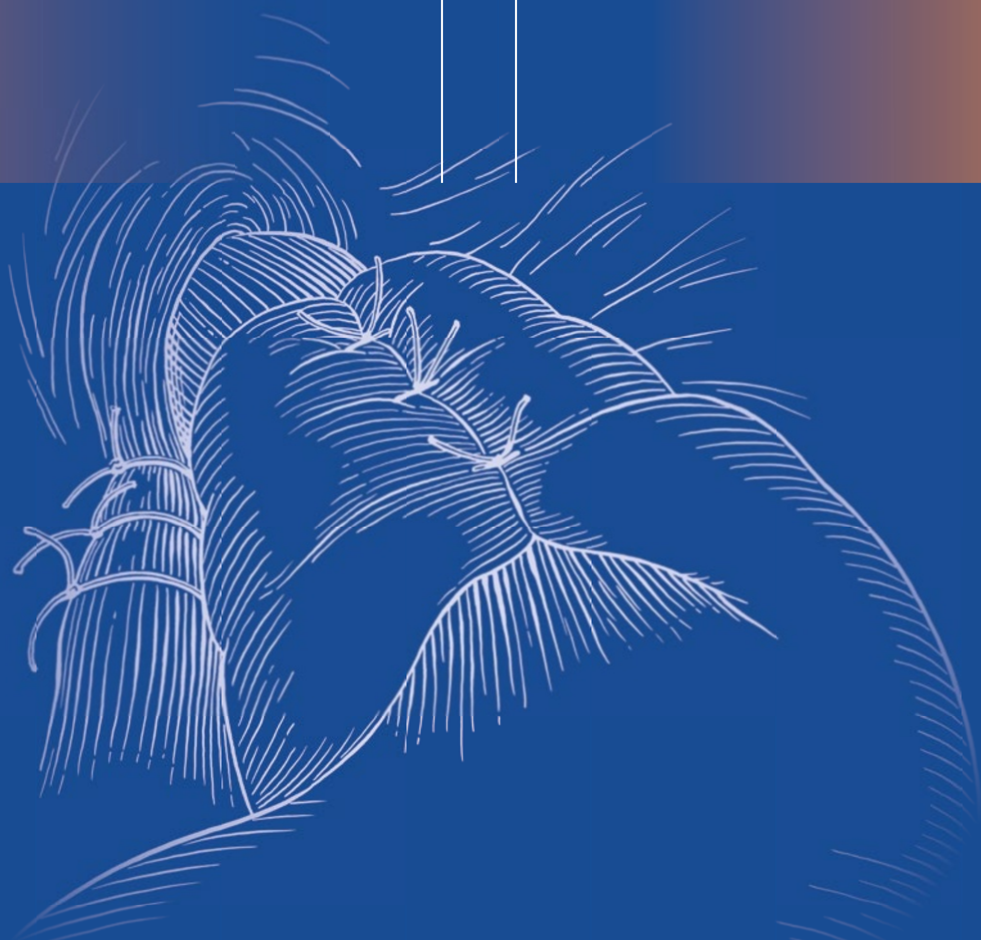
P. Marco Fisichella
Marco G. Patti
Editors

Atlas of Esophageal Surgery



Springer

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To Dr. Lawrence W. Way, master surgeon, unrivaled thinker, and educator

Foreword

The *Atlas of Esophageal Surgery* is a very nicely illustrated book focused primarily on the technical aspects of operations on the gastroesophageal junction. Each chapter presents a relatively short description of a topic (historical aspects of surgery, esophageal function tests as they apply to surgical management, radiologic aspects of esophageal pathology that require surgery, or description of operative techniques for benign and malignant esophageal disease) with a plethora of related illustrations. Descriptions are short, focused, technically oriented, and related to a specific case, which is well illustrated throughout the chapter itself. I presume it will appeal primarily to residents learning the essential aspects of a given operation on the esophagus, to young physicians that may be less experienced, and perhaps even to patients—or at least those who wish to explore the operation they are about to have, to a greater extent. By design, the chapters are not comprehensive and do not discuss alternatives; they are rather dogmatic and present a specific technique used by the author, usually a well-known dedicated esophageal surgeon. Those who are more interested in visual rather than purely intellectual learning will find the book most useful.

The book is dedicated to Professor Lawrence W. Way. Dr. Way has had a remarkable influence in the training and education of several generations of residents and faculty at the University of California, San Francisco, where he himself had trained and practiced throughout his entire professional life. I was privileged to be his disciple and proud to call him my mentor. Working with him from the day I finished my training until I became a full professor myself, I had the unique opportunity to observe and to receive firsthand his advice and guidance for more than 14 years. Larry, as he asked everyone to call him, was a master surgeon. His technical abilities were exceptional: he was at ease in the operating room, he performed the most complex abdominal operations, he was always able to find the right plane, to obtain the best outcomes. But where he excelled in a unique fashion was when he was called to the operating room to help one of us, when we found ourselves in trouble. His quiet, humble demeanor in those moments, his asking "permission to scrub and take a look," his ability to get someone out of trouble while making it look like the original surgeon had somehow solved the problem, his "thanking" the surgeon for "allowing me to scrub" . . . made a permanent impression on me—one that I committed myself to emulate. He had a unique ability to communicate, particularly in writing. His style was characterized by simplicity, straight-forwardness, and clarity. This virtue was only matched by his willingness to try to pass that ability on to others. To that end, he would edit a paper again and again until it was perfect, until it conveyed the right message in a crystal-clear way. Those of us who were privileged to work with and for him will always remember, quite vividly the "red marks" on the manuscripts. Thank you, Larry, for your patience and willingness to help each of us become better surgeons and better communicators. I thank the authors of this *Atlas* for the privilege of writing these lines and smile as I think that Larry would probably cut it in half, make it better, and/or probably eliminate it altogether because his humbleness would make him think of this dedication as being "too long." Larry, let me assure you, it is not. Indeed, it is just the tip of the iceberg.

Seattle, WA, USA Carlos A. Pellegrini, MD, FACS

Preface

Few areas of surgery have been impacted as much as esophageal surgery by the introduction of minimally invasive techniques. Today, a laparoscopic Heller myotomy for achalasia or a laparoscopic Nissen fundoplication for gastroesophageal reflux disease is considered the standard of care. In addition, diseases such as Barrett's esophagus with high-grade dysplasia or intramucosal cancer can be successfully treated by endoscopic modalities such as radiofrequency ablation and endoscopic mucosal resection, avoiding in most patients the need for an esophagectomy.

Finally, many centers are now performing esophageal resections by minimally invasive surgery (MIS), with improved morbidity and mortality and an oncologic outcome similar to that of open surgery.

This book describes the MIS approach to common esophageal diseases, stressing the technical steps through a series of color pictures and illustrations. It will be a useful guide for residents, fellows, and general surgeons with the hope that they will feel more comfortable offering MIS to their patients.

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Acknowledgments

The Editors would like to thank Claudia M. Grosz, CMI, for her assistance with the medical illustrations. Claudia M. Grosz, CMI, is an award-winning medical illustrator whose work spans more than 20 years. She began her career specializing in patient-education materials in the health care publishing field and later created illustrations for internationally known physicians and researchers at Loyola University Medical Center. Her illustrations have enjoyed wide exposure, including medical charts that have appeared on "House" and "The Sopranos," and have been recognized among her peers. She has received numerous awards from the Association of Medical Illustrators, including the prestigious Vesalius Trust Certificate of Merit for Special Contribution to Medical Education. Ms. Grosz has a Master of Fine Arts degree in Medical and Biological Illustration from the University of Michigan, where she conceived of "Claudia's Kids," a line of anatomically correct dolls designed to educate young children about the human body. Ms. Grosz currently freelances out of her studio in Evanston, IL.

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History of Esophageal Surgery

1

Fernando A.M. Herbella, Marina Zamuner,
and P. Marco Fisichella

The history of esophageal surgery is not a long one. Although there are some anecdotal reports of interventions on the cervical esophagus by surgeons from ancient civilizations and pioneers of modern surgery, series of cases of real surgical procedures—not just perioral probing of the esophagus—did not start to be published until the twentieth century. The advance of operations for benign diseases had to wait for the understanding of esophageal physiology and the development of diagnostic tools. In addition, the progress of operations for esophageal cancer was limited for decades by technical restrictions, especially the barrier of the open chest and the fear of damage to the vagus nerve, which was considered essential for cardiac function.

The original descriptions of the earliest operations and their eponyms remain solely as homage to their creators, or at least the most well-known individual to perform or modify the technique. This chapter is a brief pictorial review of the origins and development of modern esophageal operations in adults.

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1.1 Benign Diseases

1.1.1 Gastroesophageal Reflux Disease

Nissen fundoplication is the current primary surgical therapy for gastroesophageal reflux disease (GERD). This technique is employed in most patients for whom an operation is indicated. It has excellent and long-lasting results.

Rudolph Nissen (Fig. 1.1) was a German surgeon born in 1896. Nissen started his early academic life under the famous and powerful Sauerbruch, but Nissen later left Germany because of his Jewish origin and Sauerbruch's association with the Nazi party. After a period in Turkey, Nissen moved to the United States, where he spent 12 years. He then moved to Switzerland, where he became the chairman of surgery, described his fundoplication, and retired. He died in 1981.

Before 1956, GERD and hiatal hernia (almost synonyms by that time) were surgically managed with reduction of the herniated stomach and some kind of gastropexy. Not surprisingly, results were disappointing. Nissen recalled an operation in which the anastomosis of a cardia resection was protected by the stomach, like a Witzel gastrostomy, and the patient did not develop esophagitis. He tried wrapping the distal esophagus of patients with GERD with the gastric fundus, and published reports of two cases of this new operation for the first time in 1956. Nissen called the procedure "fundoplication." He later reported clinical and radiological healing of hiatal hernia and reflux in 88 % of patients undergoing this operation. His technique was very soon widely accepted.

The original fundoplication (Fig. 1.2) consisted of wrapping the posterior wall of the stomach around 3–6 cm of the distal esophagus. Short gastric vessels were not divided, nor was a hiatoplasty added. As shown on the figure, Rossetti, Nissen's assistant, described the use of the anterior wall of the fundus as a modification to be used in obese patients. Other peculiarities of the technique were the lateral closure of the hiatus in cases of large hernias, and stabilizing sutures

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fixing the wrap to the gastric wall, replacing the fixation in the esophagus of the fundoplication stitches. Over time, several modifications of the technique occurred (Fig. 1.2).

Nissen fundoplication created a new symptom, the inability to belch, and produced dysphagia in a significant number of patients. Several authors (e.g., Toupet, Lind) developed partial fundoplications in order to prevent these symptoms. For the same purpose, some surgeons insisted on some modifications to the total fundoplication. In 1977, Donahue et al. started creating a loose wrap, called floppy Nissen. DeMeester et al. in 1986 advocated a loose wrap, increasing the caliber of the bougie used to size the gastric wrap to 60 F and reducing the wrap to 1 cm. The first minimally invasive antireflux operation was carried out by Dallemagne et al. in 1991, only 4 years after the first laparoscopic cholecystectomy. Thus, the modern version of the Nissen fundoplication, the laparoscopic "short-floppy" Nissen, was created.

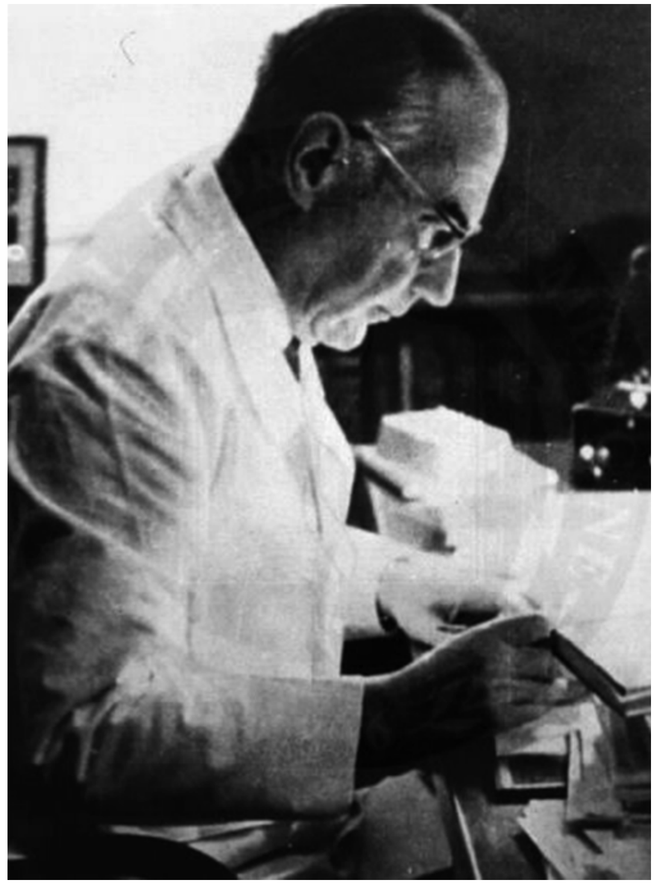
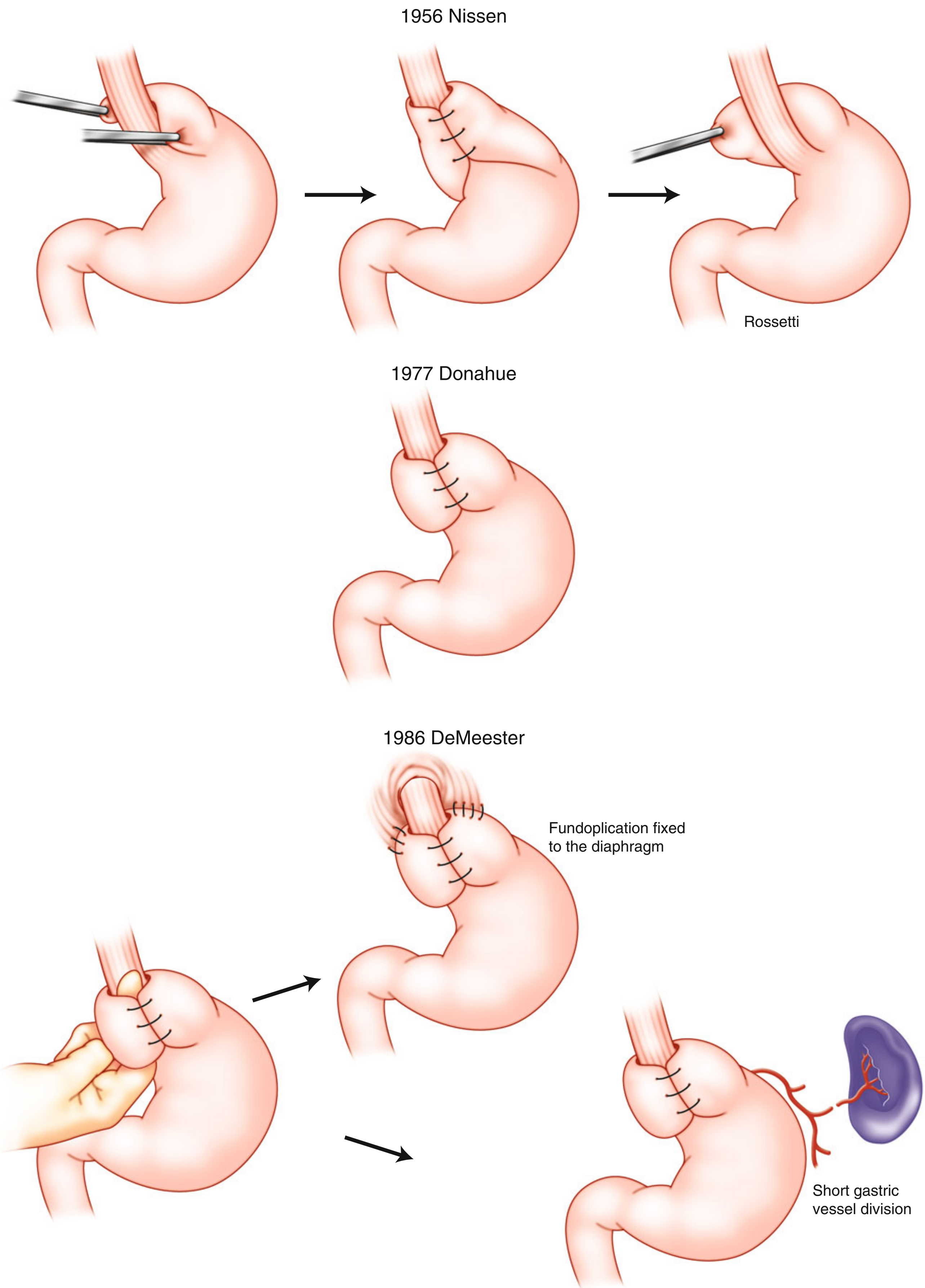


Fig. 1.1 Rudolph Nissen (Source: National Library of Medicine)

Fig. 1.2 Nissen fundoplication evolution from the original description in 1956 of a long and tight wrap to the final short-floppy valve. Minor modifications, such as the use of the anterior wall of the stomach and division of the short gastric vessels, are shown on the right-hand side


1956 Nissen
Rossetti
1977 Donahue
1986 DeMeester
Fundoplication fixed
to the diaphragm
Short gastric
vessel division

1.1.2 Achalasia

Ernst Heller (Fig. 1.3) devised a very successful technique for the surgical treatment of achalasia, which is used to treat most patients with this disease, similar to Nissen's contribution to the treatment of GERD. Heller was born in 1877 in Eichenwalde, Germany, and died in Leipzig in 1964. He described the famous myotomy in 1913, just before serving in the First World War.

Surgical treatment for achalasia started with cardioplasties of the esophagogastric junction. Heller's "extramucosal cardioplasty" (Fig. 1.4), an idea based on pyloromyotomy, was first proposed by Gottstein in 1901 but he never performed it. It consisted of an anterior and posterior vertical extramucosal esophagomyotomy of 8 cm, from the dilated segment of the esophagus to a small extension into the stomach, performed through a subcostal incision. Additionally, omentum was fixed to the anterior myotomy to prevent its approximation. A single myotomy, as described by Groeneveldt in 1918, became more usual, and a fundoplication was added later. The first minimally invasive myotomy was carried out by Shimi et al. in 1991.

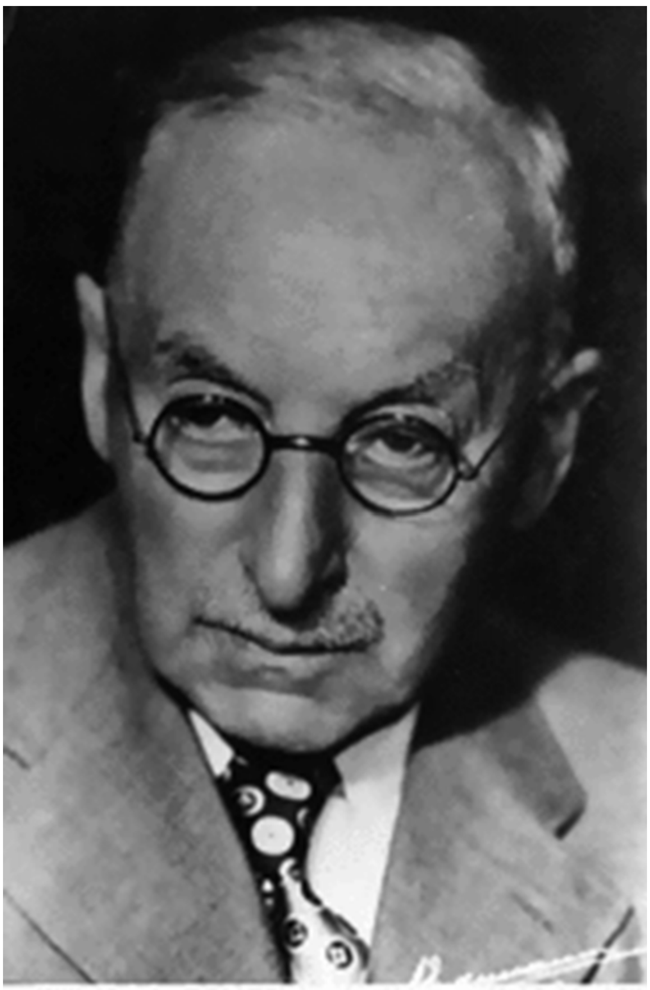


Fig. 1.3 Ernst Carl Paul Heller (From Weiner RA. Ernst Heller und die myotomie. Chirurg. 2014;85:1016–22; *with permission from* Springer Science + Business Media)

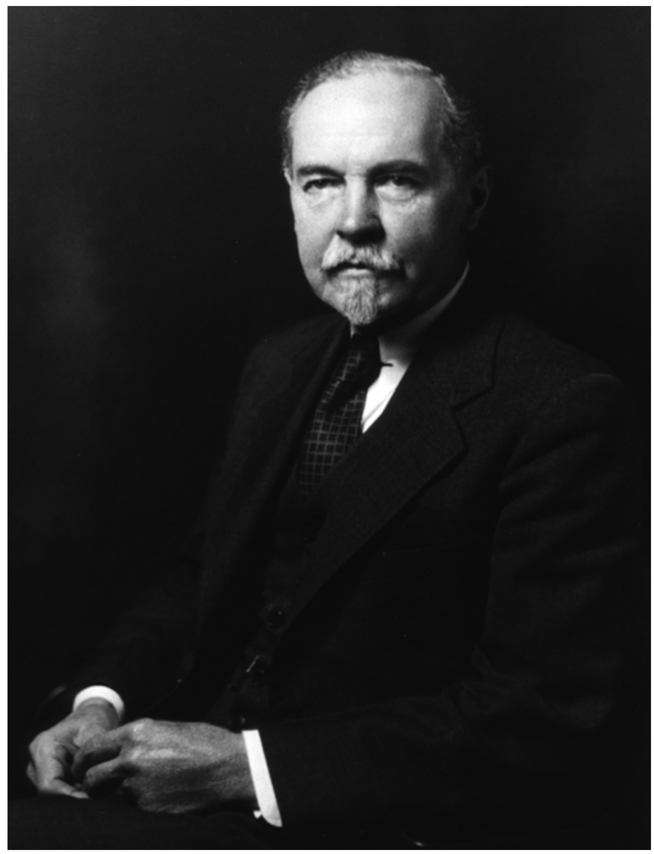


Fig. 1.4 Franz Torek (Source: National Library of Medicine)

1.2 Malignant Diseases

1.2.1 Esophageal Cancer

It is frequently said that the development of transhiatal esophagectomy preceded the transthoracic approach as a way of avoiding the open chest prior to mechanical ventilation, but in reality, 1913 marked the beginning of both procedures.

