spleen and pancreatic tail to be mobilized medially off the adrenal gland and kidney posteriorly, exposing the anterior aspect of the adrenal gland.

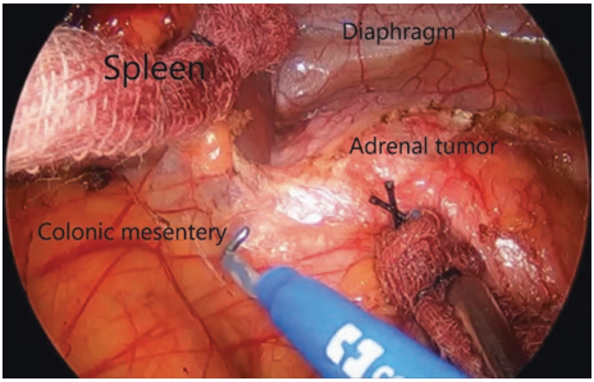


Fig. 33.2 Splenic flexure mobilization during laparoscopic transabdominal left adrenalectomy allows for the spleen and pancreatic tail to fall medially while the colon falls inferiorly

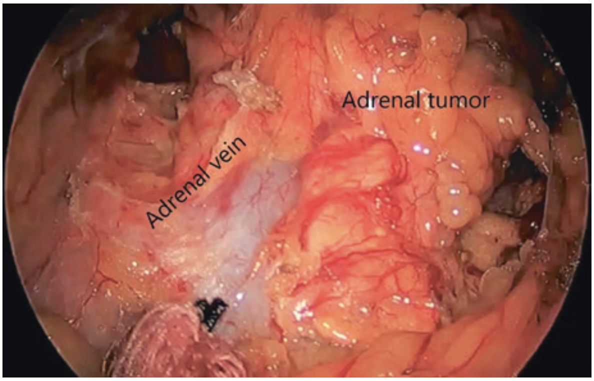


Fig. 33.3 Identification and dissection of the adrenal vein during laparoscopic transabdominal left adrenalectomy. If the left adrenal vein cannot be identified intraoperatively, the left phrenic vein can be used as a guide to track inferiorly to where it joins the adrenal vein

4. *Dissection of the adrenal gland*

   The avascular plane between the transverse mesocolon and Gerota's fascia is incised to expose the left renal vein. The left adrenal vein can be identified as it runs from the inferior aspect of the adrenal gland to the renal vein (Fig. 33.3). If the left adrenal vein cannot be identified, the left phrenic vein also can be used as a guide to track inferiorly where it joins the adrenal vein. The left adrenal vein is then dissected, ligated, and divided between clips. Arterial branches originating from the phrenic, aortic and renal areas can be coagulated or clipped and divided. The adrenal gland is dissected off the kidney inferolaterally. Superior and lateral dissection in the retroperitoneum can be delayed until later in the procedure, as these attachments help keep the adrenal suspended, facilitating medial and inferior dissection.

   Troubleshooting: If conversion to an open procedure is required, a subcostal incision can be created by connecting the subcostal trocar incisions. The authors prefer to insert a hand-assist port as an intermediate step for a very difficult laparoscopic TAA before converting to a fully open procedure if possible.

5. *Specimen retrieval*

   Once the dissection and vein ligation is complete, the adrenal gland can be placed in a specimen bag and brought out through the 11 mm port. The authors do not recommend morcellating the adrenal gland. Taking out the port and applying surgical sterile lubricant in the port site can help slide the retrieval bag out. A large adrenal mass also can be extracted via a hand-assist port if used.

33.3.2 Posterior Retroperitoneoscopic Left Adrenalectomy (PRA)

1. *Patient Positioning*

Fig. 33.4 Empty surgical bed for prone positioning, with lateral vertical supports to allow the abdominal wall to drop ventrally with gravity

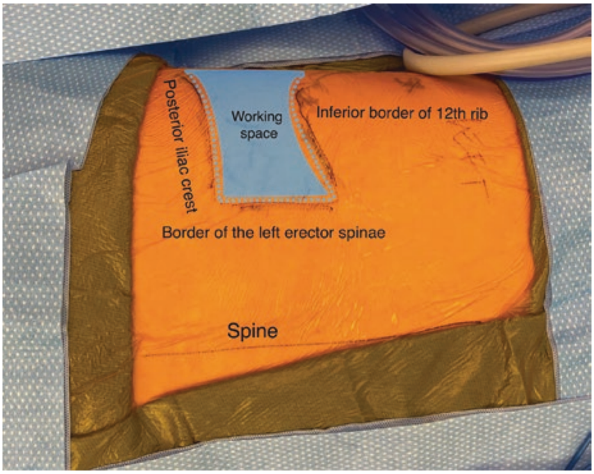
PRA requires special equipment for prone positioning. Endotracheal intubation, urinary catheter placement, and line placement are performed with the patient supine on a stretcher. The patient is then positioned prone, either on a dedicated prone bed or a standard bed with extenders that allows for flexion at the hip joints and a special bed padding that allows for abdominal support which should be empty in the middle to allow for gravity and insufflation to drop the abdominal wall ventrally, away from the retroperitoneum. This can be achieved either with vertical supports on a prone bed (Fig. 33.4), or with horizontal bolsters at the inferior rib cage and hip joint, placed at the leg break on a standard bed [13].

The bed is positioned so that the patient is flexed at the hips 90 degrees on a prone bed. The knees are bent, and the shins prevent caudal displacement. The bed should be tilted as needed, so that the patient's back is horizontal to the floor. The patient is positioned toward the left side of the bed to allow full range of motion with the laparoscopic instruments at the level of the left flank. The arms are placed toward the patient's head, bent at the elbow in the modified partial "superman" position (Fig. 33.5). The patient should be secured to the bed with tape and belts to prevent slippage during the procedure. Sequential compression devices are applied to the legs for venous thromboembolism prophylaxis.

Troubleshooting: If conversion to an open procedure is necessary, the conventional posterior technique can be undertaken, connecting the three trocar incisions, and may require resection of the 12th rib [14].

Fig. 33.5 Patient positioned prone. The patient's hips are flexed 90 degrees. Bent knees are supported with padding and taped in place to prevent rear slippage. The bed is tilted as needed

Fig. 33.6 The working space of the posterior retroperitoneoscopic adrenalectomy is bordered superiorly by the 12th rib, medially by the paraspinous muscle externally (psoas muscle internally), and the posterior iliac crest inferiorlyt



2. *Incisions/Trocar Placement*

   The anatomic location of the 11th and 12th ribs, as well as the paraspinous muscles and the posterior iliac crest are palpated. The working space is bordered superiorly by the 12th rib, medially by the paraspinous muscle externally (psoas muscle internally), and the posterior iliac crest inferiorly (Fig. 33.6).