In the same year, Alwin von Ach (1875–1924), a German surgeon, described the first esophagectomy without thoracotomy in his doctoral thesis. Not is much known about him. The esophagus was resected by stripping through the neck after the divided proximal stomach was connected to a steel rod (Fig. 1.5a). The alimentary tract was not reconstructed, and the patient died on the 17th day.

Franz John A. Torek (1861–1938), a German surgeon working in the United States, performed the first successful transthoracic esophagectomy in that year. The alimentary tract was not reconstructed, but the patient was fed with an external rubber tube connecting the cervical esophagostomy and the gastrostomy (Fig. 1.5, *top* in b). This patient had a long survival.

In 1931, Turner performed the first transhiatal esophagectomy with alimentary tract reconstruction (through a skin flap) with patient survival (Fig. 1.5, *lower left* in a). In 1933, Ohsawa, from Japan, reported the first use of the stomach for reconstruction of the resected esophagus (Fig. 1.5, *lower left* in b). In 1946, Lewis described a two-stage approach to esophageal resection, employing a right thoracotomy and a separate laparotomy with immediate reconstruction of the tract (Fig. 1.5c). In 1976, McKeown suggested a three-stage operation, with an incision in the neck through which the anastomosis was created to avoid the severe consequences of an intrathoracic anastomotic leak (Fig. 1.5d). De Paula et al. in 1995 performed the first minimally invasive esophagectomy through a transhiatal approach.

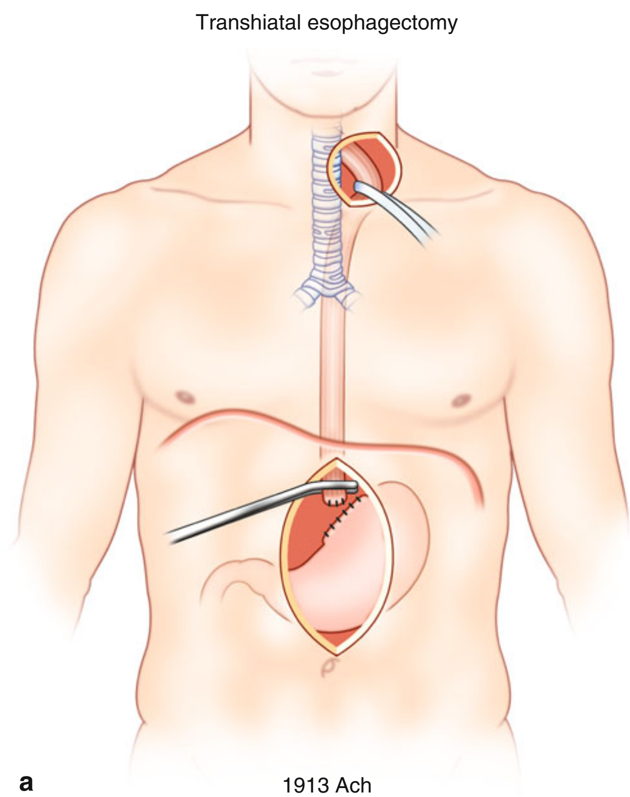
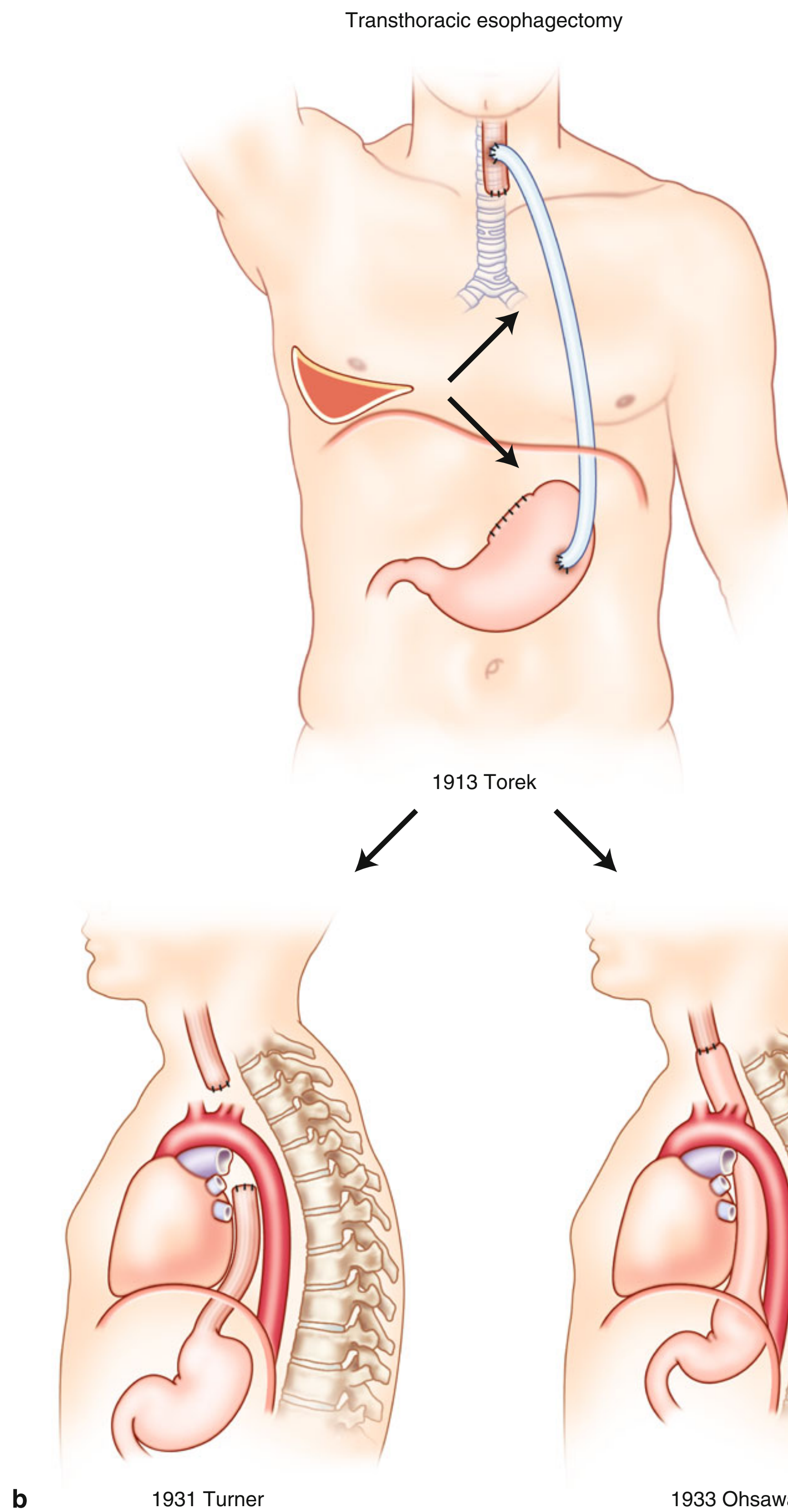


Fig. 1.5 The evolution of esophagectomy. Transhiatal (**a**) and transthoracic (**b–d**) esophagectomy had a parallel course. Alimentary tract reconstruction followed years afterwards

Fig. 1.5 (continued)



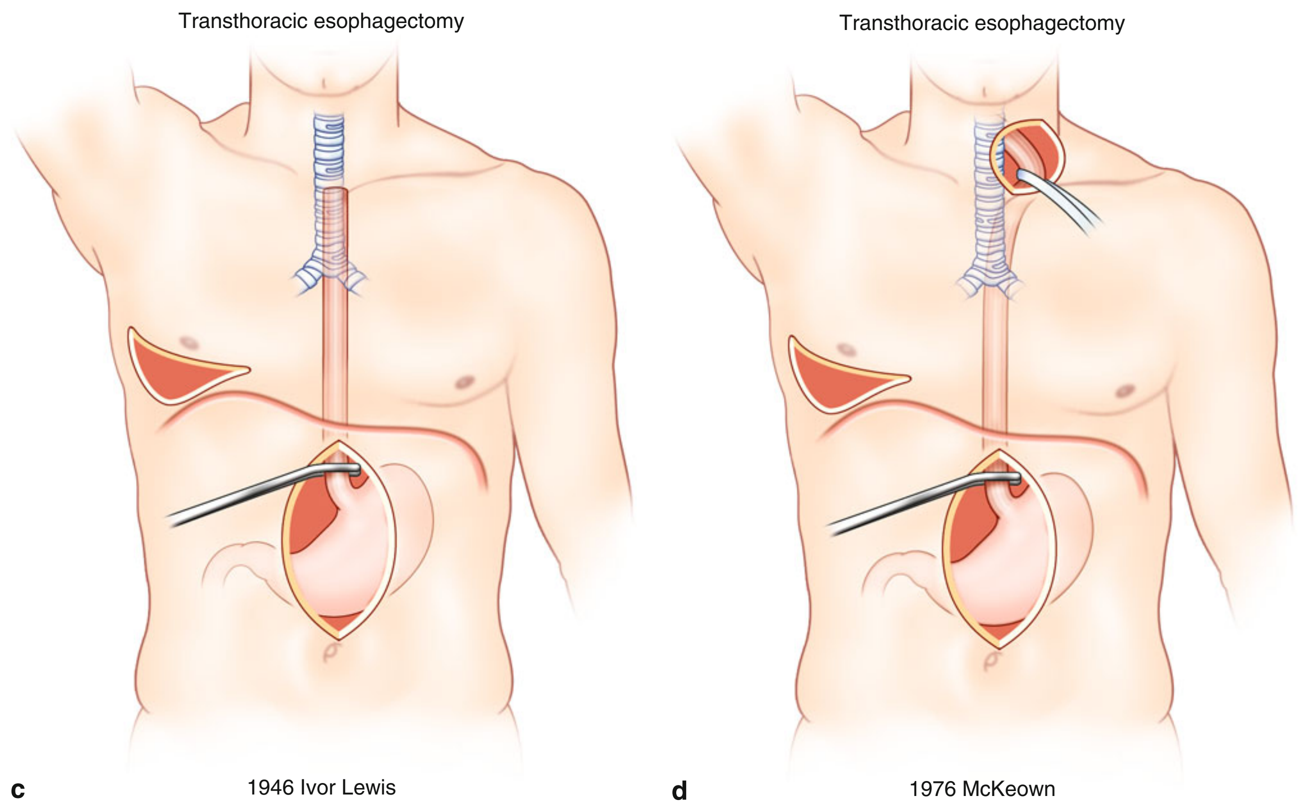


Fig. 1.5 (continued)

Suggested Reading

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2 Radiologic Evaluation of Esophageal Diseases

Bernardo Borraez and Marco G. Patti

A barium swallow (Figs. 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 2.10, 2.11, 2.12, 2.13, 2.14, 2.15, 2.16, 2.17, 2.18, 2.19, 2.20, 2.21, 2.22, 2.23, 2.24, and 2.25) is an essential part of the workup of patients with esophageal disorders. This test defines the anatomy and is very useful for planning therapy. A CT scan (Figs. 2.26 and 2.27) and a PET scan (Fig. 2.28) are an essential part of the workup of patients with esophageal cancer. The goal of this chapter is to provide the reader with normal and pathologic reference images of the most common esophageal diseases and to illustrate how the radiologic evaluation is complementary, yet essential, in diagnosis and surveillance.

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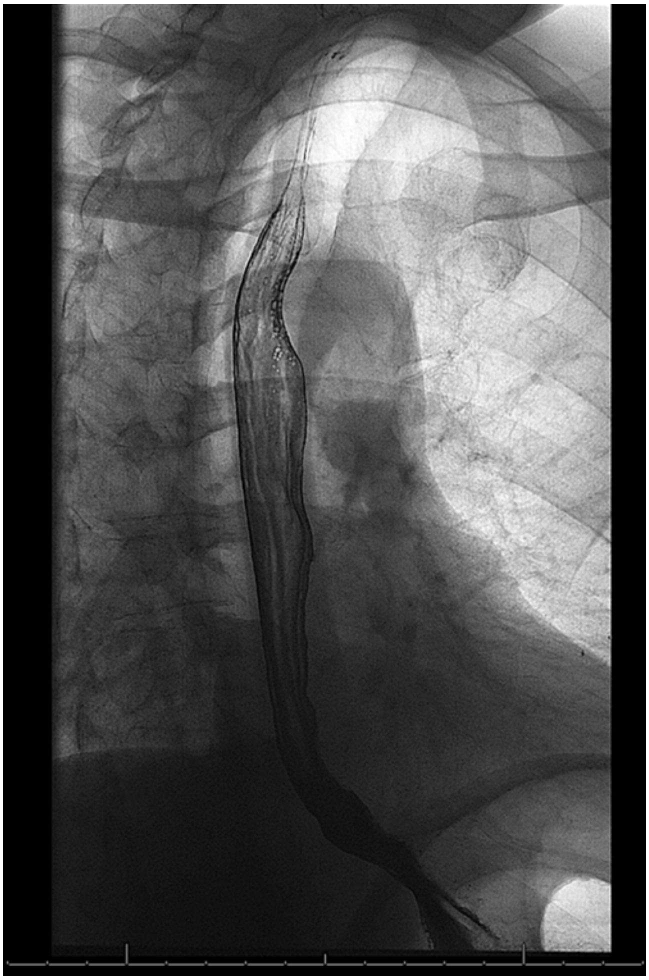