A space of at least two fingerbreadths should exist between the 12th rib and the iliac crest for optimization of this approach. The initial incision is made transversely 5 mm below the tip of the 12th rib, and the subcutaneous tissue is dissected. Using a closed Metzenbaum or Mayo scissor, the retroperitoneal space is bluntly entered through the posterior fascia. Palpation of the smooth underside of the rib confirms entry into the correct space. Blunt finger dissection creates a small space lateral, superior, and medial to the retroperitoneal entry site to allow for placement of the lateral and medial ports under direct palpation with an internal finger to ensure all ports enter the same space. The medial 5 mm trocar is placed just lateral to the sacrospinal muscles externally, and just lateral to the psoas muscle internally (this can be palpated digitally through the 12 mm port site), and the lateral 5 mm trocar is placed approximately 4–5 cm lateral to the initial incision, in approximately the midaxillary line in the flank area. A 12 mm balloon-tip trocar with adjustable sleeve is placed in the middle, initial incision site, the balloon inflated, and pulled snugly to the fascia to secure the trocar to the abdominal wall and avoid subcutaneous insufflation of CO_2.

Troubleshooting: Finger palpation is crucial to direct trocars into the same space. The index finger can be used to push the fatty tissue onto the distal end of the trocar to facilitate this, as well as to avoid scope smearing on entry and exit from the trocar. It can also palpate the kidney and protect it during trocar insertion.

3. *Creating the Retroperitoneal Space*

The retroperitoneal space is insufflated with CO_2 to approximately 20–25 mmHg, and a 30 degree laparoscope, angled toward the ceiling, inserted in the medial-most trocar. Higher pressures may be necessary for large patients or those with a significant amount of retroperitoneal adipose. Laparoscopic graspers are inserted into the lateral port and diathermy or sealing/cutting dissection instruments are placed in the middle port. The avascular plane between the retroperitoneal fatty tissue and Gerota's fascia is bluntly dissected, taking down the posterior attachments and sweeping them ventrally. Keeping the psoas muscle in view on the right side of the screen allows dissection to proceed in the correct plane.

This dissection continues cranially, working towards the superior border of the space, often visualizing the renal hilum inferiorly. The newly-developed space is bordered by the psoas muscle medially, the kidney laterally, the chest wall superiorly, and the renal hilum and the peritoneum inferiorly.

Troubleshooting: If the patient becomes hypercarbic during the procedure, temporary desufflation of the retroperitoneum and hyperventilation of the patient by the anesthesiologist may be necessary. Subcutaneous inspissation of CO_2 can occur in a prolonged procedure under high pressure; this is not dangerous to the patient and will resolve within a few hours

4. *Mobilization of the Upper Pole of the Kidney and Initial Dissection*

The perirenal fat is then gently bluntly dissected to identify the superior border of the kidney. The perirenal fat is separated from the kidney along the supe-

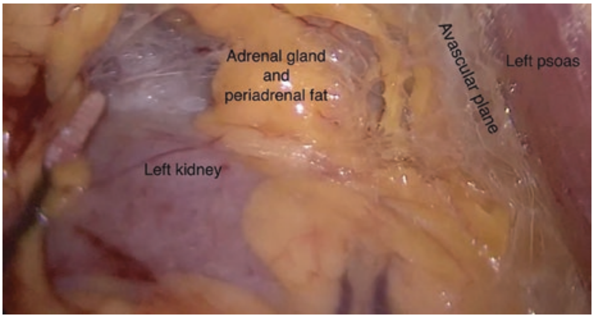


Fig. 33.7 Keeping the psoas muscle in view on the right, the avascular plane is dissected, proceeding cranially. The perirenal fat is separated from the kidney, which is retracted ventrally, laterally, and inferiorly away from the inferior border of the adrenal gland

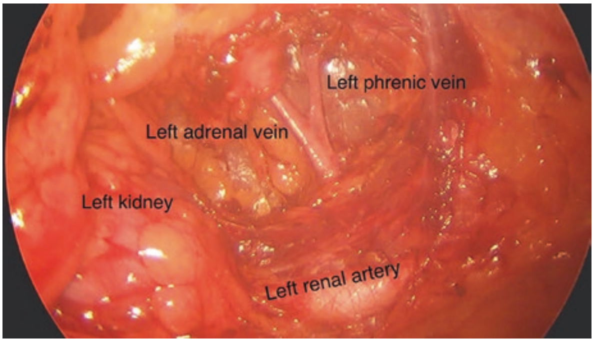


Fig. 33.8 View of the major vasculature of the retroperitoneal dissection

rior and lateral borders of the kidney using a sealer/divider device. This dissection allows for lateral and inferior retraction of the kidney away from the inferior border of the adrenal gland (Fig. 33.7). The inferior border of the adrenal gland may become visible during this point in the dissection.

After mobilizing the superior pole of the kidney, dissection of the adrenal gland often begins inferiorly and medially, sealing the small vessels between the adrenal gland and the psoas and diaphragm.

Troubleshooting: Of note, polar renal arterioles can often be seen here traversing across this area; care should be taken to follow these to the kidney and preserve them intact if they prove to be polar vessels. Transecting such vessels will make segments of the kidney ischemic, which is problematic. The adrenal gland often is just cranial to such vessels. In this infero-medial space, one usually can identify and divide the adrenal vein early (see next section). Dissection of the adrenal gland should always be performed with gentle dissection to avoid violation of the capsule.

5. *Identification and Division of the Adrenal Vein*

The left adrenal gland typically lies more caudal than the right gland, anterior to (i.e., “behind”) the upper pole of the kidney. With the kidney retracted inferiorly and medially, the anterior surface of the kidney is freed from the periadrenal fat, and the junction of the adrenal vein and the phrenic vein can be

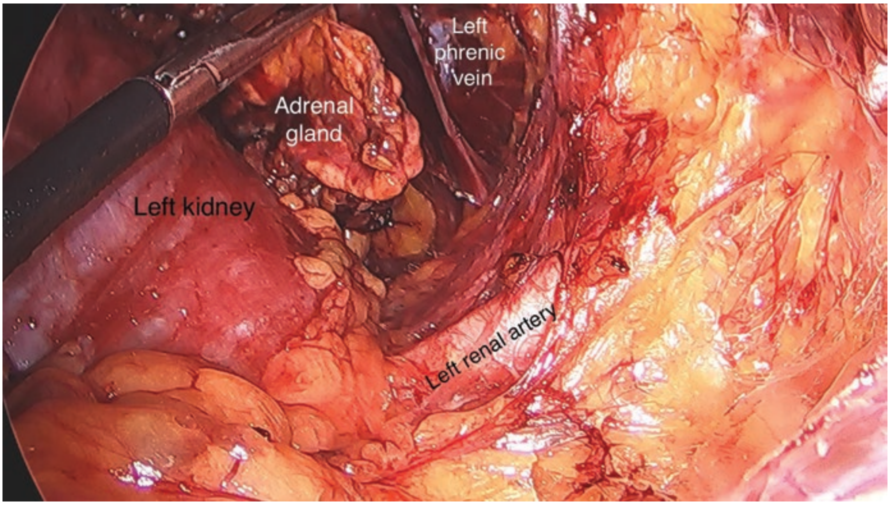


Fig. 33.9 The adrenal gland is freed from the remainder of its attachments, resting on the superior left kidney, ready for extraction

identified medially. There is often a finger of adrenal tissue extending up to this convergence. The adrenal vein is carefully dissected and divided with a vessel sealer or surgical clips (Fig. 33.8). The phrenic vein is typically left intact, though the vein may be taken distal to the confluence of the adrenal vein and phrenic vein, if necessary.