Fig. 2.1 Normal barium swallow

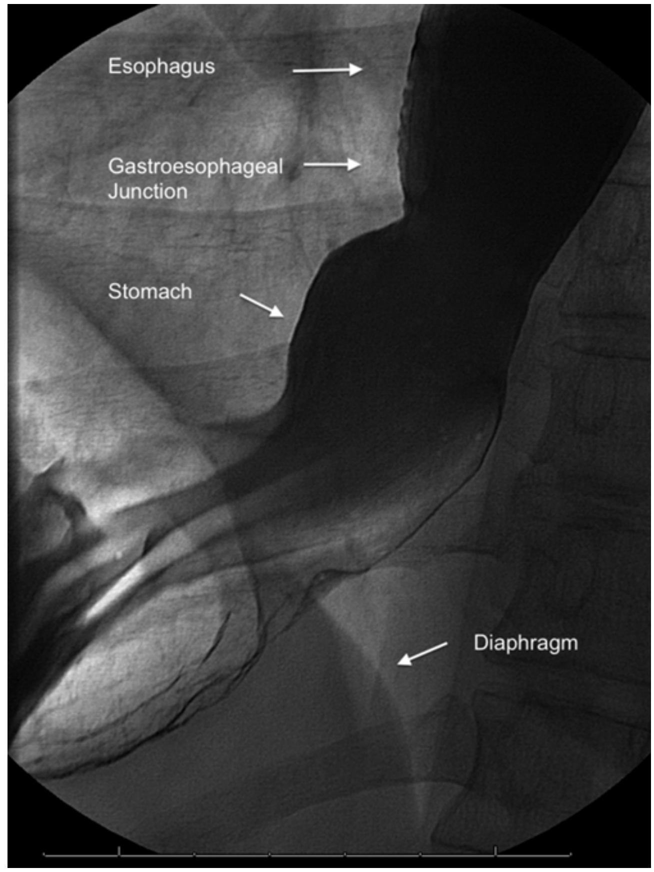

Fig. 2.2 Barium swallow. Sliding hiatal hernia

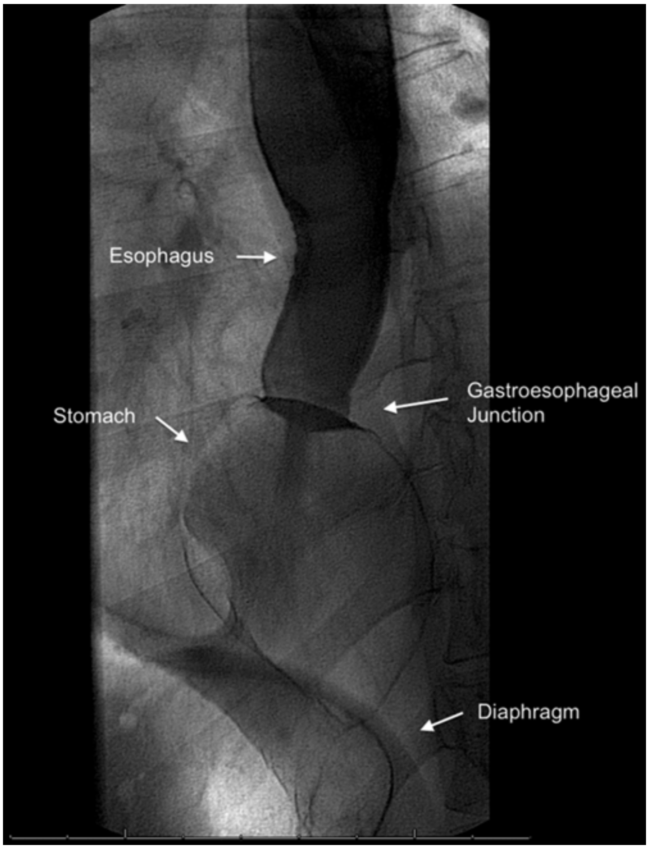

Fig. 2.3 Barium swallow. Sliding hiatal hernia

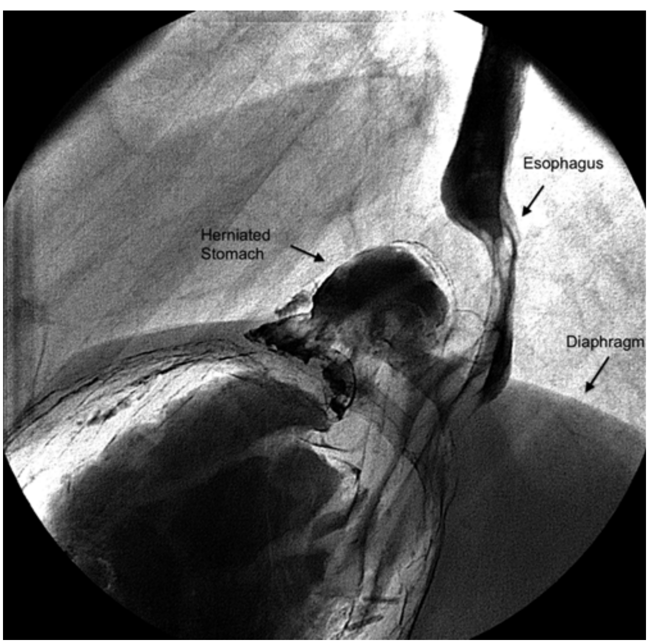

Fig. 2.4 Barium swallow. Paraesophageal hernia

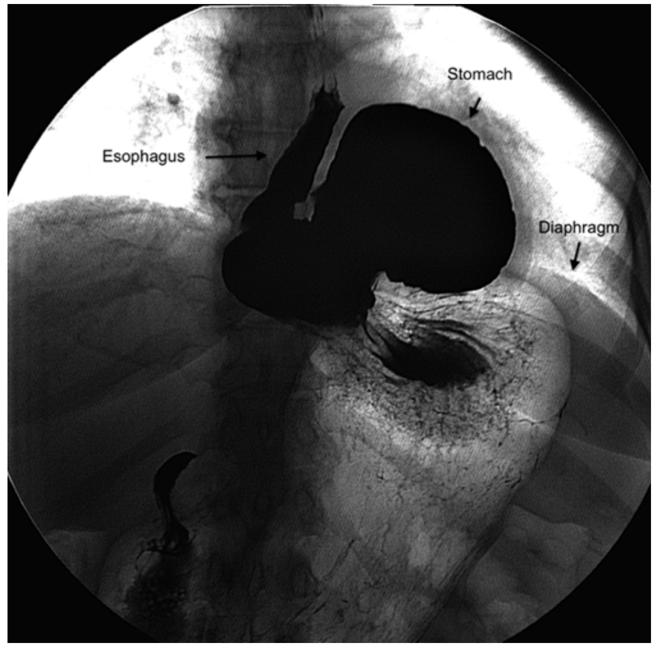

Fig. 2.5 Barium swallow. Paraesophageal hernia

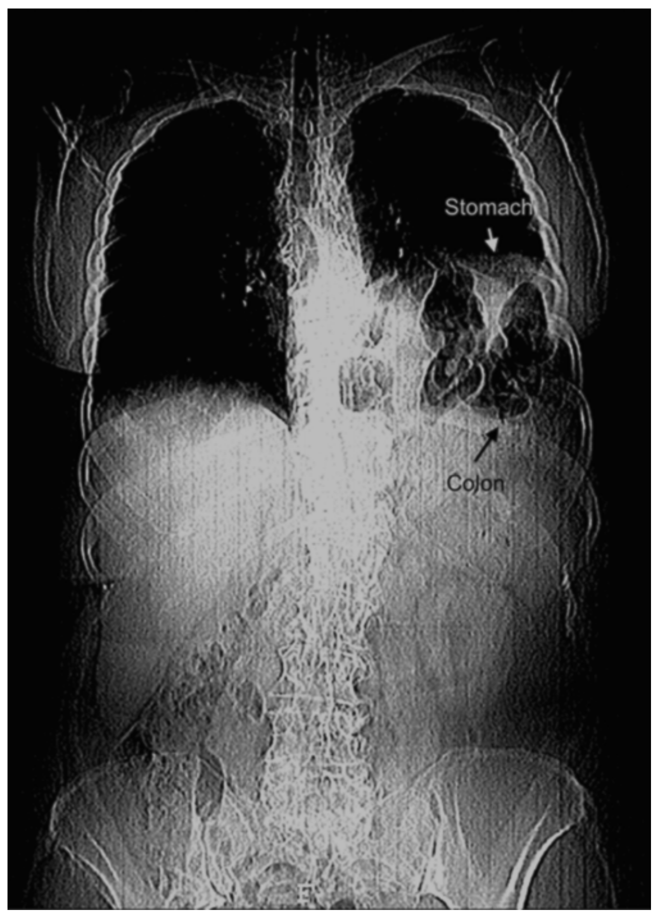

Fig. 2.6 Chest and abdominal CT scan. Type IV hiatal hernia with stomach and colon above the diaphragm

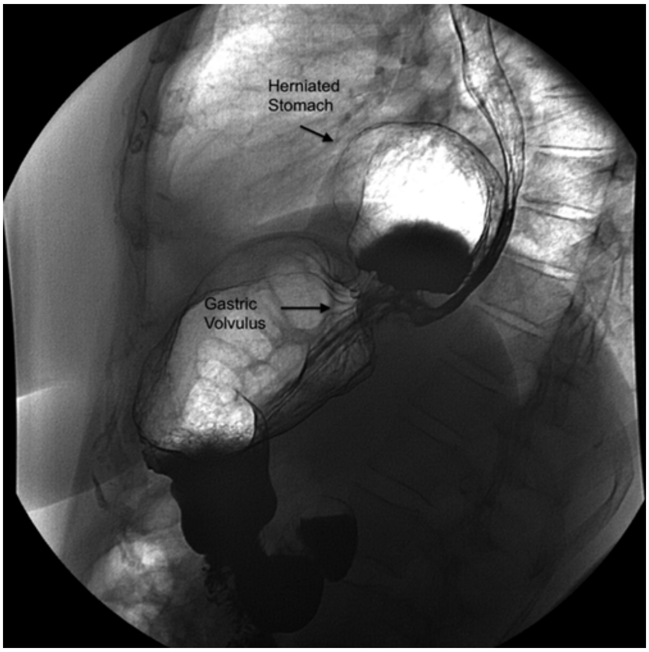

Fig. 2.7 Barium swallow. Paraesophageal hernia with gastric volvulus

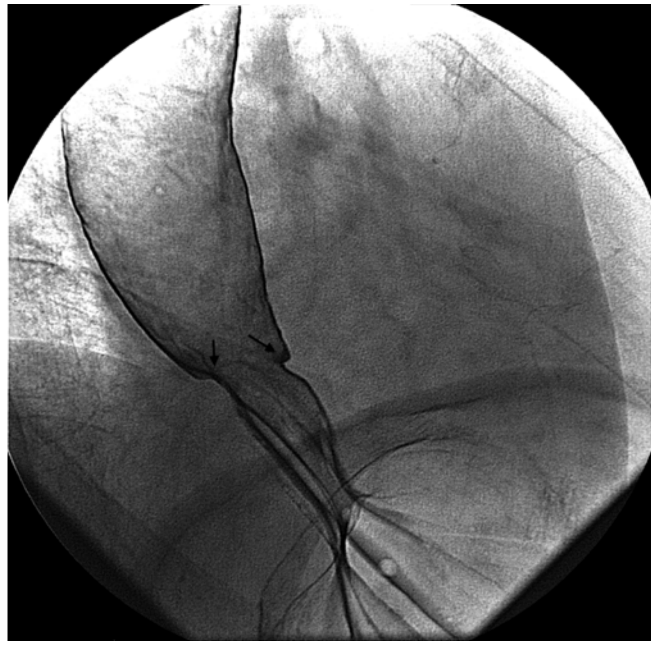

Fig. 2.9 Barium swallow. Schatzki's ring (*arrows*)

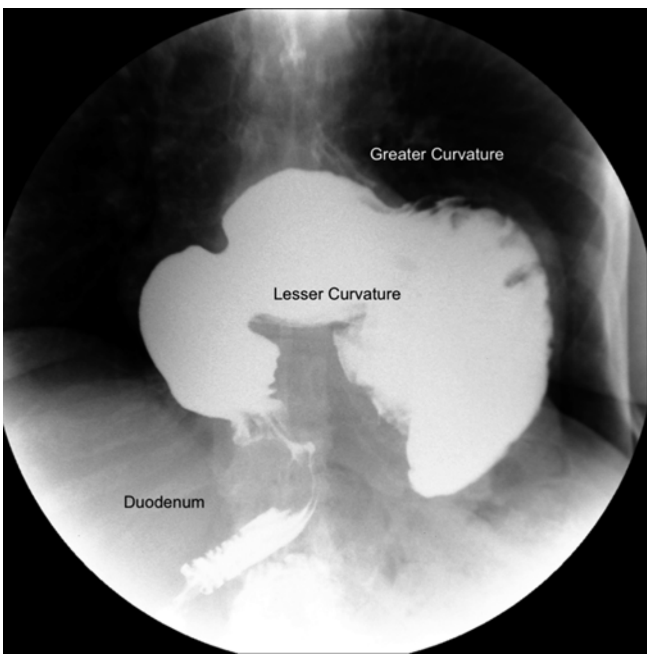

Fig. 2.8 Barium swallow. Paraesophageal hernia with gastric volvulus

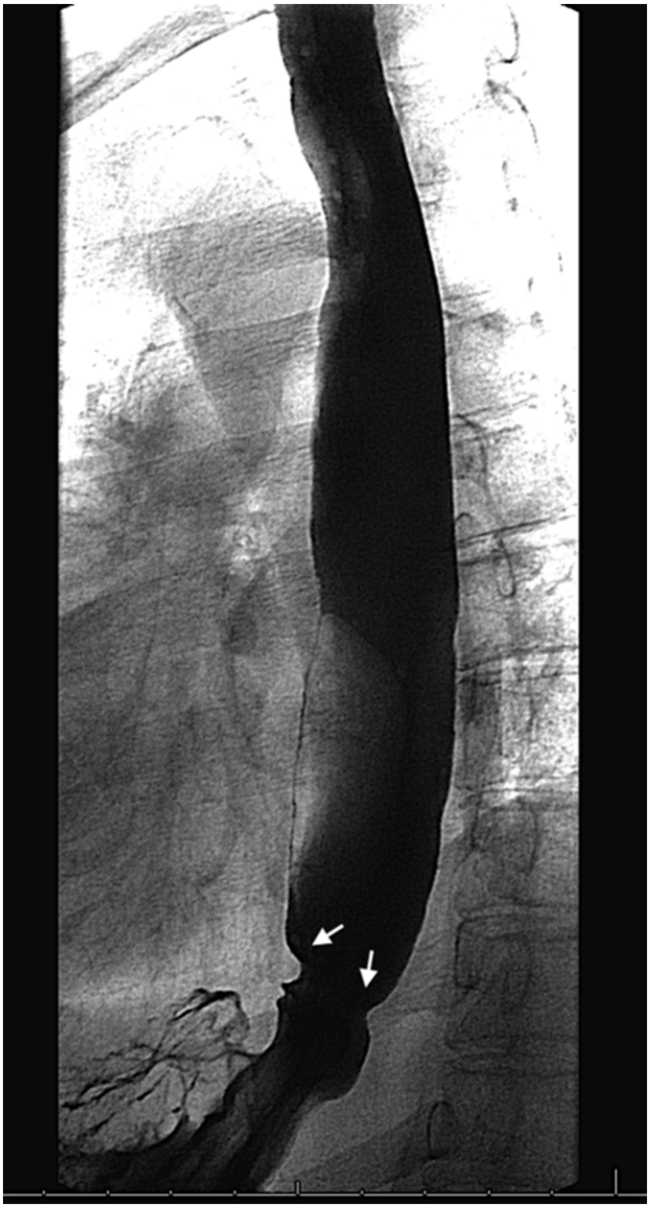

Fig. 2.10 Barium swallow. Schatzki's ring (*arrows*)

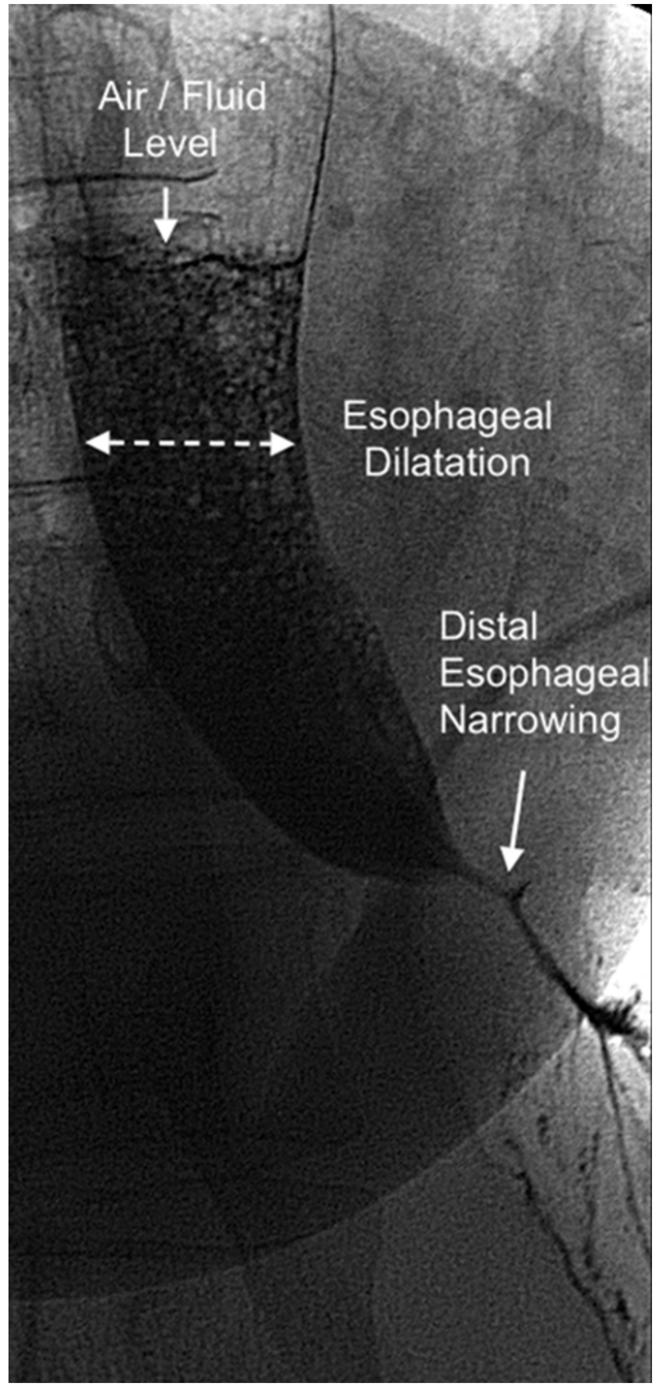

Fig. 2.11 Barium swallow. Esophageal achalasia

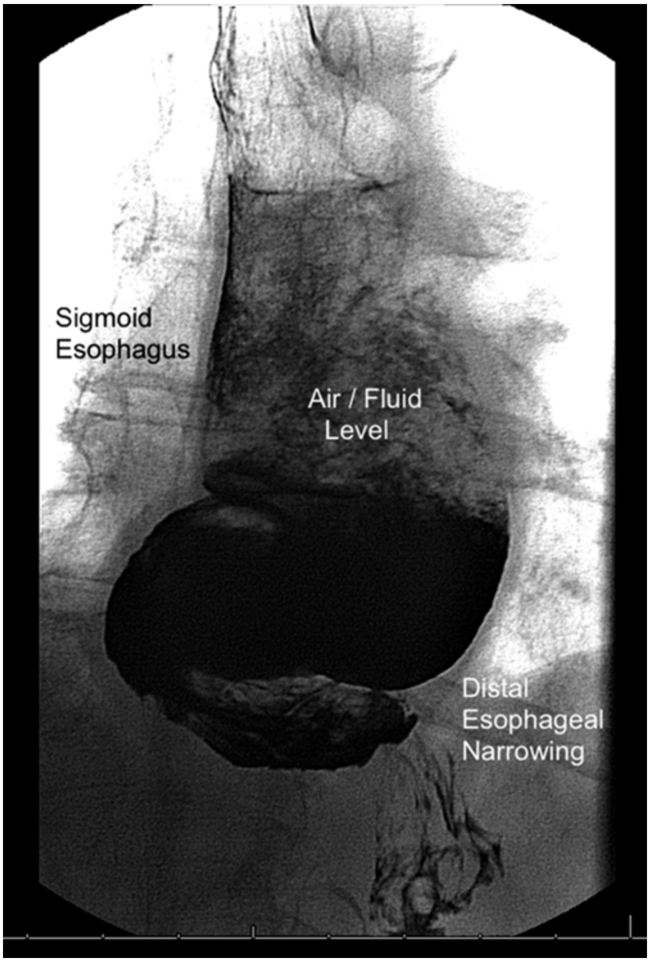

Fig. 2.12 Barium swallow. End-stage achalasia with dilated and sigmoid esophagus

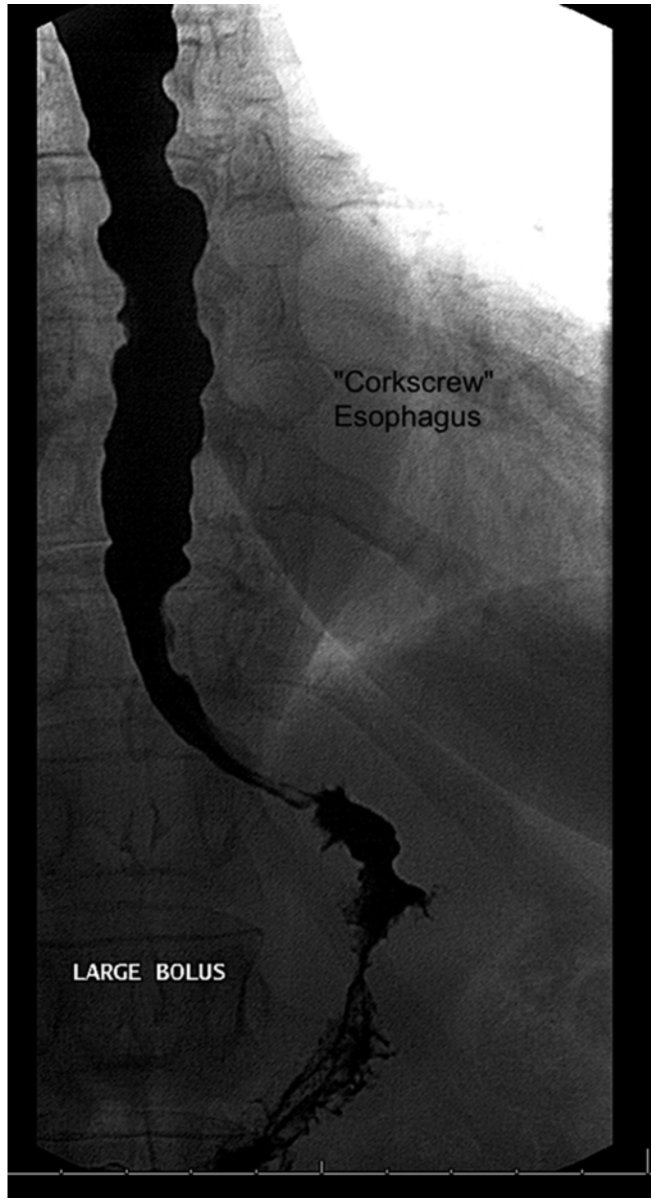

Fig. 2.13 Barium swallow. Diffuse esophageal spasm

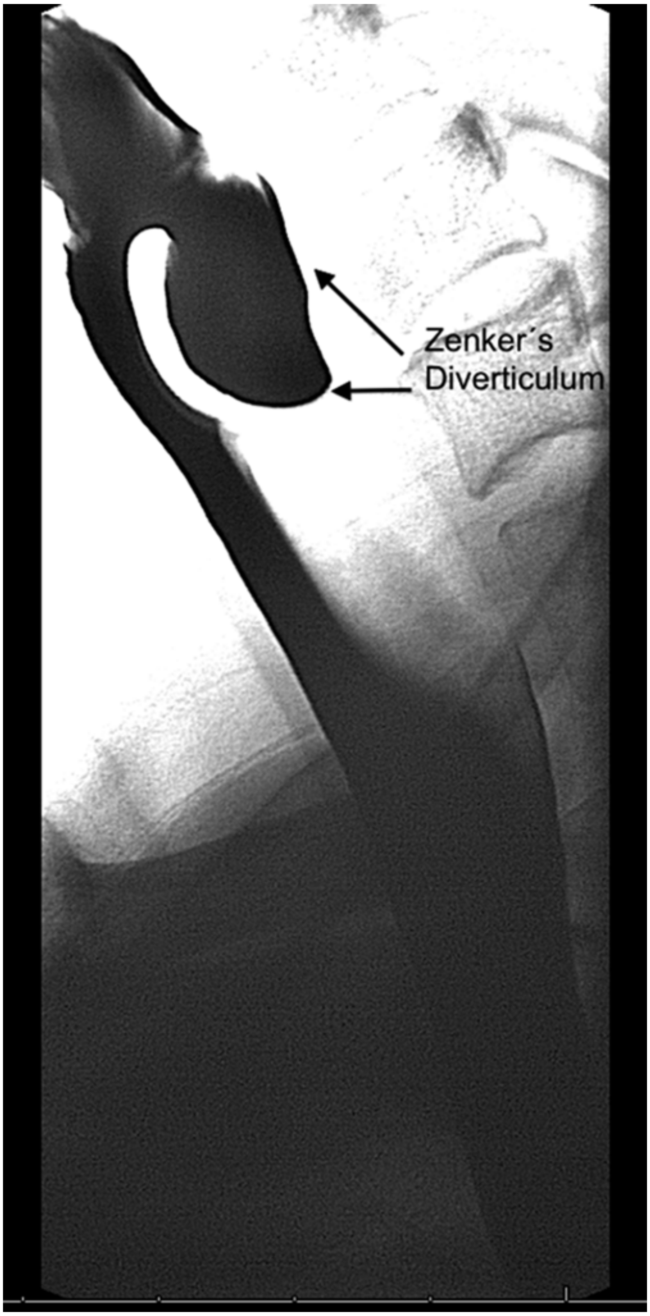

Fig. 2.14 Barium swallow. Zenker's diverticulum (*arrows*)