6. *Completion of Dissection and Extraction of Specimen*

After division of the adrenal vein, the adrenal gland can be mobilized, and freed from the remainder of its attachments medially, laterally, and cranially. The posterior attachments of the adrenal gland to the retroperitoneum (the ribcage) should be kept until the end to provide a natural suspension and avoid letting the adrenal gland fall anteriorly toward the abdomen. It is often useful to use the stump of the adrenal vein as a handle to manipulate the gland atraumatically. Blunt dissection is typically all that is necessary to release these attachments (Fig. 33.9).

Care should be taken to avoid traumatizing the peritoneum to the cranial end of the dissection in order to avoid injury of structures just beyond it, such as the splenic vessels, pancreatic tail and spleen. Once the adrenal gland is mobilized completely from all attachments, a specimen retrieval bag is placed through the center port and the specimen is extracted. Depending on the tumor size and type, the incision may need to be extended slightly [15], and sterile surgical lubricant can be placed in the incision to facilitate extraction. The authors do not recommend morcellation of the adrenal specimen. The fascia of the extraction port site is closed with an absorbable suture. Closed suction drainage is not necessary.

Troubleshooting: If the peritoneum is inadvertently torn during ventral dissection, the subsequent pneumoperitoneum may decrease the retroperitoneal working space. However, repair is unnecessary. If the patient has a thick abdominal wall, the 5 mm medial-most camera port can be enlarged into a 10 mm port to allow placement of a 10 mm scope, which will be stronger and resist inadvertent bending and destruction of the thinner scope.

33.4 Right Adrenalectomy

33.4.1 Laparoscopic Transabdominal Right Adrenalectomy (TAA)

1. *Patient positioning*

The patient is intubated, the urinary catheter placement and line placement are done in the supine position. An orograstric tube is indicated to keep the stomach

Fig. 33.10 Patient positioning for laparoscopic transabdominal right adrenalectomy

decompressed during the procedure. Sequential compression devices are applied to the legs for venous thromboembolism prophylaxis. The patient is then placed on a padded bean bag in the left lateral decubitus position (right side up). The operating table is flexed at the waist with the kidney rest elevated to open up the area between the lower ribs and the iliac crest. The right arm should be secured forward, at the level of the patient's head using a padded armrest. The left leg is flexed while the right leg is left straightened, with padding between the legs and around them; this position opens the flank area more. The bean bag air is evacuated and hardened to secure this position. The surgeon and assistant both stand on the patient's anterior/left side. The laparoscopic tower and screen are placed on the patient's right, over the patient's right shoulder, for an in-line view (Fig. 33.10).

2. *Incisions/Trocar Placement*

   The authors generally use four trocars aligned along the costal edge. The initial trocar site is where the pneumoperitoneum to 12–15 mmHg is achieved using a Veress needle, an optical trocar, or open technique with a Hasson cannula placed at the anterior axillary line just below the ribs. The liver edge often extends to this area, so care should be taken to avoid injury to the liver. This initial site is ultimately a 10–12 mm trocar. Additional ports are then placed

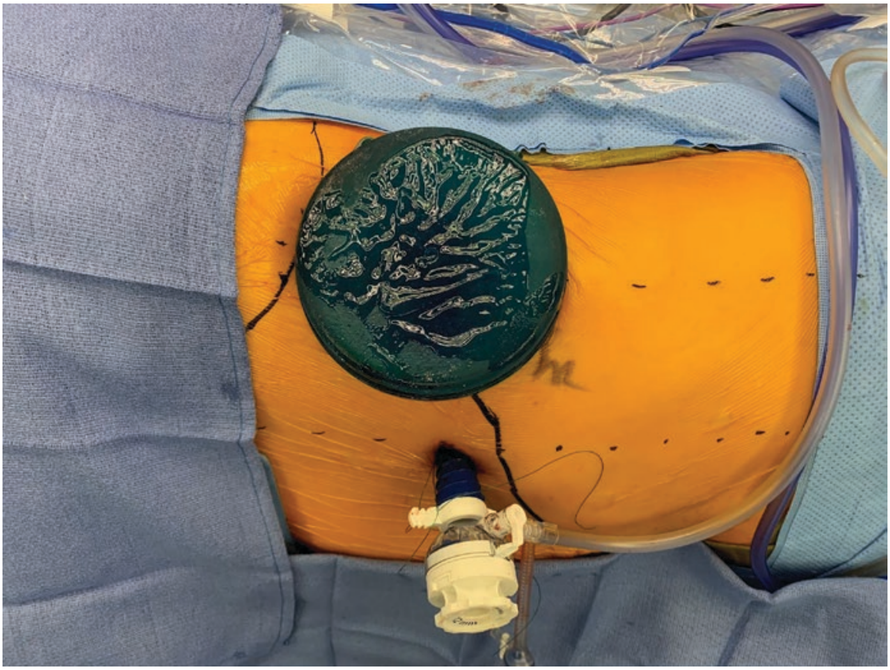


Fig. 33.11 Location of the hand-assist port, if used, during laparoscopic transabdominal right adrenalectomy

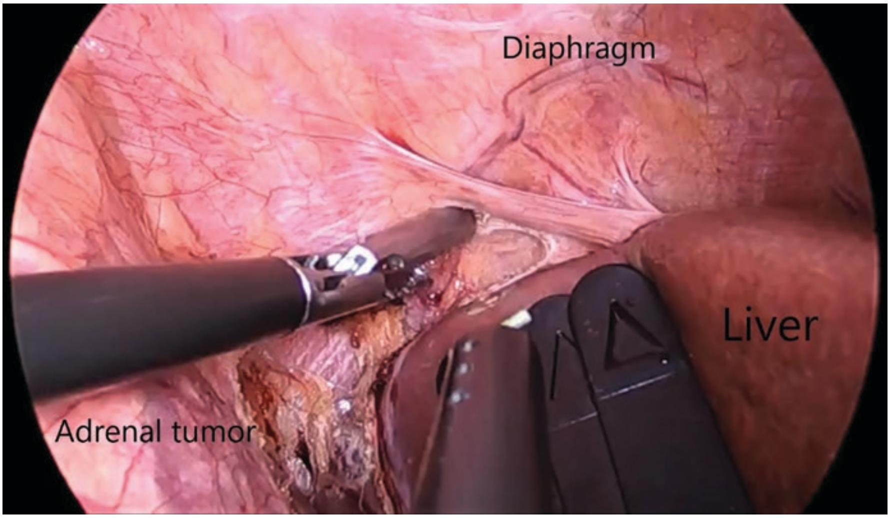


Fig. 33.12 The right triangular ligament is divided and the liver retracted during laparoscopic transabdominal right adrenalectomy

under direct vision with the help of the laparoscope as follows: one 5 mm port is placed medial to the initial trocar in the subcostal region and one 5 mm port is lateral in the subcostal region at the mid-axillary line. A fourth 10 mm port is placed in the subcostal region near the epigastrium through which a fan liver retractor can be placed.