Fig. 2.15 Barium swallow. Zenker's diverticulum (*arrow*)

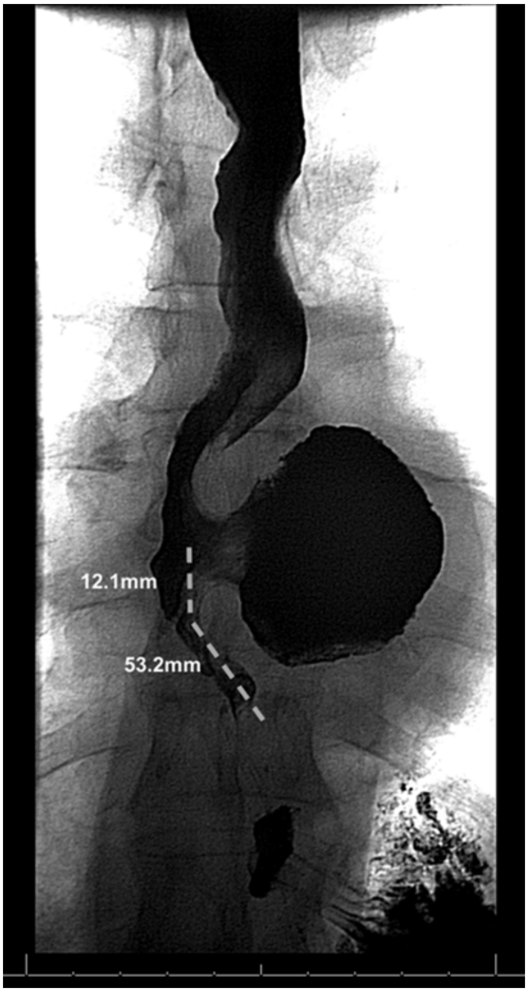

Fig. 2.16 Barium swallow. Epiphrenic diverticulum

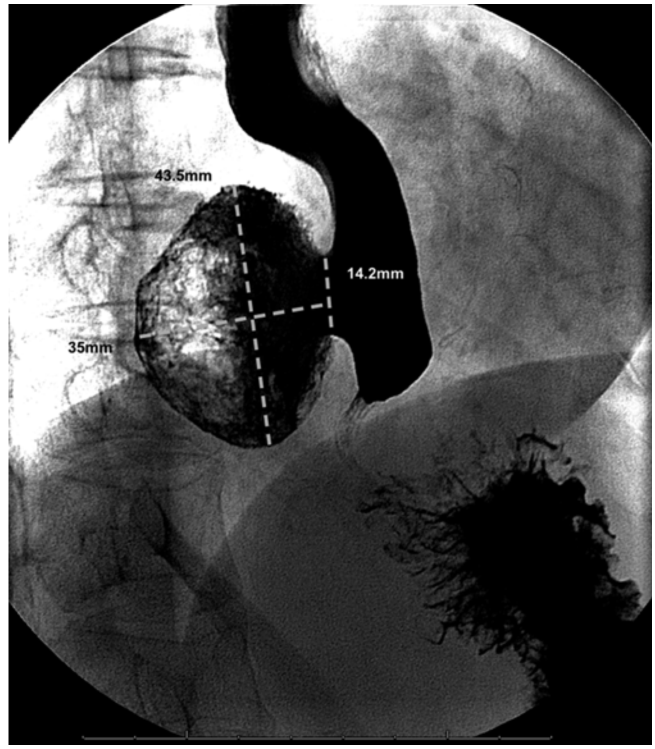

Fig. 2.17 Barium swallow. Epiphrenic diverticulum

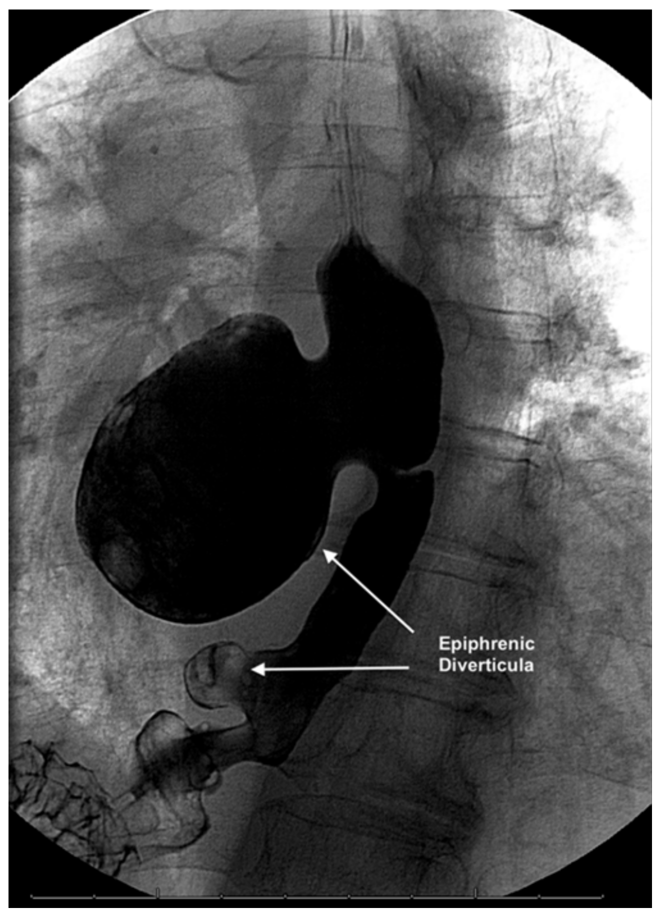

Fig. 2.18 Barium swallow. Epiphrenic diverticula (*arrows*)

Fig. 2.19 Barium swallow. Esophageal fibrovascular polyp

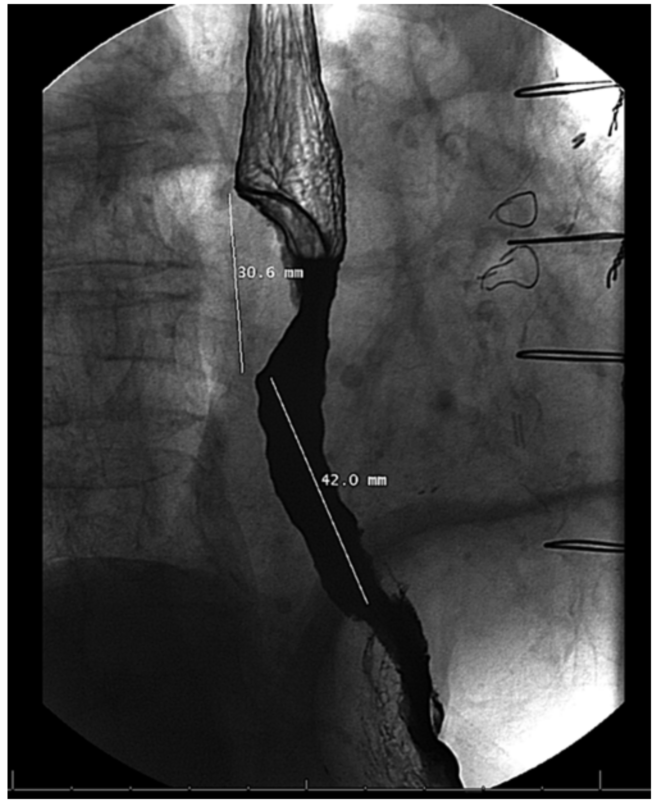

Fig. 2.21 Barium swallow. Esophageal leiomyoma

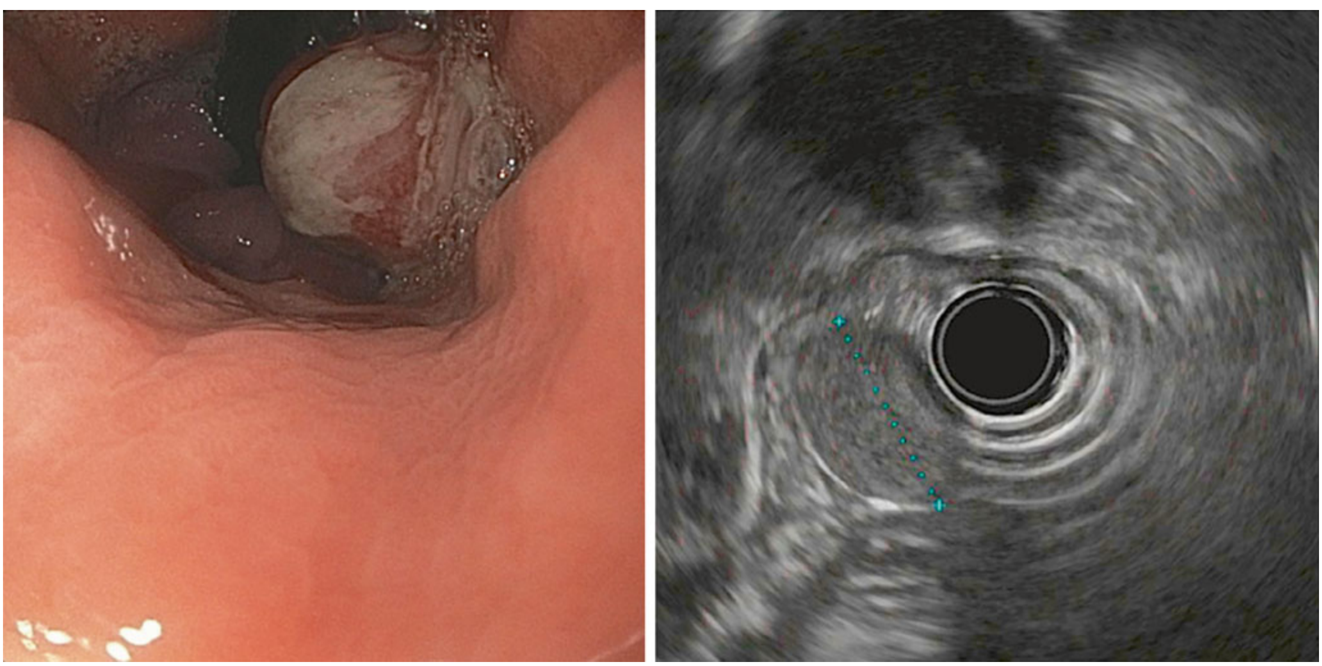

Fig. 2.20 Endoscopy (*left*) with endoscopic ultrasound (*right*). Esophageal fibrovascular polyp

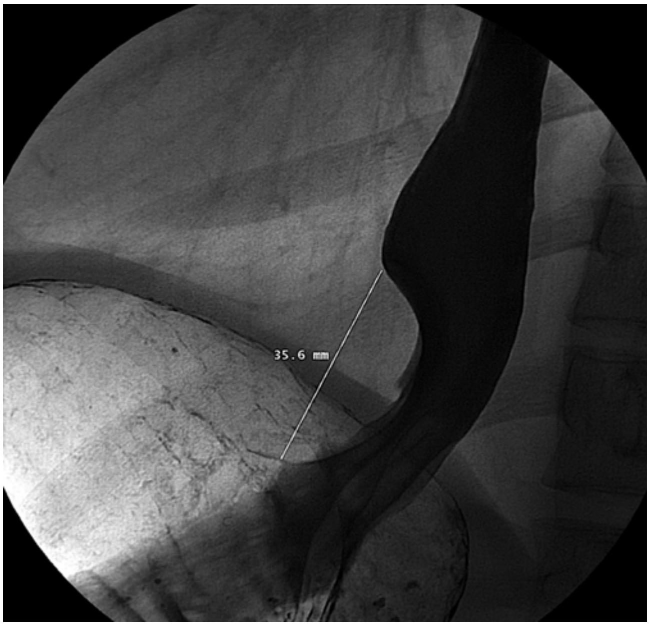

Fig. 2.22 Barium swallow. Esophageal leiomyoma

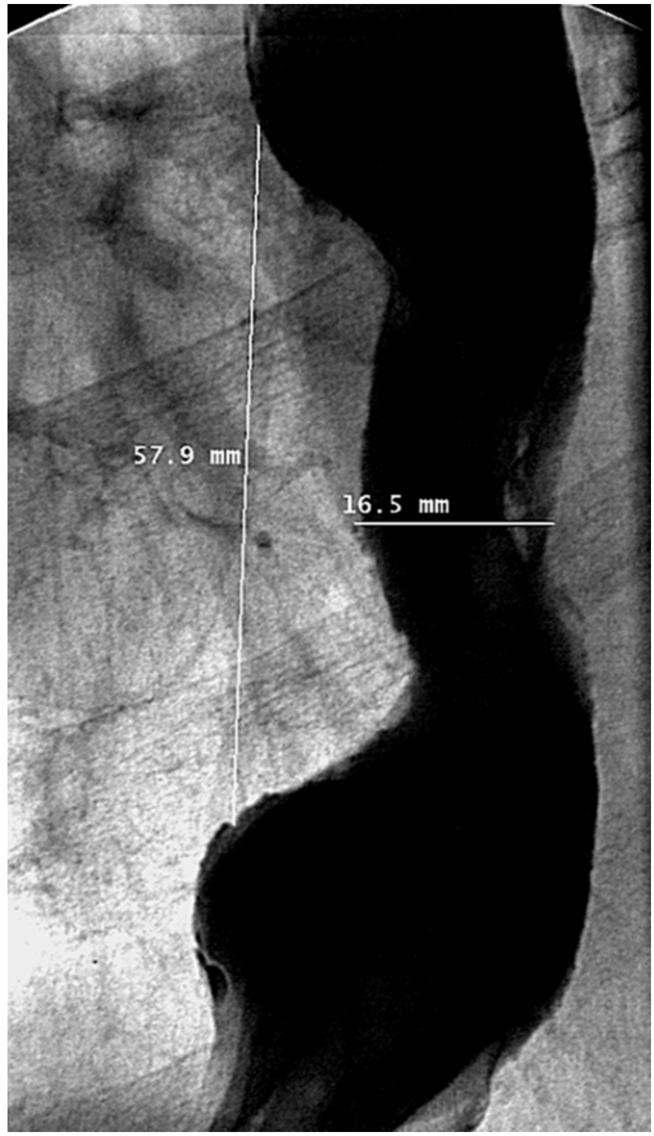

Fig. 2.23 Barium swallow. Distal esophageal adenocarcinoma

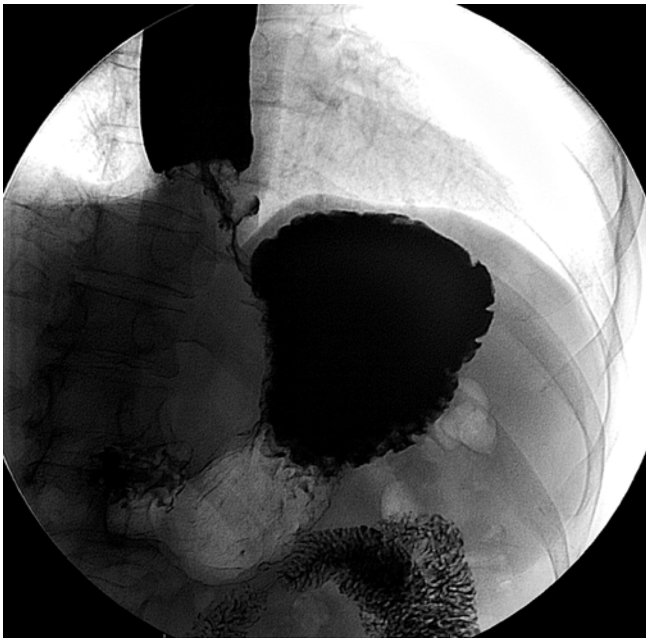

Fig. 2.24 Barium swallow. Distal esophageal adenocarcinoma

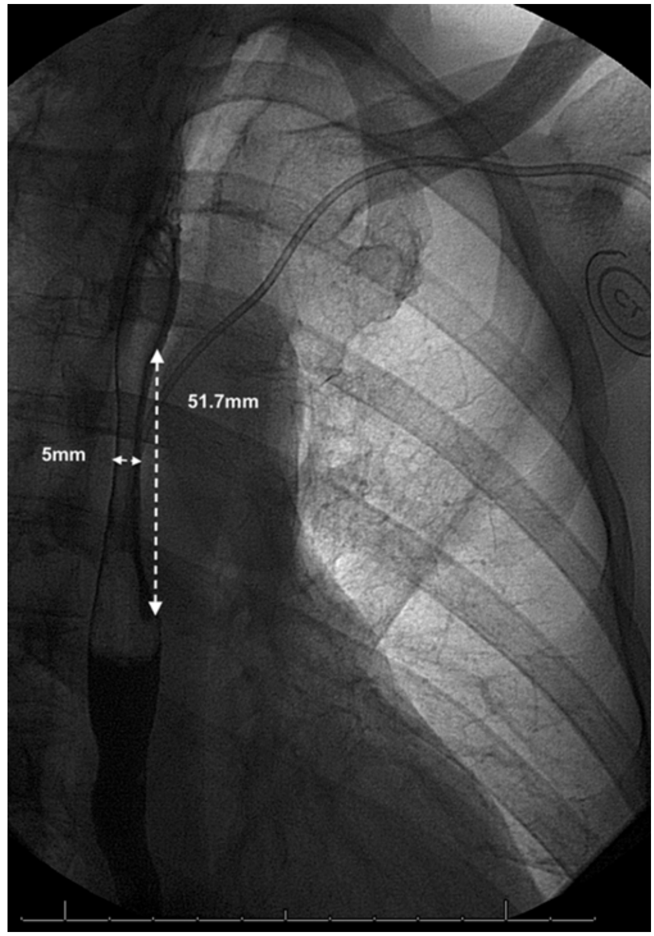

Fig. 2.25 Barium swallow. Midthoracic esophageal squamous cell cancer

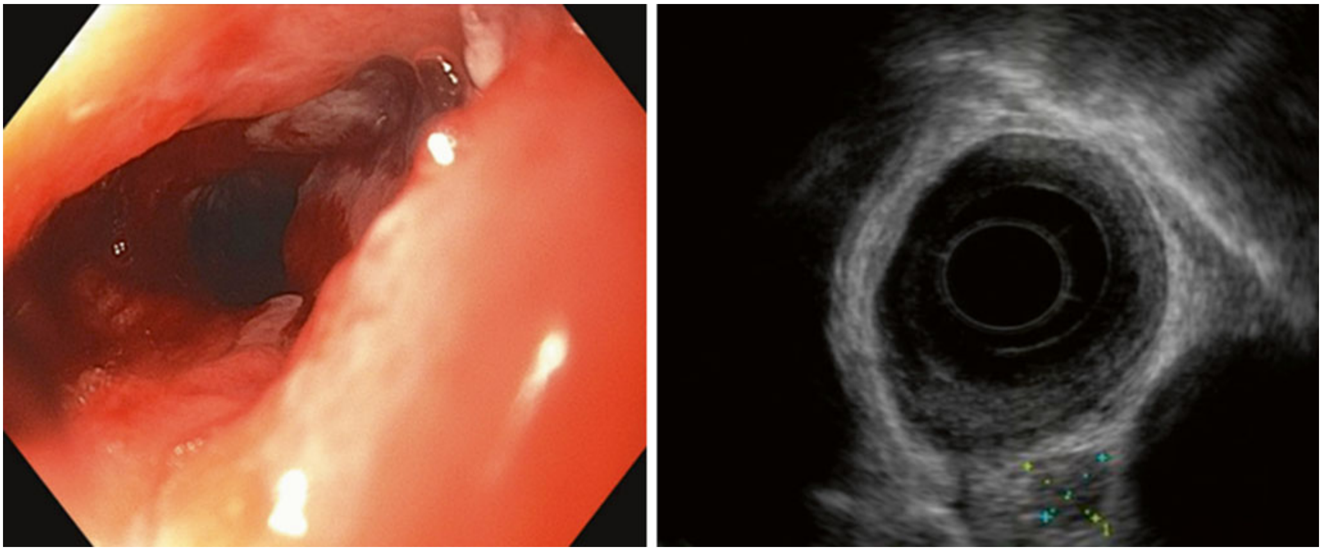

Fig. 2.26 Endoscopy (*left*) and endoscopic ultrasound (*right*). Midthoracic esophageal squamous cell cancer

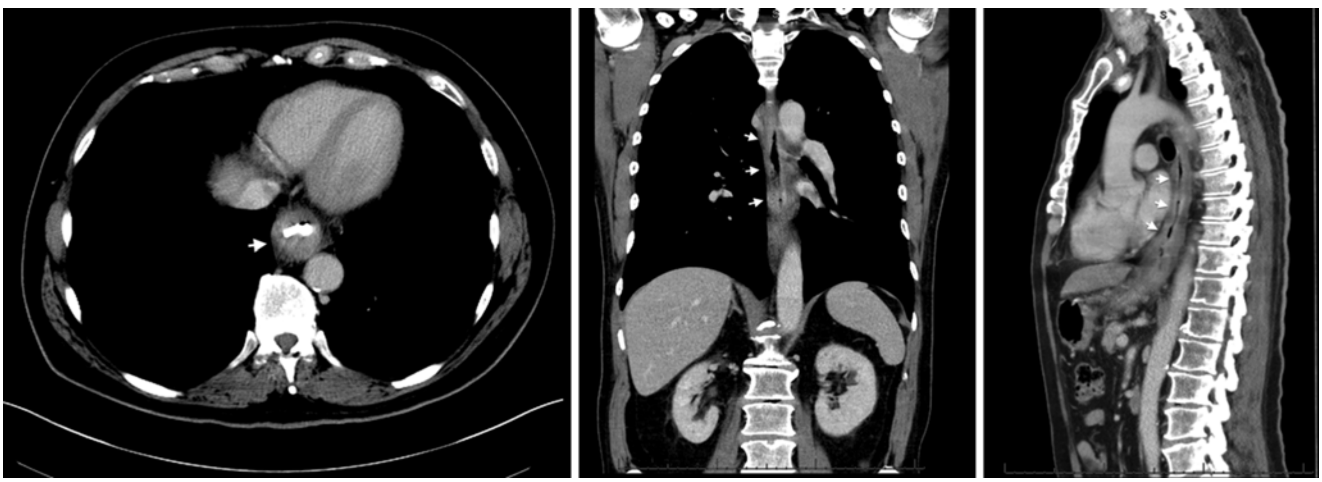

Fig. 2.27 Chest CT scan. Midthoracic esophageal squamous cell cancer (*arrows*)

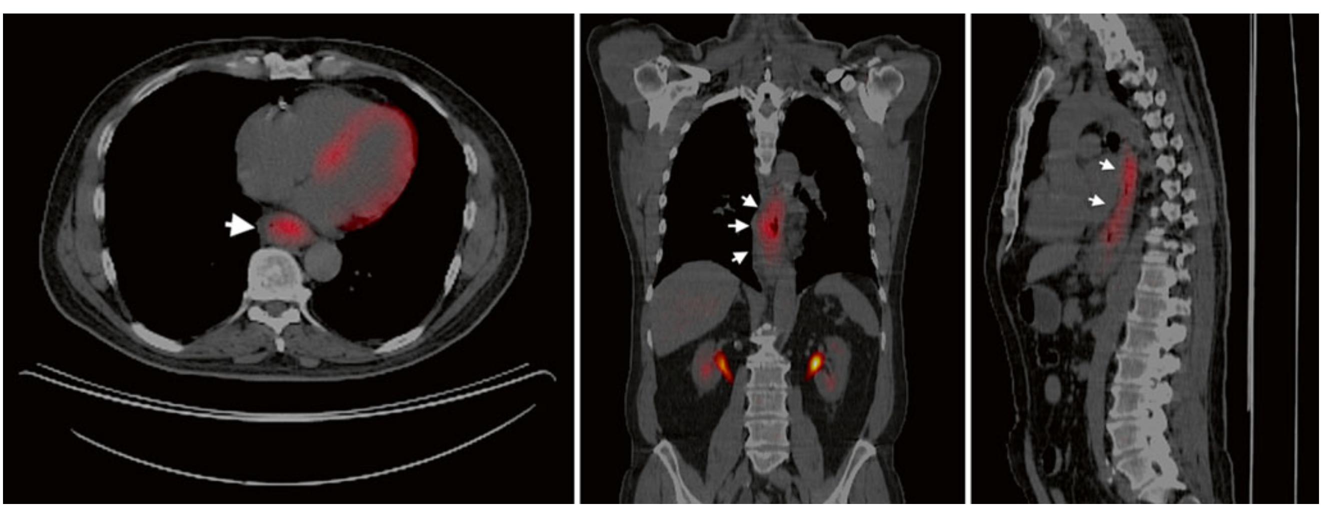

Fig. 2.28 PET scan. Midthoracic esophageal squamous cell cancer (*arrows*)

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3 Diagnostic and Interventional Endoscopy

Yutaka Tomizawa and Irving Waxman

3.1 Indications for Endoscopic Therapy

In endoscopic management of patients with esophageal malignancy, the most common aim is to diagnose and treat mucosal-based neoplasia. Esophagectomy is a curative therapy, but despite technical advances in surgical procedures, it is still associated with considerable perioperative risks, especially for the elderly. The increased perioperative risk can be partially explained by the existence of comorbidities in an aging population, notably obesity and ongoing tobacco and alcohol consumption. Most endoscopic therapy has been focused on high-grade dysplasia (HGD), primarily because of the risk of progression to cancer. HGD represents a threshold for intervention, whereas low-grade dysplasia (LGD) often just requires frequent endoscopic surveillance following society guidelines [1–4]. Endoscopic therapy has been applied to early-stage cancer since the publication of more favorable outcome data on mucosal resection and ablation therapy for mucosal esophageal cancer [5–7].

Endoscopic observation is key in identifying lesions amenable to endoscopic therapy (Figs. 3.1, 3.2, 3.3, and 3.4). Raised or elevated lesions are often suitable for endoscopic mucosal resection (EMR) techniques, whereas lesions that are ulcerated or depressed are less amenable because they tend to invade more deeply and to have inflammatory response that makes it difficult to separate the mucosa from the submucosa (Fig. 3.5). Size is another determinant factor for EMR: Generally, lesions that are smaller than 2 cm in diameter are suitable for EMR techniques [8]. Endoscopic submucosal dissection (ESD) allows for en bloc resections of lesions larger than 2 cm. Lymph node metastasis is common even in the early stages of esophageal cancer because the esophagus characteristically receives lymphatic supply networks and the risk of metastasis is higher in submucosal invasion. Radiofrequency ablation (RFA) is usually a treatment for eradication of Barrett's esophagus. Patients with a large hiatal hernia or polypoid lesions within Barrett's mucosa are not good candidates for RFA. Lastly, peroral endoscopic myotomy (POEM) is a method for performing endoscopic myotomy of the lower esophageal sphincter (LES) and is being evaluated for the treatment of achalasia. Long-term data from randomized trials to compare POEM with laparoscopic myotomy and endoscopic pneumatic dilation have not yet been demonstrated, but the existing data suggest that POEM seems promising as an alternative modality.

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P.M. Fischella, M.G. Patti (eds.), *Atlas of Esophageal Surgery*, DOI 10.1007/978-3-319-13015-6_3

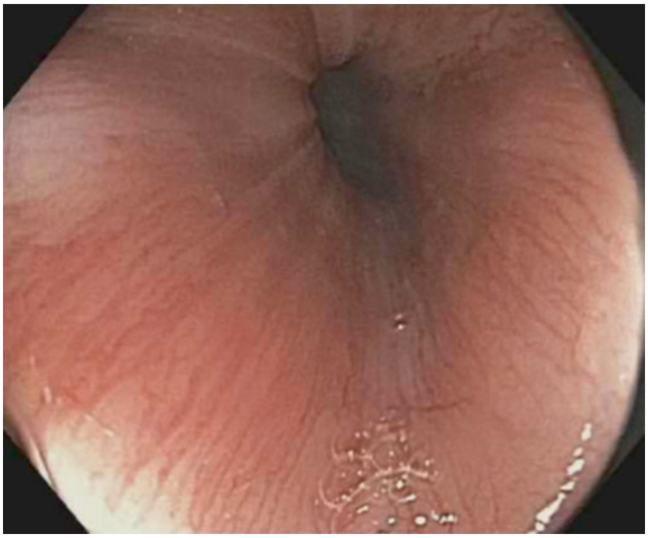

Fig. 3.1 Normal esophagus: whitish pink mucosa and branching vessels aligned as a network in the horizontal plane

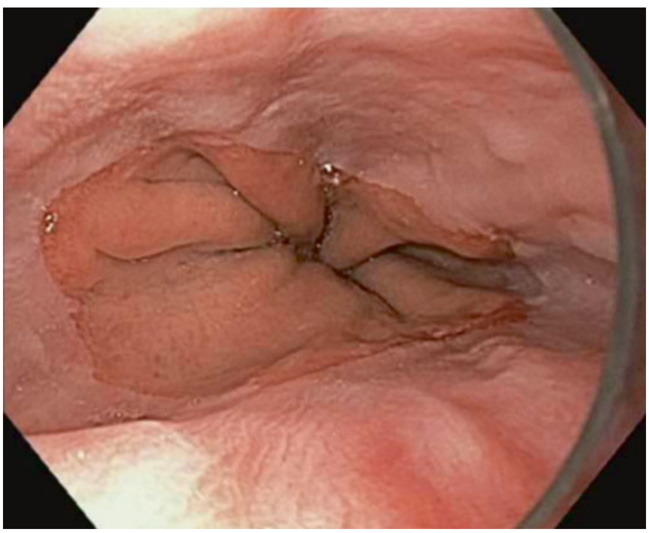

Fig. 3.2 Reflux esophagitis: one or more mucosal breaks less than 5 mm in maximal length (LA classification A)

Fig. 3.3 Reflux esophagitis: mucosal breaks involving more than 75 % of the esophageal circumference (LA classification D)

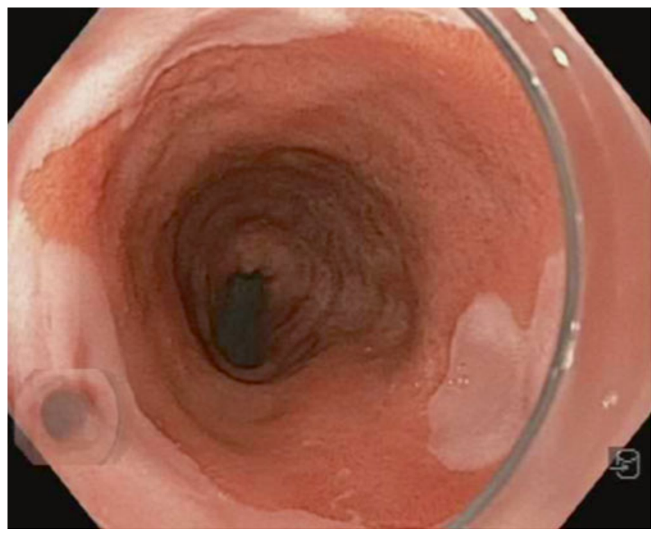

Fig. 3.4 Barrett's esophagus: salmon-colored mucosa projecting from the gastroesophageal junction

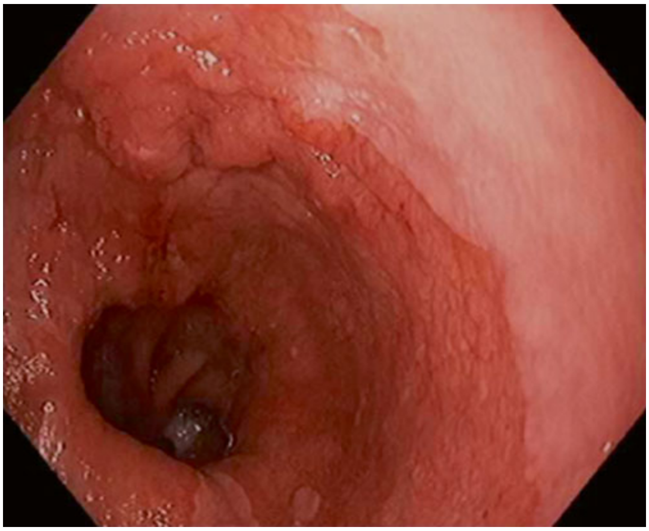

Fig. 3.5 Focal nodular lesion within the Barrett's esophagus

3.2 Preoperative Workup

The first step is careful examination with high-resolution endoscopy to visualize the area of the target lesion and identify the margins of the neoplasia (Fig. 3.6). The updated Paris classification categorizes superficial lesions in the esophagus into a number of categories [9]:

- Protruding pedunculated (type 0-Ip)
- Protruding sessile (0-Is)
- Slightly elevated (0-IIa)
- Completely flat (0-IIb)
- Slightly depressed (0-IIc)
- Excavated (0-III)
- Mixed pattern

We often need to enhance the mucosal lesion by using chromoendoscopy. Indigo carmine, a topical contrast agent, is the only dye that is not absorbed by the mucosa; absorptive dyes are less commonly used because some are considered carcinogenic, as they bind to the DNA within cells. Optical chromoendoscopy with narrow-band imaging (NBI) is now widely used (Fig. 3.7). This technique uses a narrow-band illumination of the light source to highlight mucosal structures and vascular patterns [10].

Endoscopic ultrasound (EUS) is usually performed to identify the depth of the lesion. Currently, EUS is considered the most accurate modality for preoperative locoregional staging, especially for the T stage of esophageal cancer (Figs. 3.8 and 3.9). It has been suggested that a combination of EUS and CT–positron emission tomography (PET) improves preoperative staging of esophageal cancer [11]. Even with high-frequency ultrasound probes, however, it can be difficult to distinguish between lesions confined to the mucosa and cancer invading the submucosa [12]. Another weak point is reproducibility and validity. Although EUS is often performed as part of clinical practice for all neoplastic lesions, it can be argued that EUS is not necessary in patients with very superficial cancers.

Fig. 3.6 High-resolution endoscopy with near-focus magnification, showing a type IIc mucosal lesion (updated Paris classification) within the Barrett's esophagus

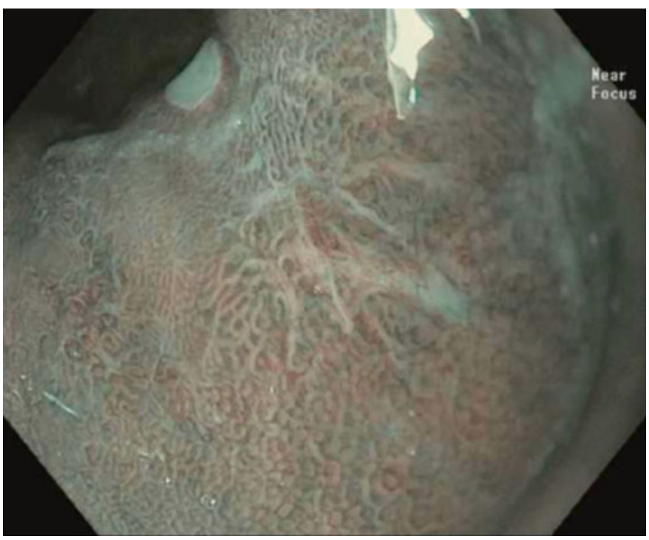

Fig. 3.7 NBI chromoendoscopy with magnification, showing type IIc mucosal lesion (updated Paris classification) within the Barrett's esophagus

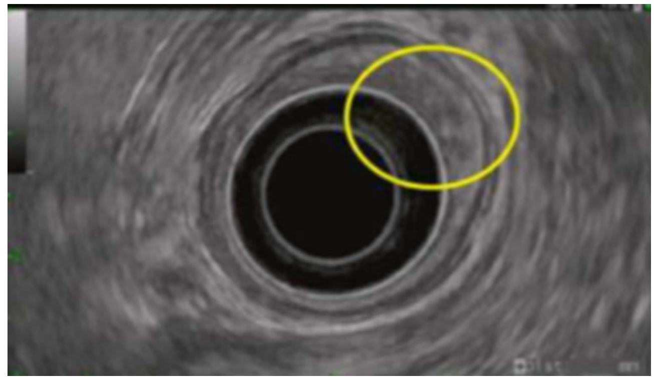

Fig. 3.8 Endoscopic ultrasound (EUS): hypoechoic mass extending into the submucosa, causing irregularity

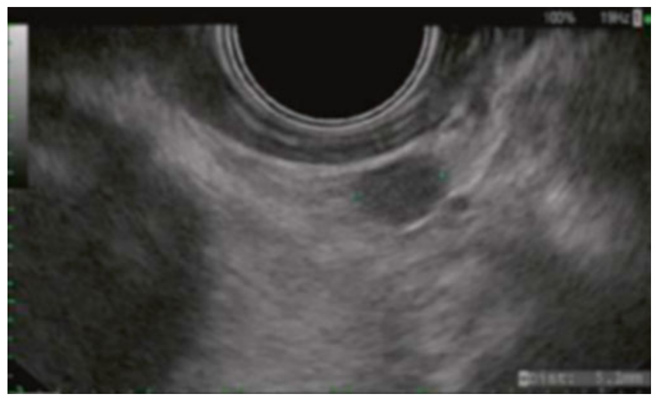

Fig. 3.9 EUS: paraesophageal lymph node (oval, hypoechoic, well-defined margin)

3.3 Endoscopic Mucosal Resection

Normal saline solution with the addition of epinephrine (1:100,000–1:200,000) is widely used for injection-assisted EMR. The volume of injected solution ranges from 5 to 50 mL, depending on the size of the lesion. Repeated injections may be required if the cushion dissipates before complete resection of the lesion. Observation of the lesion during submucosal injection is important because it helps us to decide whether to proceed with EMR. Failure of the lesion to be lifted is often the result of submucosal neoplastic invasion or submucosal fibrosis from prior mucosal resection, and those lesions should be considered for alternative treatments. The most common way to perform EMR is either using cap-assisted EMR (C-EMR) or band-ligation EMR. C-EMR requires a transparent plastic cap on the tip of an endoscope. After submucosal injection, a crescent-shaped snare must be opened and positioned on the internal circumferential ridge at the tip of the cap. The preloop can be performed by lightly pressing against and suctioning normal mucosa to seal the cap outlet. The endoscope is then positioned immediately over the target lesion and the lesion is sucked into the cap, after which the snare is closed and cautery current is applied to cut the tissue (Figs. 3.10 and 3.11). After C-EMR, the resected specimen can be collected into the cap. In band-ligation EMR, suction is applied to retract the lesion into the banding device, and the lesion is ligated by placing a band at the bottom, with or without submucosal injection. An ha snare is then placed under the band and is used to cut the lesion.

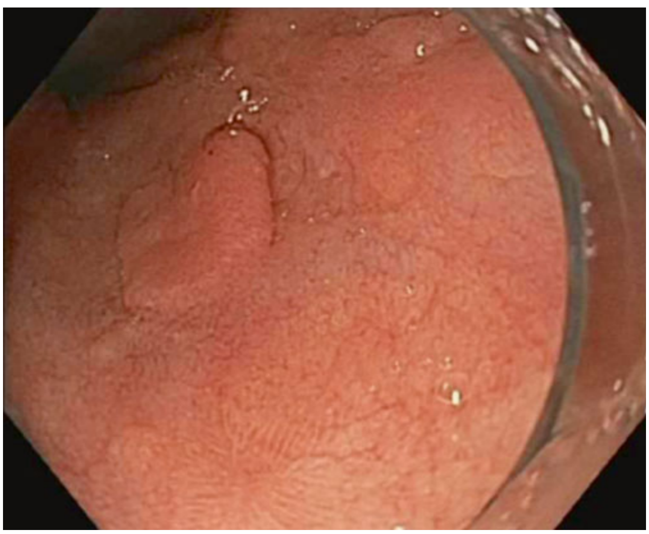

Fig. 3.10 Nodular lesion within the Barrett's esophagus, before endoscopic mucosal resection (EMR)

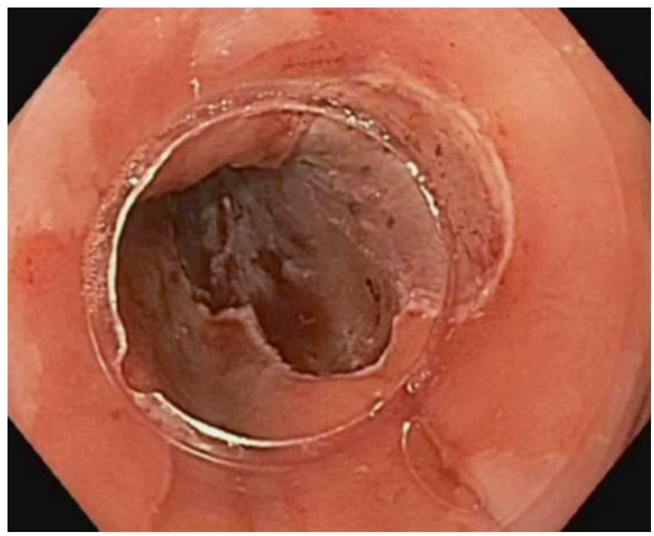

Fig. 3.11 Complete mucosal resection and resulting scar after EMR of the nodular lesion

3.4 Endoscopic Submucosal Dissection

A forward-viewing, single-channel endoscope with a distally attached transparent cap on the endoscope tip and carbon dioxide for insufflation is utilized. The area of interest is first carefully marked using cautery, argon plasma coagulation (forced APC 70 W, flow 2.0 L/min), to mark 0.5 mm from the lesion's lateral borders, as once the resection begins it is difficult to determine the boundaries of the lesion that needs to be removed (Fig. 3.12). Then, an indigo carmine solution mixed with 0.3 % hypomellose and saline is injected into the submucosal layer to separate it from the muscularis mucosa (Fig. 3.13). The lifting solution is injected via an injection needle. Subsequently, the mucosa is cut in a circumferential fashion using a dissecting knife to grab and then cut through the submucosal fibrous tissue. Injections are repeated as needed. Cautery is most commonly applied with a blended current with primary coagulation. Control of bleeding is obtained with coagulation via an electrocautery knife and hot biopsy forceps as well as hemostatic clips, or with a combination (Fig. 3.14). No type of knife has been clearly shown to be superior to the others.