If a hand-assist port is planned to be placed up front, then the 10 mm liver retractor port is not absolutely necessary. The hand-assist port can be placed in the flank/midaxillary line and the inserted left hand can hold the liver edge up with its dorsum, while the fingers manipulate the area below the liver. The authors then use the hand-assist port most laterally, the 10–12 mm port in the middle, and a 5 mm port in the midclavicular line, subcostally (Fig. 33.11). The port position is strategic for maximal visualization and manipulation, and for facilitating conversion to an open procedure by connecting all the incisions into one subcostal incision.

3. *Exposure*

The 30-degree laparoscope is inserted through the lateral-most port. Energy dissecting instruments are placed in the middle two ports. To expose the right adrenal gland, the right triangular ligament of the liver is divided to allow rotation of the right lobe of the liver medially. The retroperitoneum is incised and taken under the liver onto the right kidney and adrenal gland superiorly toward the inferior vena cava (IVC) medially. A fan retractor is inserted through the most medial port to retract/lift the liver upward (Fig. 33.12). The second portion of the duodenum will often need to be mobilized to better expose the right adrenal gland and the IVC.

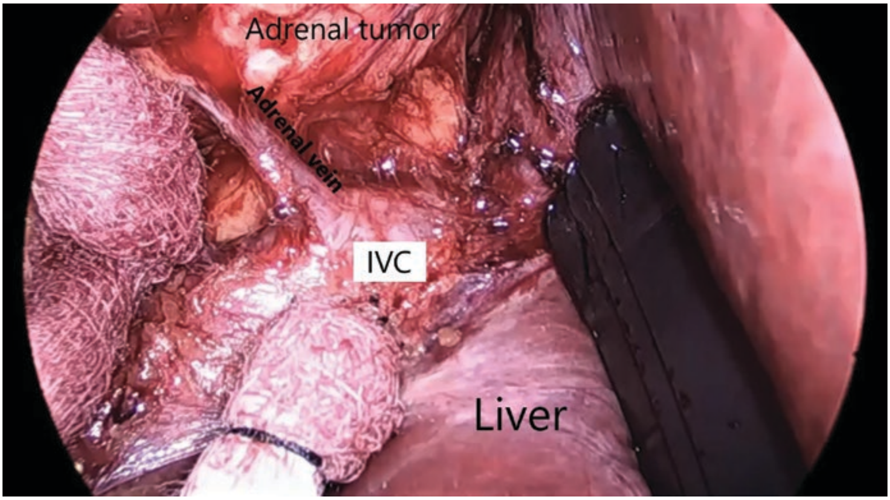


Fig. 33.13 The right adrenal vein, which is often short, is identified as it joins the IVC in laparoscopic transabdominal right adrenalectomy

Troubleshooting: Care should be taken to avoid traumatizing the gallbladder, as traumatic cholecystitis can occur postoperatively if this happens. Any prior surgery, such as the patient having had a laparoscopic cholecystectomy in the past, or prior perihepatic infection can cause adhesions, which will need to be carefully taken down. Avoid traction or trauma of the liver capsule, as this can cause liver bleeding or occult subcapsular liver hematoma. Liver tears can be controlled with manual pressure or use of the argon beam coagulator for superficial tears.

4. *Dissection of the adrenal gland*

Gerota's fascia, which covers the kidney and adrenal gland, is incised anteriorly and extended toward the diaphragm. The IVC is separated from the right superior aspect of the kidney, which is gently retracted downward and laterally. This opens the space between the lateral retroperitoneal structures and the IVC. Blunt and diathermic dissection can be carried craniad, between the IVC and the adrenal gland. The right adrenal vein can then be identified where it joins with the inferior vena cava (Fig. 33.13). It is often short, and can insert slightly onto the posterior aspect of the IVC. It should be dissected circumferentially, clipped and divided. Arterial branches can be coagulated, clipped and divided. The adrenal gland is dissected superiorly free from under the liver, and then inferiorly off the kidney. As mentioned for the left adrenalectomy, lateral dissection can be delayed until later in the procedure, as these attachments help keep the adrenal suspended, facilitating medial dissection.

Troubleshooting: Timing of vein ligation can be variable based on the disease process as well as intraoperative findings. In cases of pheochromocytoma, early venous ligation may reduce intraoperative hemodynamic instability. If the vein

cannot be identified or is adherent to the IVC, the vein can be ligated after lateral and inferior mobilization.
Under the liver, small direct draining veins from the hepatic lobe into the IVC can be encountered. These should be either avoided or carefully clipped to avoid tearing the IVC in a deep space, which would be difficult to control.

5. *Specimen retrieval*
   Once the circumferential dissection and vein ligation is complete, the adrenal gland can be placed in a specimen bag and brought out through the 12 mm port. The authors do not recommend specimen morcellation, but placement of a sterile surgical lubricant into the trocar site can facilitate bag removal. Closed suction drainage is not necessary. The extraction port may have to be enlarged slightly, and then it will need to be closed by approximating the transverse/oblique muscle layers with absorbable sutures.

33.4.2 Posterior Retroperitoneoscopic Right Adrenalectomy (PRA)

1. *Patient Positioning*
   The patient is positioned as discussed above for left PRA, with the exception that the patient is positioned toward the right side of the bed to allow free access to the right flank.
2. *Incisions/Trocar Placement*
   Please refer to the segment of the left PRA for complete description of trocar placement. Briefly, the initial 12 mm incision is made transversely just below the tip of the 12th rib, and the retroperitoneal space is bluntly accessed. Blunt finger dissection creates a small space lateral, superior, and medial to the retroperitoneal entry site to allow for placement of the medial 5 mm trocar just lateral to the paraspinous and psoas muscles and the lateral 5 mm trocar in approximately the posterior axillary line, both under direct palpation, directing all trocars into the posteriorly created space. A 12 mm balloon-tip trocar with adjustable sleeve is placed in the middle, initial incision site, the balloon inflated, pulled snugly to the fascia, and secured in place. Insufflation to a pressure of 20–25 mm Hg is achieved. For patients who have significant retroperitoneal adipose or musculature, higher pressures may be indicated.
   Troubleshooting: If the patient becomes hypercarbic during the procedure, temporary desufflation of the retroperitoneum and hyperventilation of the patient by the anesthesiologist may be necessary. Subcutaneous inspissation of CO_2 can occur in a prolonged procedure under high pressure; this is not dangerous to the patient and will resolve within a few hours.
3. *Creating the Retroperitoneal Space*
   The 30 degree scope is placed in the medial port, and the dissecting instruments in the lateral ports. The psoas muscle should be kept in view on the left