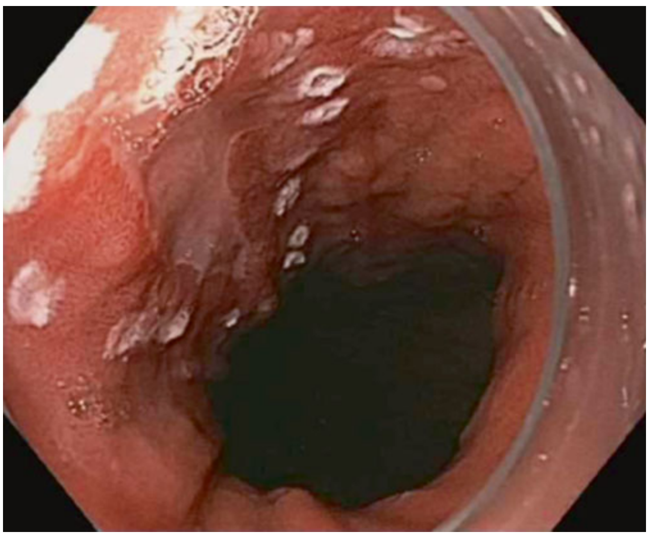

Fig. 3.12 Endoscopic submucosal dissection (ESD). Before dissection, the area of interest is marked using cautery

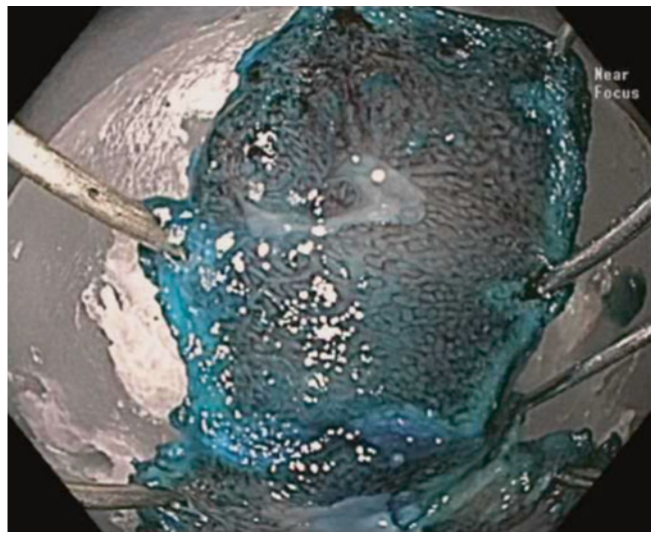

Fig. 3.14 ESD: dissection of the lesion in a circumferential fashion using hemostatic clips

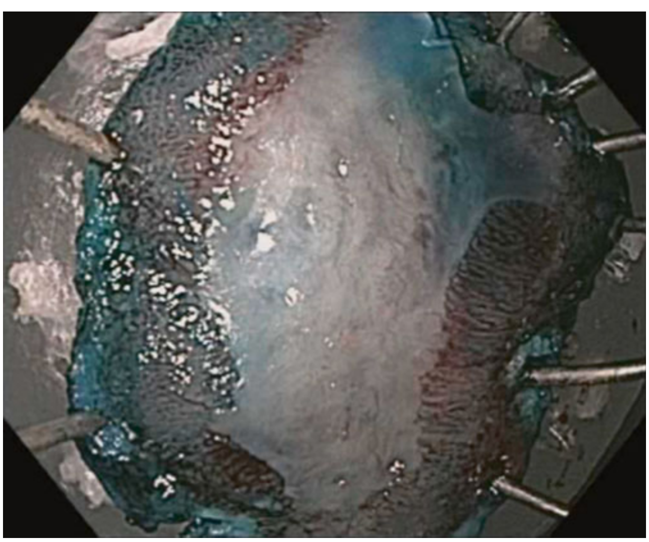

Fig. 3.13 ESD: separation of the lesion from the muscularis mucosa

3.5 Radiofrequency Ablation

RFA is generally a stepwise circumferential ablation technique, followed by focal ablation for any residual lesions. The primary circumferential ablation uses a balloon-based bipolar electrode, and secondary treatment of residual lesion is performed by an endoscope-mounted bipolar electrode on an articulated platform. The first step is to remove mucus and clean the esophageal wall, usually by water flushing. The location of the top of the gastric folds and the proximal extent of the lesion are recorded. A guidewire is then introduced and the endoscope is removed, leaving the guidewire in place. A sizing catheter is introduced over the guidewire and is inflated via a footswitch. (There is a 1-cm scale on the catheter shaft for reference.) Based on the esophageal inner diameter measurements, an ablation catheter of appropriate size is selected. The electrode encircles the balloon, and catheters of five different diameters are available (18, 22, 25, 28, and 31 mm on inflation). The ablation catheter is introduced over the guidewire, and then the endoscope is advanced alongside the ablation catheter. Under endoscopic visualization, the proximal margin of the electrode is placed 1 cm above the most proximal extent of the lesion. The ablation catheter is then inflated and radiofrequency energy is delivered to the electrode. Energy delivery typically lasts less than 2 s, after which the balloon automatically deflates. The catheter is then moved distally and the balloon is repositioned with a small amount of overlap (5–10 mm) with the previous ablation zone. Ablation is repeated until the entire length of disease has received radiofrequency energy (Fig. 3.15). After the entire lesion is ablated, the guidewire, ablation catheter, and endoscope are removed. For focal ablation, the electric current is delivered through an electrode array attached to the end of the endoscope. The electrode is brought into close contact with the mucosal lesion, and the electric current is delivered through an electrode array attached to the end of the endoscope.

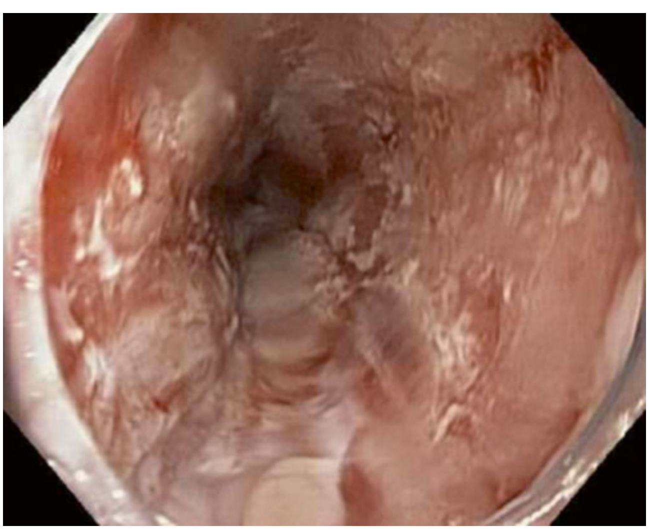

Fig. 3.15 Radiofrequency ablation (RFA): circumferential ablation of the Barrett's esophageal mucosa

3.6 Peroral Endoscopic Myotomy

Because it is time-consuming and complex, the POEM procedure requires general anesthesia. A forward-viewing therapeutic endoscope with a large-bore working channel is usually used with CO_2 insufflation. A transparent oblique cap attached at the distal tip of the endoscope is necessary to deploy a clip to the esophageal mucosal defects. An overtube is used to maintain the endoscope position, in order to avoid mucosal lacerations at the mucosal incision site during the procedure. Esophagogastroduodenoscopy (EGD) should be performed before the POEM procedure, to evaluate any other lesions and determine the distance of gastroesophageal junction (GEJ) from the incisors. An initial submucosal entry site is determined, typically 10–15 cm from the GEJ. After a submucosal injection of saline solution with dye (e.g., indigo carmine), a 2-cm longitudinal incision is made on the anterior wall with cutting current to expose the submucosa. A submucosal tunnel is then made with semicircumferential dissection of the esophageal lumen. Myotomy at right anterior orientation (2 o'clock) continues toward the lesser curvature. The dissection of the circular muscle bundle is usually started 2 cm distal to the mucosal entry point in the submucosal tunnel. Circular muscle dissection is performed in most patients. The dissection plane for the submucosal tunnel dissection is maintained in proximity to the muscularis propria to avoid injury of the mucosal flap. The submucosal tunnel is then extended down to 2–3 cm from the GEJ in the submucosa of the gastric cardia. As dissection gets close to the level of the GEJ, increased resistance is felt, followed by prompt expansion of the submucosal space with increased vascularity, which is the hallmark for the endoscopic measurements of the optimal dissected length (average 6–8 cm) [13]. After the myotomy is completed, the endoscope is withdrawn from the submucosal tunnel. An endoscope should be passed down in the lumen and easily passed through the GEJ to ensure an adequate myotomy. The mucosal entry site is closed with endoscopy clips.

3.7 Care After Endoscopic Procedures

After endoscopic therapy, acid-suppressive therapy is very important. This medication is intended not only to minimize patient discomfort but also to allow the esophagus to heal optimally and regenerate with epithelium. All patients should receive high-dose proton pump inhibitors (PPIs) as maintenance therapy. In addition, supplemental acid suppression for 2 weeks with a histamine receptor antagonist and sucralfate suspension is advisable. The PPI is continued as maintenance therapy. Patients should adhere to a liquid diet for the first 24 h. After 24 h, patients may gradually advance to a soft diet and then a normal diet as tolerated, generally guided by their symptoms. Patients may experience chest discomfort or difficult or painful swallowing, symptoms that usually improve daily and are self-limited.

If the patient complains of severe chest pain, fever, or both, additional imaging studies such as CT scanning are necessary to rule out perforation, especially if there is a clear suspicion of severe complications. Patients who underwent POEM procedures are usually hospitalized for observation and are given nothing by mouth until postoperative day 1, when a Gastrografin esophagram is obtained. If no leak is confirmed, a liquid diet is started and continued for a couple of days; the patient then is gradually advanced to a regular diet.

3.8 Pitfalls of Endoscopic Procedures

In EMR, it is crucial to observe the lesion during submucosal injection to see if it is lifted or not, because nonlifting is often a sign of submucosal neoplastic invasion or submucosal fibrosis from prior mucosal resection. Alternative treatment should be considered in such cases.

In the band-ligation EMR, problems include the lack of ability to localize the site of removal of a single resection unless the endoscope is withdrawn. In addition, the bands obscure lateral vision, decreasing the field of view. Some experts usually recommend preinjection of a dilute solution of epinephrine with saline, both to confirm the pliability of the tissue and to decrease any bleeding that may obscure vision [8].

In C-EMR, after the tissue is captured within the prepositioned snare, the tissue is pushed out of the cap and the reaction of the wall of the gastrointestinal tract is assessed to determine whether the captured tissue represents primarily mucosa. If there is evidence of wall motion, the possibility of entrapment of muscularis propria must be considered.

In ESD, the knife usually used is the HookKnife™ (Olympus America, Center Valley, PA). The insulation tip (IT) knife, which is widely used for gastric ESD, is not suitable for esophageal ESD because of the higher risk of perforation. After the tip of the HookKnife™ is inserted into the submucosal layer, the mucosa is hooked and cut with the hook part of the knife, which prevents perforation [14]. The arm part of the HookKnife™ is used for longitudinal mucosal incision. The mucosa is captured by the arm part of the knife and cut by the combination of spray coagulation and endocut mode in order to prevent bleeding during submucosal dissection.

In RFA, the outer diameter of the ablation balloon should be smaller than the narrowest measured esophageal diameter. In patients with prior mucosal resection, the ablation catheter selected should be one size smaller than the actual measurement. The sizing balloon calculates a mean inner diameter over a length of 4 cm, which may overestimate the esophageal inner diameter at the site of an EMR scar.

In POEM, preserving the longitudinal muscle is the key to maintaining mucosal integrity. It is important to begin myotomy step by step under good visualization through the incision site and advance carefully until the longitudinal muscle layer is identified at the bottom of the myotomy site. Careful CO_2 insufflation and endoscopic maneuvering are warranted to avoid accidental splitting of the muscular layer.

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4 Esophageal Function Testing

Wai-Kit Lo and Hiroshi Mashimo

Esophageal functional testing comprises assessments of esophageal motility and reflux, for the diagnosis of esophageal motility disorders and acid and nonacid reflux in gastroesophageal reflux disease (GERD). Testing is accomplished using a catheter-based esophageal manometry system, as well as catheter-based and capsule-based pH and impedance systems.

4.1 Evaluation of Motility Disorders: High-Resolution Esophageal Manometry

High-resolution esophageal manometry (HREM) is a recent technology that has enhanced the evaluation of motility disorders of the esophagus. Indications for the study include evaluation of dysphagia for the diagnosis of primary motility disorders of the esophagus. Additionally, it is a follow-up test in patients with persistent reflux, as motility disorders such as achalasia and scleroderma may mimic reflux symptoms. It is also helpful in the preoperative assessment of fundoplication candidates to minimize postsurgical dysphagia. Finally, it may be used to assess the location of the lower esophageal sphincter to assist with multichannel impedance and pH catheter placement.

Figure 4.1 shows a normal HREM tracing. Esophageal contraction is bordered by the upper esophageal sphincter (UES) above and the lower esophageal sphincter (LES) below. The upper thoracic transition zone represents the transition from striated to smooth muscle in the upper esophagus.

Peristalsis brings the swallowed fluid bolus to the stomach, creating the diagonal shape of the curve as esophageal pressurization pushes the bolus toward the LES. LES pressure (LESP), LES relaxation, distal esophageal contraction amplitude, and bolus clearance are HREM measures that can inform the diagnosis of an esophageal motility disorder. More recently, the Chicago Classification has been developed to assist with study interpretation using an algorithmic approach. These criteria continue to be refined annually.

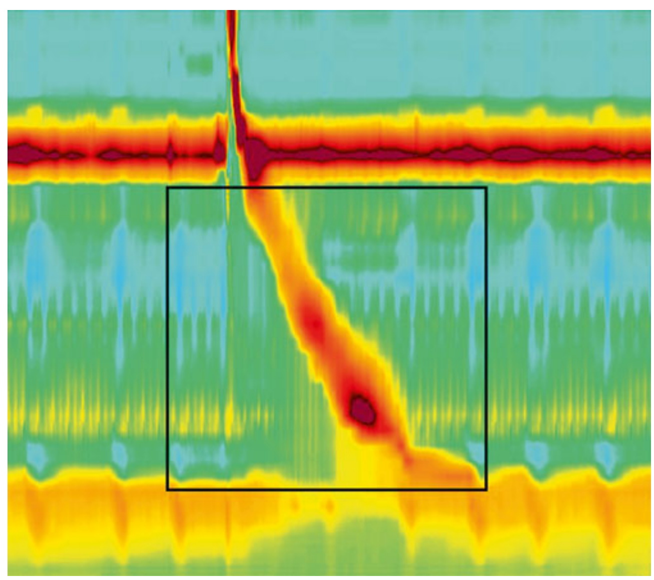

Fig. 4.1 A normal high-resolution esophageal manometry (HREM) tracing, with time on the *x-axis* and esophageal distance on the y-axis

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4.1.1 Motility Disorders Diagnosed by High-Resolution Esophageal Manometry

Motility disorders diagnosed by HREM include achalasia (Figs. 4.2, 4.3, and 4.4), scleroderma (Fig. 4.5), diffuse esophageal spasm (Fig. 4.6), nutcracker esophagus (Fig. 4.7), and ineffective esophageal motility (Fig. 4.8).

4.1.1.1 Achalasia

Three manometric subtypes can be diagnosed by HREM:

- Type 1, classic subtype (Fig. 4.2)
- Type 2, esophageal compression subtype (Fig. 4.3)
- Type 3, spastic subtype (Fig. 4.4)

Treatment outcomes have been shown to differ among these subtypes. Type 2 achalasia is most responsive to treatment by pneumatic dilation or laparoscopic Heller myotomy. Type 1 is more refractory to treatment, and Type 3 is the least amenable to either treatment. Given the greater risks of surgery versus pneumatic dilation, one proposal suggests that Type 2 patients be treated with pneumatic dilation and Type 1 patients be treated with surgery, if unresponsive to medical therapy. Botox injection should be reserved for Type 3 patients or any Type 1 or Type 2 patient who is a poor candidate for pneumatic dilation or surgery because of medical comorbidities.

4.1.1.2 Scleroderma

HREM in patients with scleroderma (Fig. 4.5) shows evidence of low to absent LESP, accompanied by weak or absent lower esophageal body contraction amplitude. Striated muscle contraction in the upper esophagus may be normal.

4.1.1.3 Diffuse Esophageal Spasm

In this disease, more than 20 % of swallows studied with HREM (Fig. 4.6) feature simultaneous contractions, but peristalsis is present on other swallows, and the LES relaxes normally. Incomplete bolus transit is often present.

4.1.1.4 Nutcracker Esophagus

Here, esophageal body contraction amplitude is elevated above 180 mmHg (Fig. 4.7). There may be incomplete LES relaxation, but bolus transit is usually complete. Clinical correlation is important in these situations, as this finding can be detected in some normal patients. Symptoms of chest pain, rather than dysphagia, are more suggestive of actual pathology.

4.1.1.5 Ineffective Esophageal Motility

Findings in these patients do not meet criteria for other motility disorders. LES relaxation is complete, but there may be low-amplitude or nontransmitted contractions in the esophageal body (Fig. 4.8). Bolus transit may be complete or incomplete, and abnormal swallows may be seen alongside normal peristaltic contractions. This finding can accompany a diagnosis of GERD.

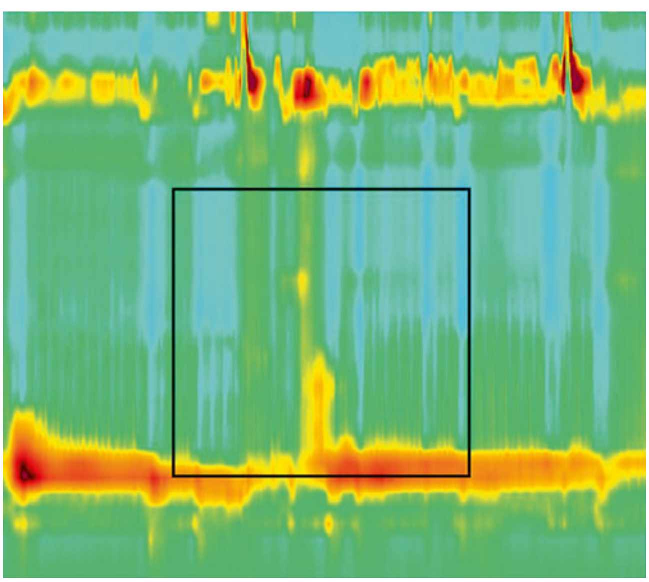

Fig. 4.2 Achalasia, type 1. This HREM tracing shows the swallow pattern of the classic subtype. Absent peristalsis is required for diagnosis. Esophageal pressurization is fully absent. Lower esophageal sphincter pressure (LESP) may be elevated, with poor LES relaxation

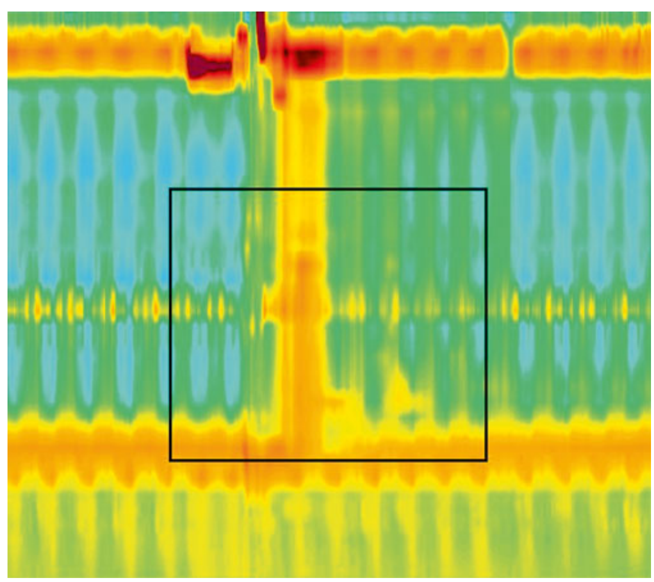

Fig. 4.3 Achalasia, type 2. This HREM tracing shows the swallow pattern of the esophageal compression subtype. This diagnosis requires absent peristalsis and panesophageal pressurization of the esophagus in more than 20 % of swallows. LESP may be elevated, with poor LES relaxation

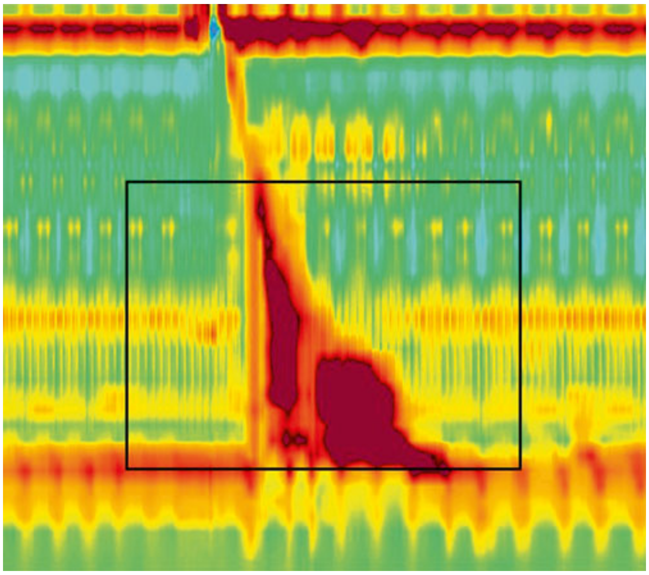

Fig. 4.4 Achalasia, type 3. This HREM tracing shows the swallow pattern of the spastic subtype. This diagnosis requires high-amplitude spastic contractions of the esophagus in more than 20 % of swallows, with or without preservation of distal peristalsis. LESP may be elevated, with poor LES relaxation

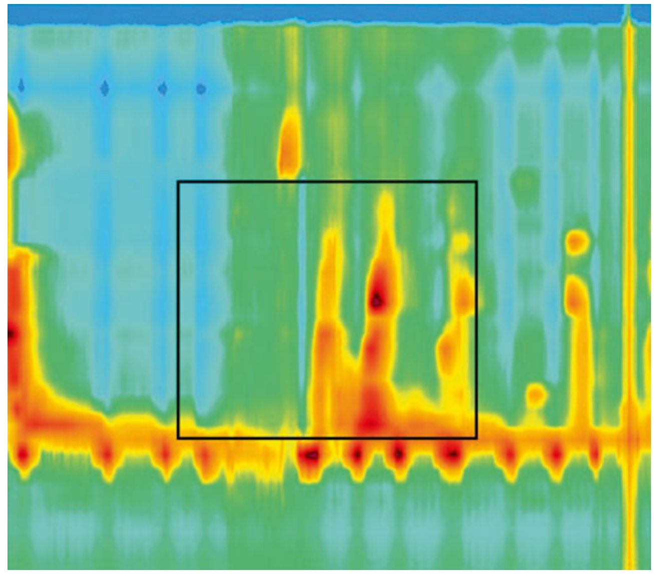

Fig. 4.6 Diffuse esophageal spasm, shown on HREM tracing. More than 20 % of swallows feature simultaneous contractions, but peristalsis is present on other swallows, and the LES relaxes normally

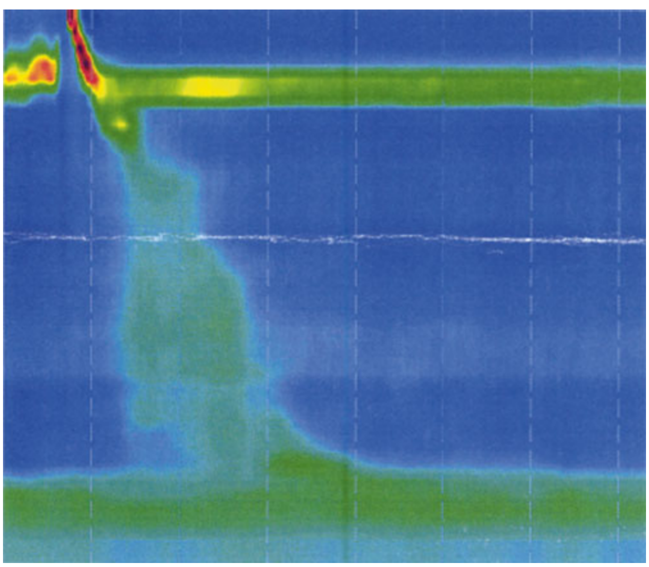

Fig. 4.5 Scleroderma. This HREM tracing shows evidence of low to absent LESP, accompanied by weak or absent lower esophageal body contraction amplitude. Striated muscle contraction in the upper esophagus may be normal. Incomplete bolus transit is detected. This finding can also be seen in severe cases of gastroesophageal reflux disease (GERD)

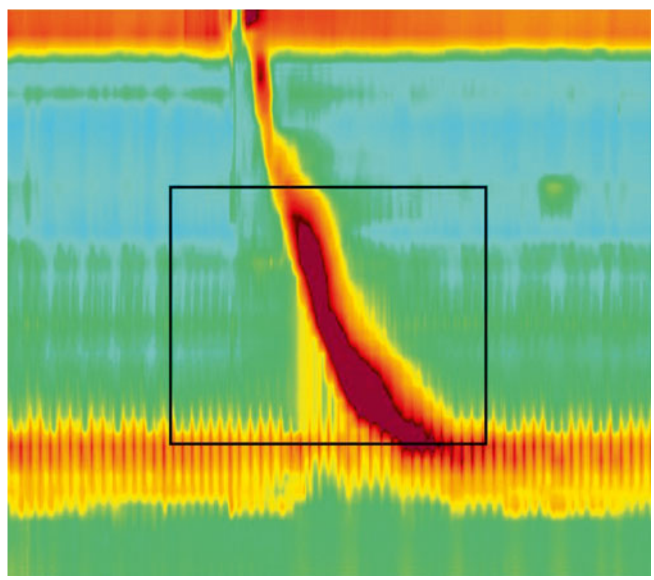

Fig. 4.7 Nutcracker esophagus, shown on HREM tracing. Esophageal body contraction amplitude is elevated above 180 mmHg. There may be incomplete LES relaxation, but bolus transit is usually complete

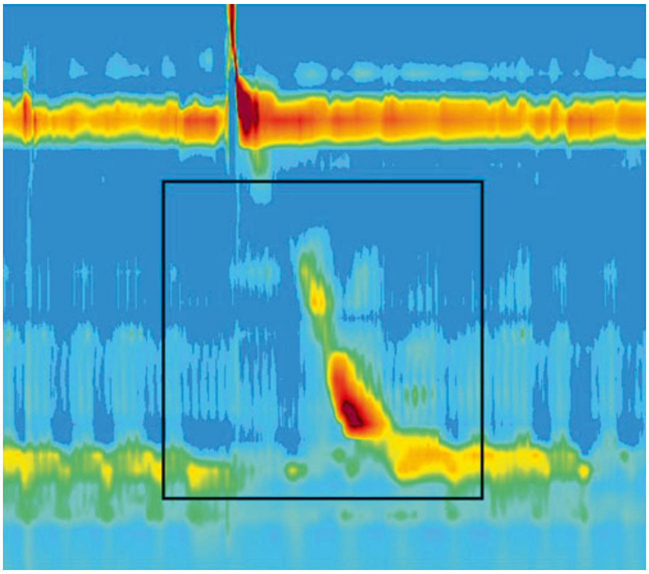

Fig. 4.8 Ineffective esophageal motility on an HREM tracing. This finding does not meet criteria for other motility disorders. LES relaxation is complete, but there may be low-amplitude or nontransmitted contractions in the esophageal body. Bolus transit may be complete or incomplete

4.2 Evaluation of Gastroesophageal Reflux Disease: Multichannel Intraluminal Impedance and pH Catheter, BRAVO® Capsule

Both catheter-based and capsule-based systems are available for the diagnosis of reflux in GERD. Esophageal pH testing is indicated in the assessment of patients with reflux symptoms unresponsive to medical therapy, and in the preoperative assessment of fundoplication candidates. There is no gold standard for the diagnosis of GERD, but the results of pH testing can be helpful in directing management.

Multichannel intraluminal impedance and pH (MII-pH) is a catheter-based system that detects acid and nonacid reflux over a 24-h period (Fig. 4.9). The impedance portion of the test may be omitted, limiting the assessment to acid reflux only. BRAVO® (Given Imaging, Yoqneam, Israel) is a capsule-based system for acid reflux detection, with a 48-h recording duration to capture reflux episodes and symptoms.

A benefit of the catheter-based system is the assessment of nonacid reflux episodes, but catheter placement can be difficult to tolerate, and recording is limited to 24 h. Dual-channel probes can be used to assess gastric pH while on or off proton pump inhibitors to evaluate the efficacy of gastric acid suppression or to correlate gastric acidity with the type of reflux events (acid or nonacid) in the esophagus.

Benefits of the capsule-based system include a longer recording period of 48 h, and generally greater convenience and comfort to the patient. It requires endoscopic evaluation prior to placement, however, and it cannot be used to detect nonacid reflux episodes.

Another pH-measuring probe used particularly to assess laryngopharyngeal reflux is produced by Restech (Respiratory Technology Corporation, San Diego, CA, USA). This probe does not require identification of the LES, and its thin catheter is readily positioned transnasally by aid of an LED light visualized directly from the mouth during placement.

All these systems require active participation from the patient to document body position, mealtimes, and clinical symptoms. A minimum recording time of 20 h is suggested, to improve diagnostic accuracy.

Data analysis of testing results (Fig. 4.9) reveals the percent-time in acid and nonacid reflux in upright and recumbent positions, the number of reflux episodes, and the DeMeester score for assessment of acid reflux severity. Mealtimes are excluded from analysis. Symptom association probability (SAP) is calculated to give a statistical measure of association between clinical symptoms and reflux episodes.

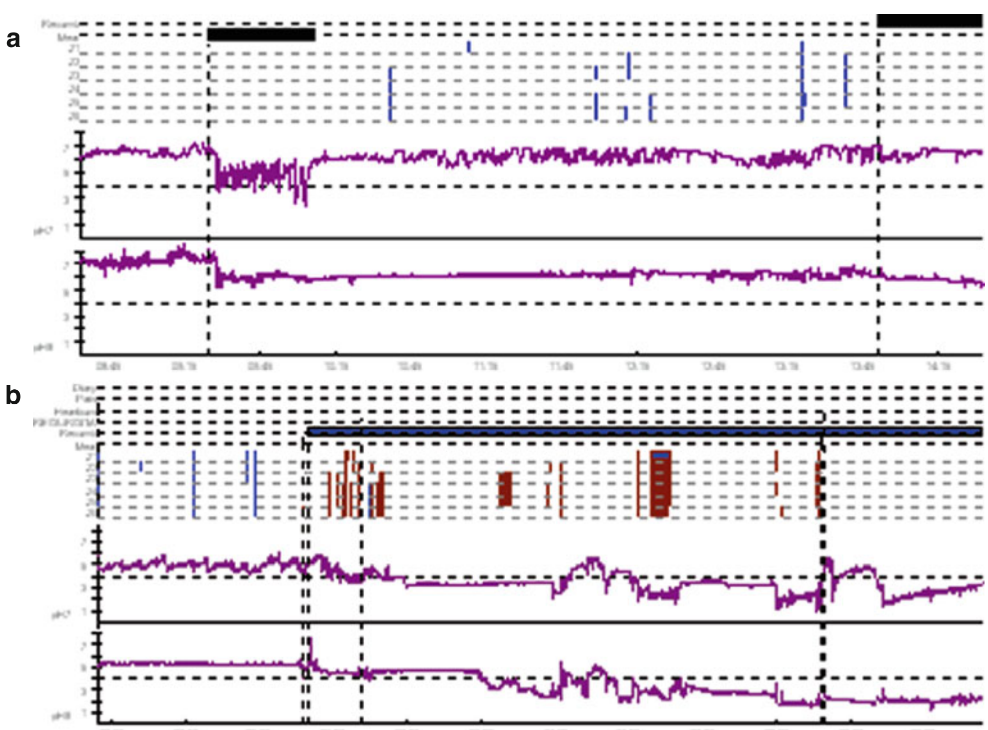

Fig. 4.9 (**a**, **b**), Representative results of multichannel intraluminal impedance and pH (MII-pH) testing for esophageal reflux. Time is on the x-axis and pH is on the y-axis. (**b**), Episodes of acid reflux, during which the graph falls below pH 4

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Patient Positioning

5

Bernardo Borraez, Mauricio Ramirez, and Marco G. Patti

This chapter illustrates the proper positioning of the patient for operations to treat esophageal diseases, including laparoscopic antireflux surgery, laparoscopic Heller myotomy, and Ivor Lewis hybrid esophagectomy. The placement of ports for these operations is also shown and discussed.

5.1 Patient Positioning for Laparoscopic Antireflux Surgery, Laparoscopic Heller Myotomy, and the Laparoscopic Part of Ivor Lewis Hybrid Esophagectomy

As shown in Figs. 5.1, 5.2, and 5.3, the patient is positioned supine on the operating table over a bean bag that is inflated to prevent sliding during the operation when a steep reverse Trendelenburg position is used. After induction of general endotracheal anesthesia, the legs are extended on stirrups, and the knees are flexed at angle of 20°–30°. The surgeon performs the procedure standing between the patient's legs, with an assistant on the right side of the operating table and another one on the left side.

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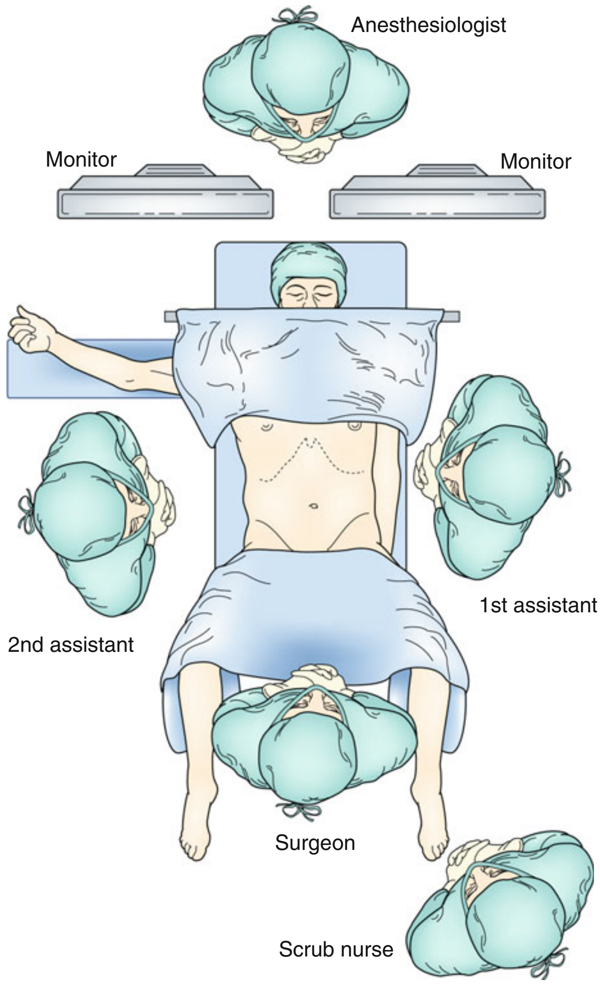

Fig. 5.1 The surgeon performs the procedure standing between the patient's legs, with an assistant on the *right* side of the operating table and another one on the *left* side

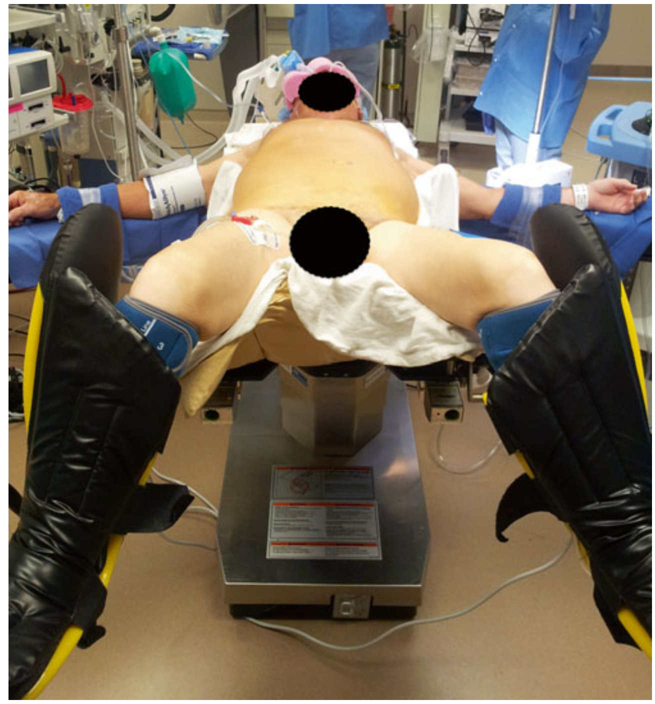

Fig. 5.2 The patient is positioned supine on the operating table. The legs are extended on stirrups, and the knees are flexed at angle of 20°–30°

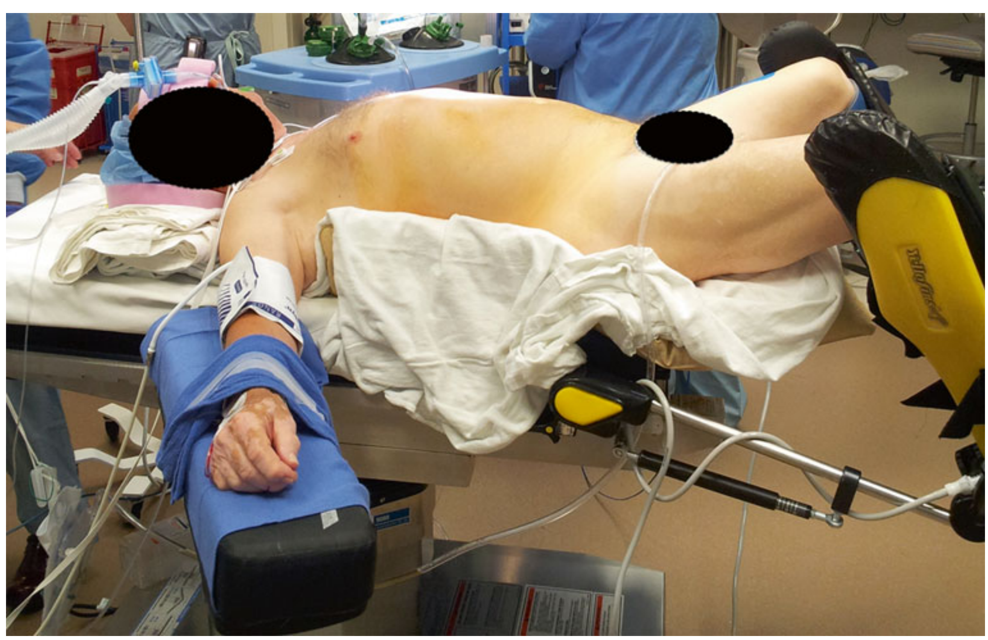

Fig. 5.3 The patient is positioned over a bean bag that is inflated to prevent sliding when a steep reverse Trendelenburg position is used

5.2 Trocar Positions for Laparoscopic Antireflux Surgery and Laparoscopic Heller Myotomy

Using a Veress needle that is placed 14 cm below the xiphoid process, we initially inflate CO_2 into the abdominal cavity to a pressure of 15 mmHg. Alternatively, a Hasson cannula can be used. We recommend using an optical trocar with a 0° scope to obtain access.

Figures 5.4 and 5.5 illustrate the positions of the five 11-mm trocars that are used for these operations. Trocar 1, which is used for the 30° camera, is placed in the same location as the Veress needle. Trocar 2 is placed in the left midclavicular line at the same level as trocar 1; it is used for insertion of a Babcock clamp, a grasper to hold the Penrose drain surrounding the esophagus, or a device to take down the short gastric vessels. Trocar 3 is placed in the right midclavicular line at the same level as the first two trocars; it is used for insertion of a retractor to lift the left lateral segment of the liver. Trocars 4 and 5 are placed under the right and left costal margins, so that their axes form an angle of about 120° with the camera. They are used for the dissecting and suturing instruments.