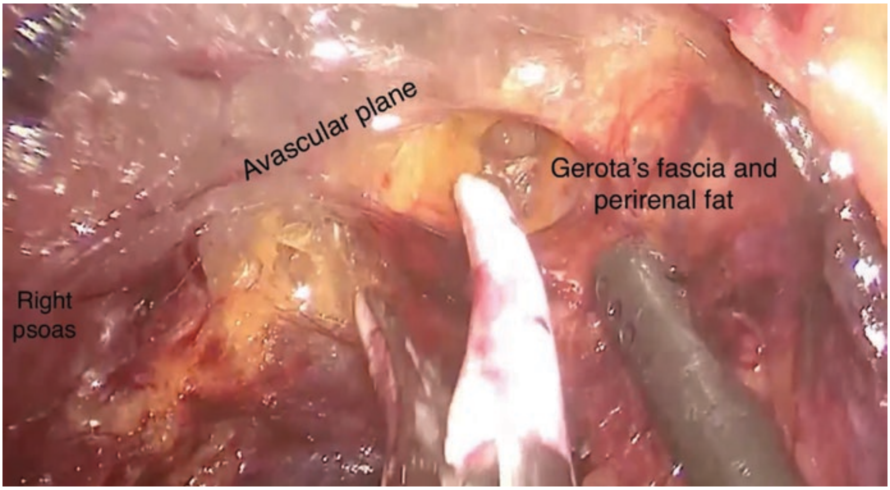


Fig. 33.14 Upon entry, the avascular plane between the psoas muscle medially (left of image) and the retroperitoneal fatty tissue and Gerota's fascia laterally (right of image) is bluntly dissected, sweeping the posterior attachments ventrally

side of the screen. The kidney should be identified and kept on the right side of the screen. The avascular plane between the psoas muscle medially and the retroperitoneal fatty tissue and Gerota's fascia laterally is bluntly dissected, sweeping the posterior attachments ventrally (Fig. 33.14). This dissection continues cranially, often identifying the renal hilum below, continuing working towards the superior border of the kidney, and until the adrenal gland is encountered.

4. *Mobilization of the Upper Pole of the Kidney and Identification of the IVC*

The perirenal fat is bluntly dissected to identify the superior border of the kidney. The perirenal fat is then separated from the kidney along the superior and lateral borders of the kidney using a sealer/divider device, and the kidney is retracted laterally and ventrally, away from the inferior border of the adrenal gland. After mobilizing the superior pole of the kidney, the adrenal gland is identified medially. Dissection may begin inferiorly and medially, using blunt dissection to identify the IVC ventrally and medially, under the adrenal gland. The IVC is flattened by the high insufflating pressures and will appear like a broad flat bluish band. Once the IVC is identified, dissection of the adrenal gland can be undertaken medially and cranially along the IVC. Blunt dissection and diathermy can be used to clear the medial aspect of the adrenal gland toward the liver dome and diaphragm. Medially and ventrally, the duodenum is located, but this will not be visible; its location should be expected and respected. Dissection of the adrenal gland should always be performed with gentle, blunt or diathermic dissection to avoid violation of the capsule.

Troubleshooting: The renal artery often has significant anatomic variations. An upper pole renal artery may enter superiorly, outside of the hilum, and should be avoided as the upper pole of the kidney is mobilized. Any arteriolar

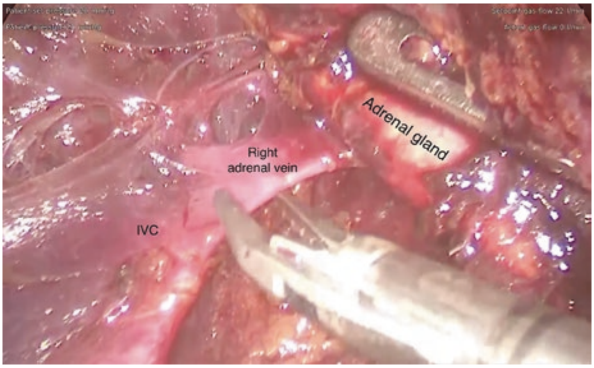


Fig. 33.15 The right adrenal vein originates from the lower medial adrenal gland and enters directly into IVC. The adrenal vein is bluntly dissected and clipped

appearing structure should be traced distally, to assure it is a true adrenal feeding artery (which can be taken) and not a renal polar artery (which should be preserved). The attachment of the adrenal gland to the superior aspect, the liver dome, and the sacrospinous muscles should be kept intact to allow natural suspension of the gland, which will aid dissection in the ventral portion, onto the IVC.

5. *Identification and Division of the Adrenal Vein*

   The adrenal gland is freed medially away from the psoas muscle, inferiorly away from the kidney and laterally away from the right hepatic lobe. Small adrenal arteries crossing the IVC posteriorly entering directly into the adrenal gland are divided with a vessel sealer or clips, allowing the gland to be gently lifted posteriorly to visualize the IVC. The adrenal vein typically enters the lower medial adrenal gland anteriorly (deep to the dissection) into the IVC. Once identified, the adrenal vein is bluntly circumferentially dissected free from the periadrenal fat in order to cleanly clip/seal with a vessel sealer and divide (Fig. 33.15).

   Troubleshooting: If significant bleeding is encountered while mobilizing the adrenal gland in the retroperitoneum, assess the surgical plane to ensure dissection is not entering the gland itself. If the IVC is torn by traction of the adrenal vein, bleeding can be controlled by compressing the IVC further with increased retroperitoneal pressure and direct pressure to the IVC with a blunt, non-traumatic instrument. This can allow control of the hemorrhage until it can be examined and controlled permanently adequately either by clip or suture. CO_2 embolization is very rare, but the pressure should be dropped once the IVC tear is clearly identified, examined, understood, controlled, and a repair plan put forth. If the hemorrhage is not controllable, performing an open retroperitoneal PRAprocedure may be necessary.

6. *Completion of Dissection and Extraction of Specimen*

   The adrenal gland is then mobilized and bluntly freed from the remainder of its attachments medially, laterally, and cranially. At this point, the adrenal gland is fully under the dome of the right lobe of the liver, so care must be taken to avoid injury to the liver. Once the adrenal gland is mobilized completely from all attachments, a specimen retrieval bag is placed through the center port, and the specimen is extracted. The authors do not recommend morcellation of the specimen. The fascia of the medial port site is closed with an absorbable suture. Closed suction drainage is not necessary.

33.5 Postoperative Management

Post-operative care for patients who undergo TAA or PRA is similar, and nuances in management are dictated by the preoperative diagnosis. Patients can receive a regular diet postoperatively, and their urinary catheters are removed right after surgery. Electrolytes should be measured especially for patients with Cushing syndrome or primary hyperaldosteronism.

Most patients are discharged within 8–30 hours after surgery, except for those with Cushing syndrome who may require steroid replacement postoperatively. To assess subclinical hypoadrenalism, a morning serum cortisol level can be obtained on postoperative day 1. Depressed levels of cortisol will denote hypothalamic-pituitary-adrenal axis suppression and supplemental steroids will be necessary. Steroid taper schedules vary depending on the severity of the adrenal insufficiency; they typically start with one or two intravenous doses, then transition to oral doses once the patient is tolerating adequate oral intake. Patients who undergo unilateral adrenalectomy for Cushing syndrome may require steroids for many months, while those who undergo bilateral adrenalectomy will require lifelong steroid replacement with hydrocortisone or prednisone and fludrocortisone. Follow up with a medical endocrinologist is indicated on an outpatient basis. Acute adrenal insufficiency can manifest with nonspecific symptoms such as fever, nausea, hypotension and lethargy. Laboratory studies will often demonstrate hyponatremia, hyperkalemia and hypoglycemia. Acute adrenal insufficiency is diagnosed with an ACTH stimulation test, but treatment should be started based on clinical suspicion, especially after adrenalectomy [3].

For patients who are post-pheochomocytoma excision, continuous immediate postoperative measurement of vital signs and telemetry is indicated, but most patients can be weaned off any pressors in the operating room or recovery room, and will be able to be admitted overnight to a regular inpatient floor. Telemetry can be continued overnight if necessary. All preoperative alpha blockade should be stopped; any beta-blockade that was started specifically for the purpose of controlling heart rate preoperatively should be weaned over a medically determined time.

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Chapter 34
Laparoscopic Feeding Jejunostomy and Gastrostomy

Dallas D. Wolford and Marc A. Ward

34.1 Introduction

Malnutrition is common and often unrecognized in hospitalized patients [1, 2] and is estimated to affect 20–50% of adults [3, 4]. It plagues patients with dysphagia, cancer of the upper gastrointestinal tract and biliary system, those undergoing extensive surgery with prolonged periods of fasting, and hypercatabolic states requiring supplemental nutrition [5]. Protein-calorie malnutrition (PCM) is both a cause and effect of poor health and negatively affects outcomes in all patients, specifically critically ill, oncologic, and surgical patients [6–8]. The first reported association between PCM and outcomes in surgical patients was in a 1936 study of patients undergoing surgery for peptic ulcers and found a 33% mortality rate in malnourished patients vs 3.5% in appropriately nourished patients [9]. Since then, PCM's profound negative impact on patients has been well corroborated. PCM leads to immune system dysfunction and increased risk for infection, poor wound healing, anastomotic leaks, overgrowth of gastrointestinal microbiota leading to derangements in digestion and absorption, increased frequency of decubitus ulcers, and deep venous thrombosis [10–16]. Furthermore, there is an 8-fold increase in mortality in malnourished patients regardless of their premorbid status [17].With

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regard to surgery, postoperative malnutrition is associated with increased postoperative mortality [18–20]. Stress from surgery, cancer, critical conditions and illnesses, creates a hypermetabolic state increasing metabolic demands for protein and energy increasing the risk and rate at which malnutrition develops [6–8, 14, 21, 22]. Thus, it is not surprising that malnutrition is observed in patients with chronic conditions such as cancer or end organ failure [15, 23–28]. Baseline nutritional status, severity of disease, extent of surgical procedure, and systemic involvement all play a role in the development of malnutrition in hospitalized patients.

Nutritional optimization in these patient populations is crucial for improving outcomes. When supplementing nutrition, parenteral nutrition (PN) is favored over enteral nutrition (EN) in the setting of chronically nonfunctional gastrointestinal (GI) tracts [29, 30]. But in patients with functional GI tracts, early EN is the gold standard [31–35]. It is well established in literature that early enteral feeding is far superior with regard to mucosal immunity, GI function, gut flora, diminished acute phase response, and healing [36–38]. As such, various enteral feeding devices have garnered significant traction. For most, a nasogastric tube or nasojejunal (NJ) tube will suffice, however in patients who require long-term supplementation, gastrostomy, jejunostomy, or gastrojejunostomies are available modalities. Regarding jejunal access, indications include inability to tolerate per oral or gastric supplementation [39]. Gastrostomy and jejunostomy tubes have traditionally been placed via open approach, with multiple different surgical techniques; open Witzel (transverse or longitudinal), open gastrojejunostomy, etc. However, the advent of minimally invasive methods has created a shift towards endoscopy with percutaneous needle catheter and laparoscopy [9, 10, 39, 40].

34.2 Preoperative Evaluation

Evaluating patients who are candidates for feeding tubes requires subjective and objective assessment. After completing a thorough history and physical exam, appropriate workup of the underlying condition necessitating enteral access should be performed. This may comprise of laboratory tests to determine baseline nutritional status, imaging modalities, motility studies, electrocardiogram, and optimization of comorbidities.

34.3 Clinical Presentation

Typically, long term feeding access is obtained via a gastrostomy tube placed using either percutaneous and endoscopic techniques (PEG) or laparoscopically. Utilization of jejunal feeding access is a common procedure that is required in patients who are unable to tolerate nutrition via oral and gastric routes or those at risk for aspiration [5, 41–43]. When jejunal nutrition is indicated for 2 to 4 weeks, NJ access is preferred as it is associated with fewer long-term complications [44–46]. However, NJ tubes are associated with high frequencies of displacement, occlusion, local catheter related irritation of mucosal lining, and enteric perforation [47]. Jejunostomy tubes are favored in patients with pathologies that contraindicate the replacement of a dislodged NJ tube.This can be performed as an independent procedure in patient who have a contraindication of nasojejunal access; gastric atony or gastric outlet obstruction;diabetic gastropathy;gastroesophageal dysmotility; pancreatitis; high risk for bronchial aspiration from gastroesophageal reflux; laparotomy patients with expected difficult postoperative recovery; prolonged fasting and/or hypermetabolic state; head and neck cancers; esophagectomy patients; those undergoing or who anticipate undergoing radiation or chemotherapy; upper gastrointestinal tract perforations proximal to Ligament of Treitz; UGI malignancies; dysphagia; impaired swallowing; chronic nausea and emesis; geriatric patients with difficult care demands [48–51]. In pediatric patients, jejunostomy tubes may be indicated in cases of congenital UGI problems or defects, tracheoesophageal fistula, cystic fibrosis, or in setting of significant neurologic impairment [52].

Laparoscopic jejunostomy is contraindicated in patients with ascites due to associated risk of peritonitis. History of multiple abdominal operations confer a relative contraindication especially when significant adhesions or scar tissue impair the surgeons ability to perform the procedure safely. Feeding tubes should be avoided in chronic inflammatory disease due to the increased risk of developing enterocutaneous fistulas. Additionally, extreme care should be taken inpatients with severe immunodeficiency as feeding tubes can pose a risk for causing necrotizing fasciitis of the abdominal wall. Uncorrected coagulopathy is also a contraindication as the propensity of intraabdominal bleeding or intraluminal hematoma formation causing obstruction could complicate postoperative care. With regard to placement technique, laparoscopy should be avoided in patients with severe chronic obstructive pulmonary disease that could be potentiated by pneumoperitoneum or those who cannot tolerate general anesthesia.[4, 5, 53]

34.4 Operative Technique

The operative technique outlined in this chapter is similar for both laparoscopic gastrostomy and jejunostomy tubes. Although not required, using an introducer kit is preferred as it decreases the size of the enterotomy preventing unwanted leakage around the tube upon completion of the procedure. We recommend introducer kits that are 2Fr greater than that of the jejunostomy tube and 4Fr greater than the gastrostomy tube. Typically, we use a 14Fr introducer kit for a 12Fr jejunostomy tube and a 22 Fr introducer kit for an 18 Fr gastrostomy tube.

Laparoscopic feeding tube placement should be performed in the operating room under general anesthesia with patient supine and arms tucked. The entire abdomen should be prepped and draped in the usual sterile fashion. The surgeon should be positioned on the patient's right side. The operation begins with a 5 mm incision in

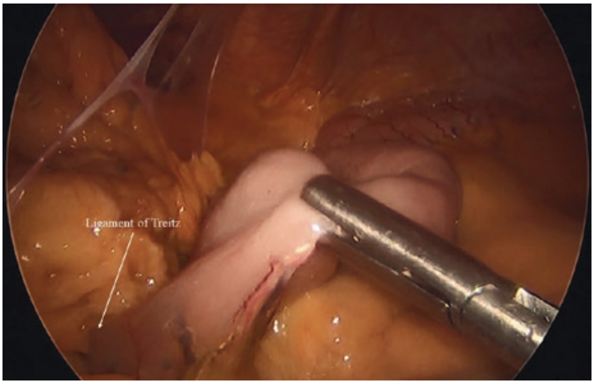

Fig. 34.1 Identify the Ligament of Treitz. Ideally the jejunostomy tube is placed 40 cm distal from this location

right upper quadrant, 2 cm medially from anterior axillary line and 2 cm inferior to costal margin in order to avoid injury to epigastric vessels. This is followed by Veress needle and 5 mm trocar placement. A 30 degree laparoscope is inserted. An 8 mm trocar (used for ease of inserting needles) is placed in right lower quadrant and another 5 mm trocar placed in left lower quadrant under direct visualization. The camera is placed through the 5 mm trocar in the left lower quadrant, with the operating surgeon using the trocars on the right side of the patient. The operating table should then be placed in 30 degree reverse trendelenberg to allow caudal displacement of small bowel for ease of access to Ligament of Treitz. Using laparoscopic graspers, the greater omentum and transverse colon are placed cephalad with the nondominant hand. Using two handed technique, the bowel is run proximally until the Ligament of Treitz is encountered (Fig. 34.1). Proper jejunostomy tube placement should be 40 cm distal to the Ligament of Treitz. Attention is then turned toward the abdominal wall to identify tube insertion site. The left upper quadrant is the optimal site for tube placement, 3 cm superior to the umbilicus and 2–3 cm lateral to rectus muscle sheath. However, the tube can be placed more laterally if additional abdominal surgery is anticipated. Additionally, avoiding placing the tube to close to the costal margin or within a skin fold is not advised. Once the site has been marked, measuring tape is used to mark four locations 1 cm superiorly, inferiorly, medially, and laterally around the planned jejunostomy tube site as well as a mark 1–2 cm distal to the most inferior marking. These locations mark the sites where the Carter-Thomason will be used to bring up the sutures to transfascially fixate the bowel to the abdominal wall.

With an atraumatic grasper the surgeon should grasp the intended location of the jejunostomy tube and raise it toward the anterior abdominal wall to ensure that it is tension free. The most proximal aspect of the jejunum should be oriented superolaterally, inferomedially distally. Once comfortable with the placement site, using a needle driver, a 2-0 PDS suture is passed into the abdomen through the 8 mm trocar. On the antimesenteric side of the intended jejunostomy tube site, the stitch is thrown through the serosa ensuring that a portion of the muscularis layer is included. A total of five stitches are used to secure the bowel to the abdominal wall. Two parallel stitches placed longitudinally and two transversely, creating a 2 × 2 cm square configuration. An anti-torsion stitch is placed transversely 1–2 cm distal to this to prevent bowel rotation around the tube. After each stitch, the needle is not cut from the suture. A Carter-Thomason is used to pull the needle as well as the suture through the abdominal wall (Figs. 34.2 and 34.3). The purpose of not cutting the suture intra-abdominally using laparoscopic scissors, is to save time and facilitate ease of removing the needle extra-corporeally in a more controlled fashion. Hemostat clamps are used to pull up the most superior and lateral stitches so that the bowel is oriented in an angle and the jejunostomy tube site is easily visualized (Fig. 34.4). Under Saldinger technique with a 14-French introducer kit, a needle is used to place a wire intraluminally in the jejunum and then dilated (Figs. 34.5 and 34.6). A 12-French jejunostomy tube is passed into the jejunum and the balloon is inflated. Extracorporeal suture ends are then tied under direct visualization and cut, bringing the jejunum to the abdominal wall (Fig. 34.7). The tube should be flushed with ease to confirm the tube is intraluminal. This terminates the operation. Trocars should be removed under direct visualization and incisions closed with 4-0 monocryl and dermabond or steristrips.

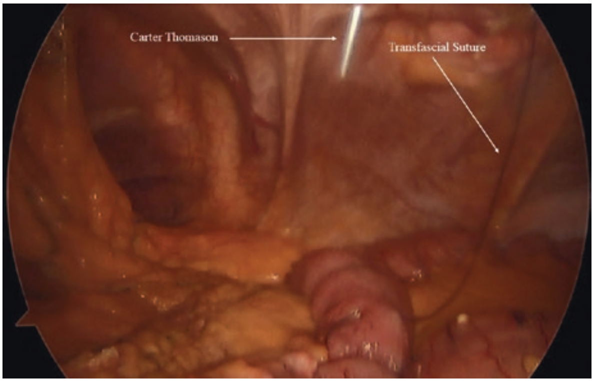

Fig. 34.2 The Carter Thomason is passed into the abdominal wall so that transfascial fixation of the bowel can occur

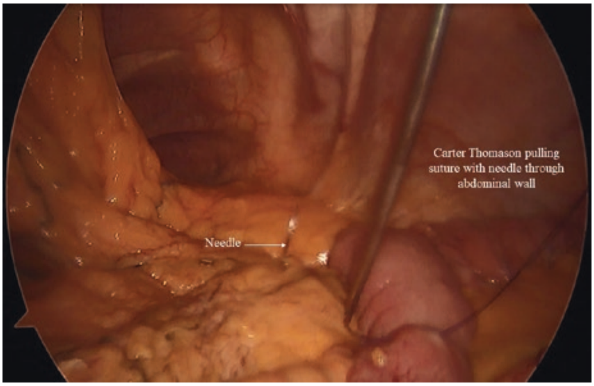

Fig. 34.3 The Carter Thomason is grabbing the sutures and needle to carry it through the abdominal wall

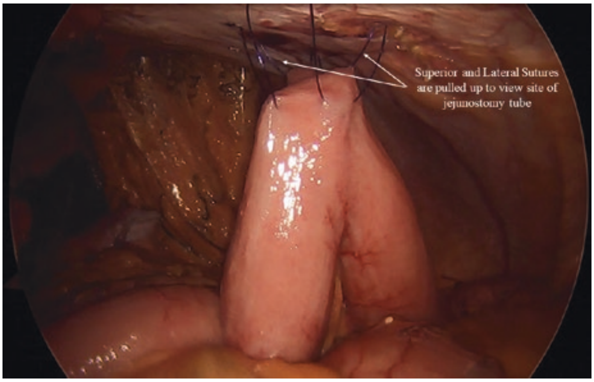

Fig. 34.4 The superior and lateral sutures are raised to easily visualize the site of entry for the jejunostomy tube

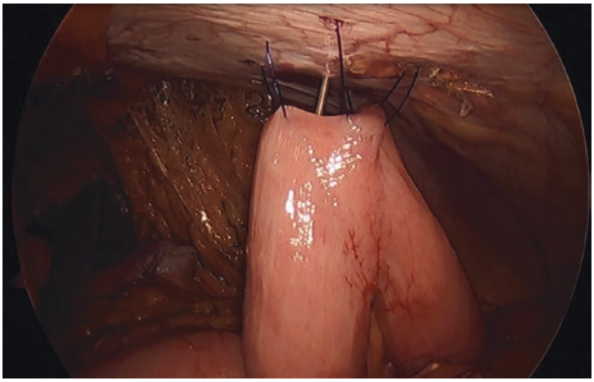

Fig. 34.5 The needle in the introducer kit is passed through the abdominal wall and into the jejunum

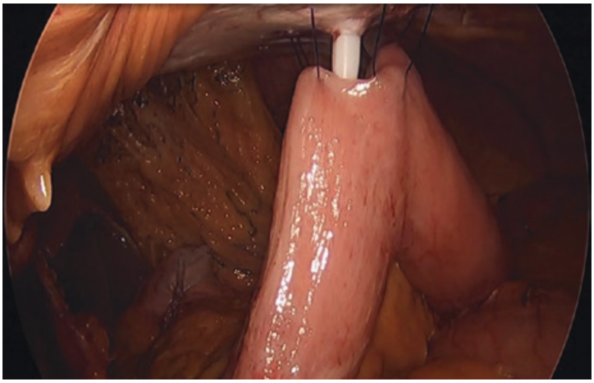

Fig. 34.6 The dilator is passed through the abdominal wall and into the jejunum

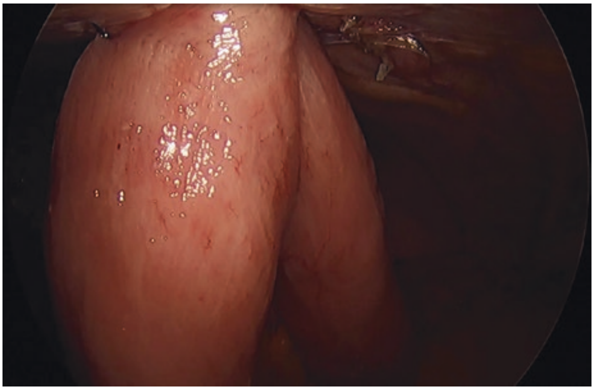

Fig. 34.7 All sutures are tied to secure the bowel to the abdominal wall with the jejunostomy tube in its proper location

Postoperatively, the jejunostomy tube is flushed with 10 ml every 6–8 hrs. Rate of tube feedings should be advanced incrementally to ensure the patient can tolerate the goal rate. Dietary consultation is recommended for selection of formula and rate based on patient's needs.

The technique to place a laparoscopic gastrostomy tube is similar to the technique described above. Three ports are also placed, except in a different configuration. A 5 mm camera port is placed in the left upper quadrant approximately 3 cm superiorly and 3 cm laterally to the umbilicus. Eight and 5 mm ports are placed in the right upper quadrant and are used as the working ports. Four 0 PDS sutures are used to create a 2 × 2 cm square configuration around the planned gastrostomy site. 0 PDS is used instead of 2-0 due to the increased thickness of the stomach compared to the small bowel. No anti-torsion stitch is required for gastrostomy tubes. The ideal location for tube placement is along the anterior stomach near the inferior pole of the gastric body. This location is sufficiently distal from the gastroesophageal junction to prevent aspiration and proximal enough from the pylorus to prevent obstruction. The rest of the technique is identical to that described above.

There are several steps during these operations, where troubleshooting may be required. If the trocar locations mentioned above have signs of previous surgery or dense adhesions upon entry, options include starting a Palmer's point (2 cm distal to the left costal margin, midclavicular line) or entering using a Hasson technique. Sometimes, the small bowel or the stomach is under tension when lifting it towards the anterior abdominal wall. Placing sutures under normal insufflation pressure (12–15 mmHg), but then tying them at a lower insufflation pressure (6–8 mmHg) can be helpful in this instance. When inserting the feeding tube, the balloon can get popped and deflated. It is important to blow up the balloon distal to the tube insertion site and pull the tube until the balloon is in the proper location. If it has popped, then reinsert the wire through the feeding tube and use it to guide a new feeding tube into the appropriate location.

34.5 Post-operative Management

Overall complication rates with laparoscopic feeding tubes are low. In the immediate perioperative period, the complications are often inherent to laparoscopy; injury to bowel with trocar placement, issues related to increased intraabdominal pressure [5, 54]. Other complications pertain to having a transcutaneous drain entering into the bowel for enteral nutrition. One of the more commonly encountered complications is dislodgement of the tube. As it takes 4 weeks for the tract to mature, if dislodgement occurs before the tract matures, it could require surgery to replace. However, beyond the 4 weeks, a displaced tube can usually be replaced at the bedside. Clinical acumen should be used to determine whether a fluoroscopic tube study is indicated to confirm placement. If a tube is dislodged for longer than 24 hrs the tract will likely close and require interventional radiology or surgery to replace [55]. Volvulus can occur around the fixation point of the jejunum to the abdominal wall. Tacking the jejunum distal to the jejunostomy tube insertion site detailed in this chapter is intended to reduce the incidence of volvulus. Jejunostomy leakage can also occur. In a randomized study of 150 patients undergoing esophageal resection, 79 received enteral access via jejunostomy tubes and 71 via nasoduodenal tube. Of the 79 jejunostomy tube patients, only one patient had leakage that required reoperation [56]. Another study of enteral catheter-related complications reported that the most common complication encountered was blockage of the tube in 10.5% of the 100 patients who underwent pancreatic resections [57].

34.6 Summary

In summary, laparoscopic feeding tube placement is an effective way to provide enteral nutrition to patients who cannot obtain adequate nutrition by mouth. The technique for both gastrostomy and jejunostomy tube placement is similar, utilizing sutures to transfascially fixate the bowel around the planned tube site. Insertion kits are recommended, but are not required, for both ease of tube insertion and to limit the size of the enterotomy; thereby preventing unwanted leakage around the feeding tube. Although complications can occur, the majority of these relate to leakage around the tube, displacement, or tube obstruction.

Conflict of Interest The authors have no conflicts of interest to declare

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