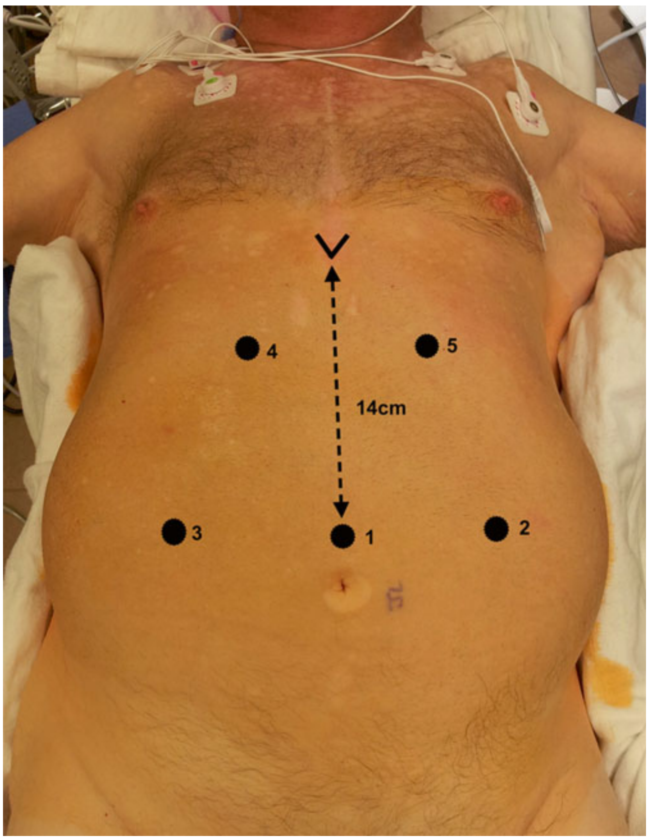

Fig. 5.4 The positions of the five 11-mm trocars used in laparoscopic antireflux surgery and Heller myotomy (see text for details)

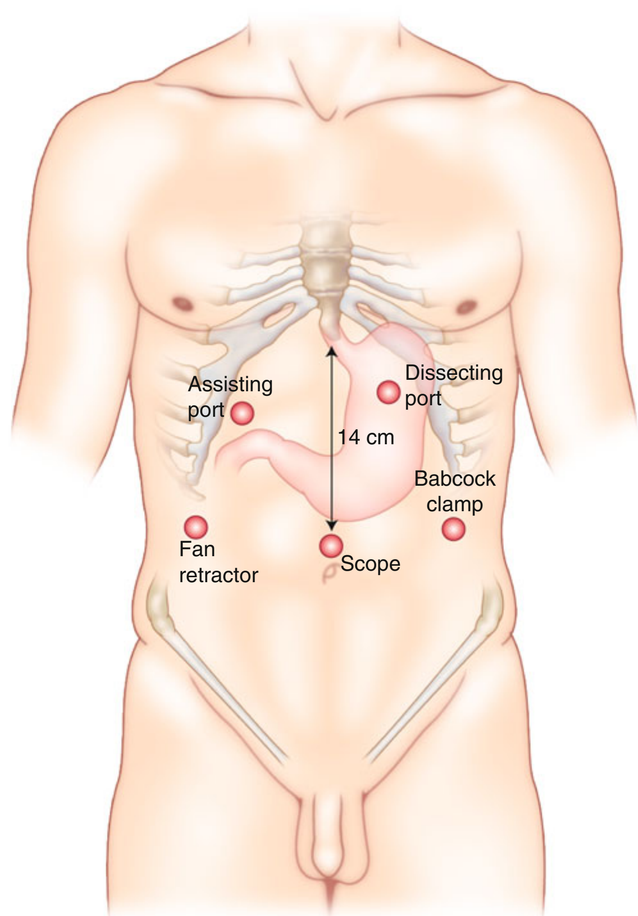

Fig. 5.5 The positions and functions of the five trocars

5.3 Trocar Positions for the Laparoscopic Part of Ivor Lewis Hybrid Esophagectomy

We initially inflate CO_2 into the abdominal cavity to a pressure of 15 mmHg, through a Veress needle that is placed 16 cm below the xiphoid process. Alternatively, a Hasson cannula can be used. We recommend using an optical trocar with a 0° scope to obtain access.

Figure 5.6 shows the placement of the four 11-mm trocars and one 12-mm trocar (for the insertion of the mechanical stapling device) that are used for the operation. Trocar 1, which is used for the 30° camera, is placed in the same location as the Veress needle. Trocar 2 is placed in the left midclavicular line at the same level as trocar 1; it is used for insertion of the a Babcock clamp, a grasper to hold the Penrose drain surrounding the esophagus, a device to take down the short gastric vessels, or the stapling instrument. Trocar 3 is placed in the right midclavicular line at the same level as the other two trocars; it is used for insertion of a retractor to lift the left lateral segment of the liver and then for the insertion of the camera during the performance of the pyloroplasty. Trocars 4 and 5 are placed under the right and left costal margins, so that their axes form an angle of about 120° with the camera. They are used for the dissecting and suturing instruments. An additional 5-mm trocar (5bis) can be placed in the right upper quadrant for the performance of the pyloroplasty.

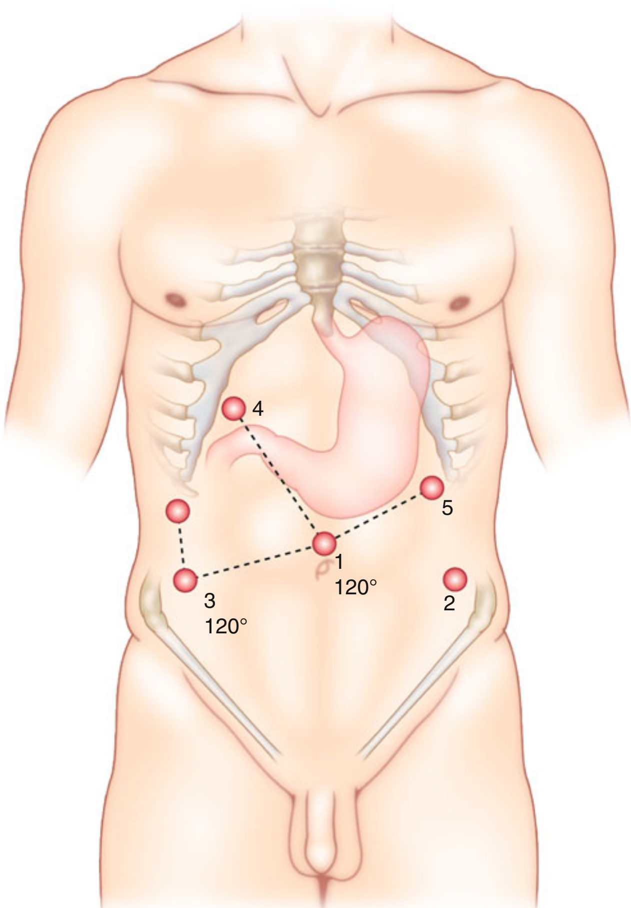

Fig. 5.6 The positions of the trocars used in the laparoscopic part of Ivor Lewis hybrid esophagectomy (see text for details)

5.4 Patient Positioning for the Thoracic Part of Ivor Lewis Hybrid Esophagectomy

For this procedure, the patient is on left lateral decubitus. Figure 5.7 shows the location of the right thoracotomy used for this procedure.

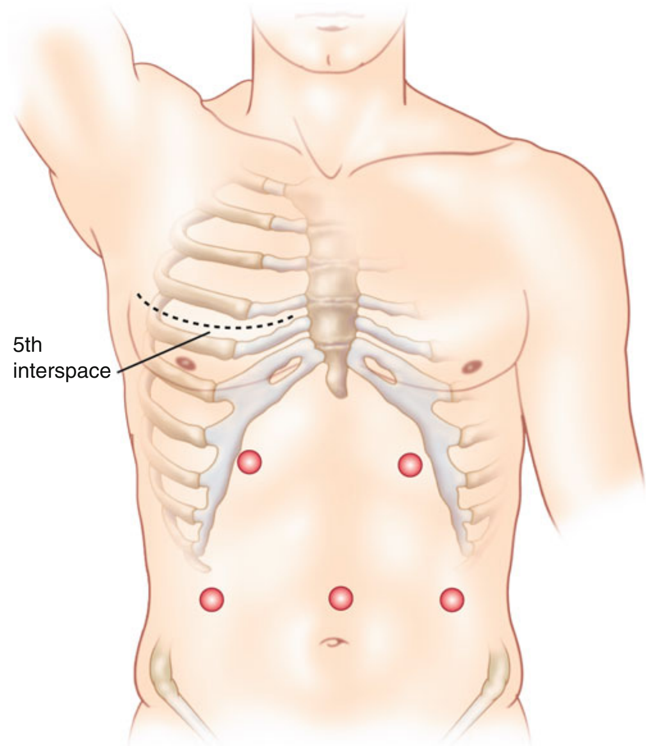

Fig. 5.7 The thoracic part of Ivor Lewis hybrid esophagectomy is performed using a right thoracotomy, with the patient in the left lateral decubitus position

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6 Operations for Gastroesophageal Reflux Disease

Bernardo Borraez, Mauricio Ramirez, and Marco G. Patti

6.1 Clinical History

The patient is a 58-year-old man with idiopathic pulmonary fibrosis (IPF). His pulmonary function tests have become progressively worse over the past 2 years. He has had heartburn and regurgitation for many years, and frequently wakes up at night with fluid in his mouth and coughing. His evaluation included these findings:

- Barium swallow: 3-cm sliding hiatal hernia (Fig. 6.1a)
- Upper endoscopy: small hiatal hernia and grade B esophagitis (Los Angeles classification)
- High-resolution esophageal manometry: hypotensive lower esophageal sphincter (LES), normal esophageal peristalsis (Fig. 6.1b).
- Ambulatory pH monitoring with two sensors located 5 and 20 cm above the manometrically determined LES: distal and proximal reflux (Fig. 6.1c).
- Bronchoscopy with lavage: presence of pepsin in the bronchoalveolar lavage

We chose to perform a Nissen fundoplication in this patient, as manometry documented normal esophageal peristalsis. We reserve partial fundoplication for patients who have very poor or absent peristalsis (achalasia, scleroderma). A laparoscopic total fundoplication is the gold standard for the surgical treatment of gastroesophageal reflux disease (GERD). A few studies have suggested that in patients with IPF and GERD in whom aspiration of gastric contents is documented, a fundoplication may stop the progression of the disease or even improve the respiratory status. Currently, a phase II multicenter trial and a randomized trial by the National Institutes of Health (NIH) are specifically assessing the effect on the natural history of IPF of controlling GERD by a fundoplication.

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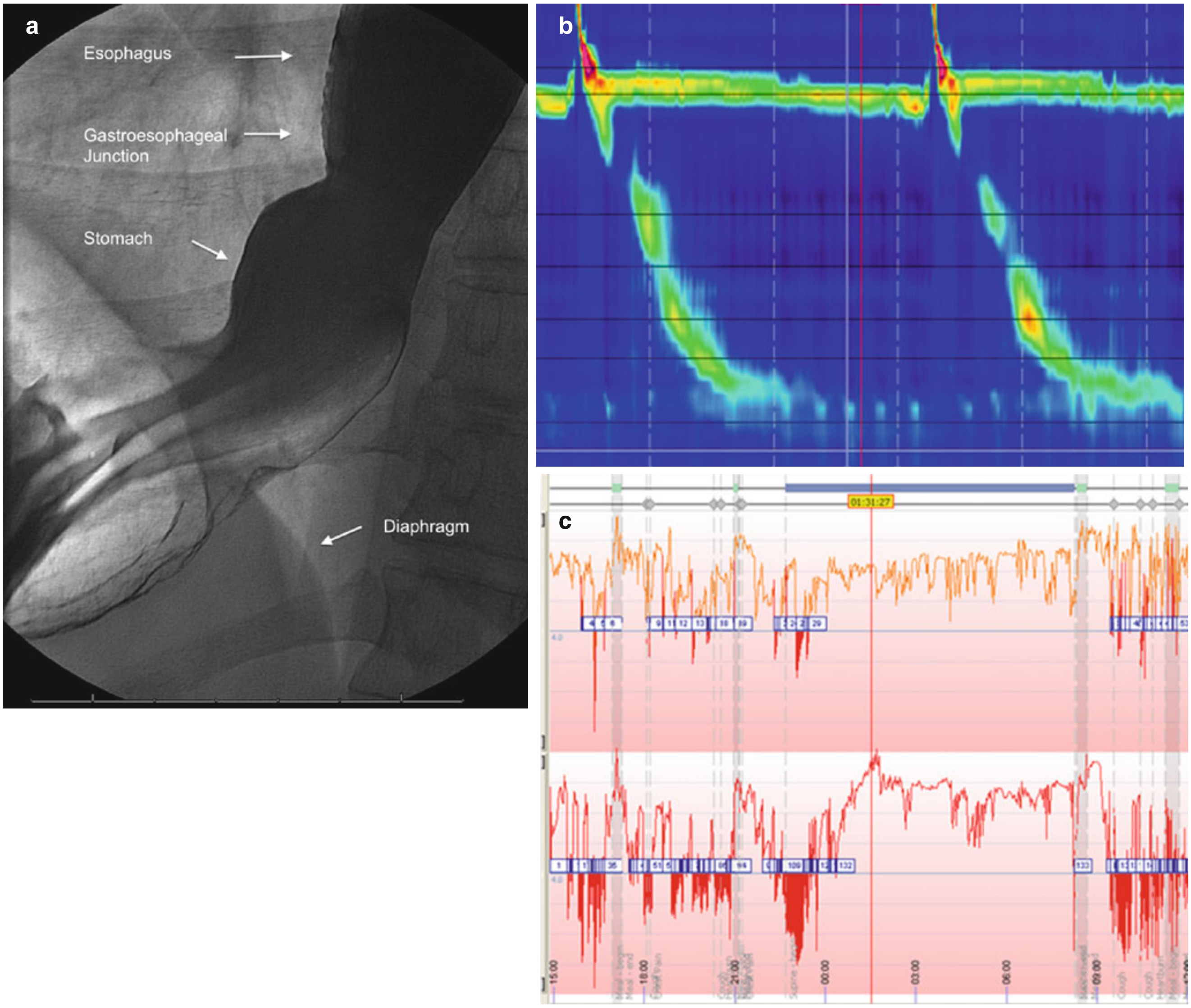

Fig. 6.1 (**a**) Barium swallow shows 3-cm sliding hiatal hernia. (**b**) High-resolution esophageal manometry shows hypotensive lower esophageal sphincter (*LES*) and normal esophageal peristalsis. (**c**) On ambulatory pH monitoring, two sensors show distal and proximal reflux. (**d**) Arrangement of the operating room for laparoscopic total fundoplication

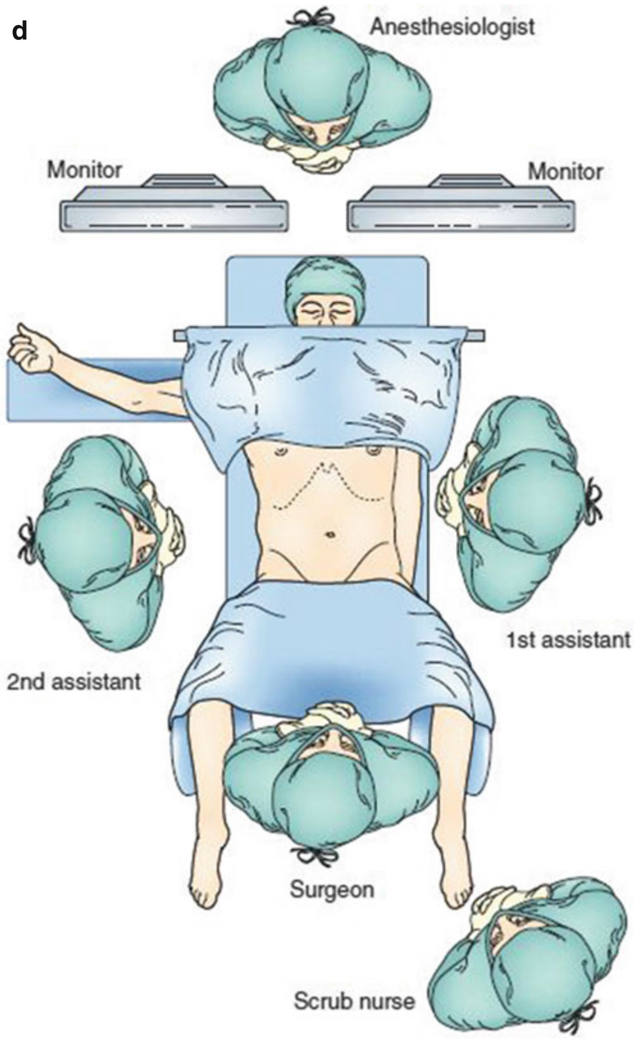

Fig. 6.1 (continued)

6.2 Laparoscopic Total Fundoplication (360°)

6.2.1 Positioning of the Patient and Placement of Trocars

- The patient lies supine on the operating table in low lithotomy position with the lower extremities extended on stirrups with knees flexed 20–30°
- A bean bag is inflated to avoid sliding of the patient as a consequence of the steep reverse Trendelenburg position used during the entire procedure.
- Pneumatic compression stockings are used to reduce the risk of deep venous thrombosis that is associated with both increased abdominal pressure secondary to pneumoperitoneum and the decreased venous return secondary to the steep reverse Trendelenburg position.
- An orogastric tube is placed to decompress the stomach, and it is removed at the end of the procedure.
- The surgeon stands between the patient's legs, while the first and second assistant stand on the right and left sides of the operating table (Fig. 6.1d).
- Trocars are placed in the positions shown in Fig. 6.2, similar to the placement used for antireflux surgery (Chap. 5).

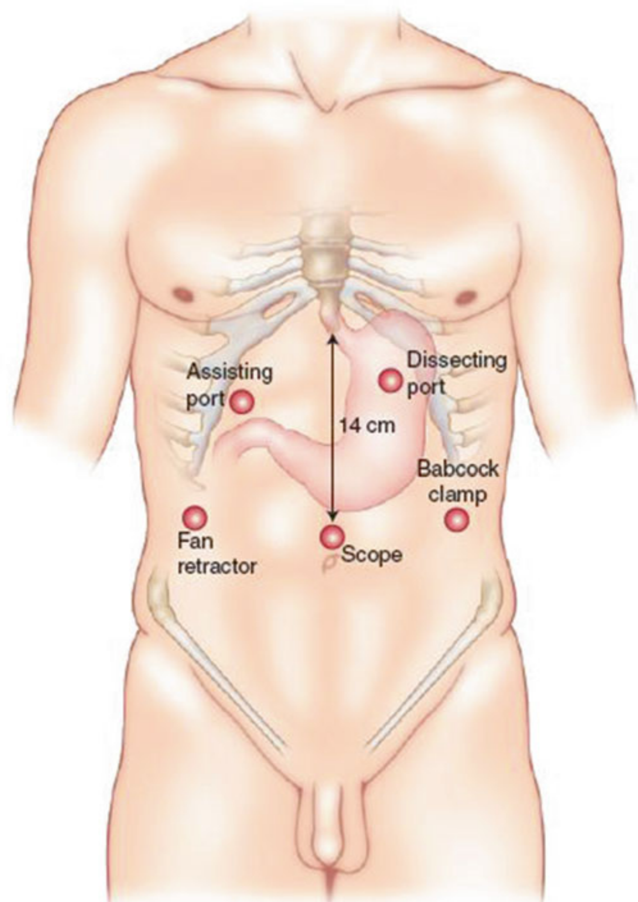

Fig. 6.2 Placement of trocars for laparoscopic fundoplication

6.2.2 Operative Procedure

Step 1 *Division of gastrohepatic ligament; identification of right crus of the diaphragm and posterior vagus nerve* (Figs. 6.3, 6.4, 6.5, 6.6, 6.7, and 6.8)

- The gastrohepatic ligament is divided, beginning above the caudate lobe of the liver, where the ligament is usually very thin, until the right crus of the diaphragm is identified. An accessory left hepatic artery originating from the left gastric artery is frequently present in the gastrohepatic ligament. If it limits the exposure, it may be divided with no clinical consequences.
- The right crus is separated from the right side of the esophagus by blunt dissection, the posterior vagus nerve is identified, and the right crus is dissected inferiorly toward the junction with the left crus. The use of a bipolar instrument allows right crus dissection to be performed more safely than with electrocautery, with a reduced risk of injury to the posterior vagus nerve due to the lateral spread of the electrical current from a monopolar instrument.

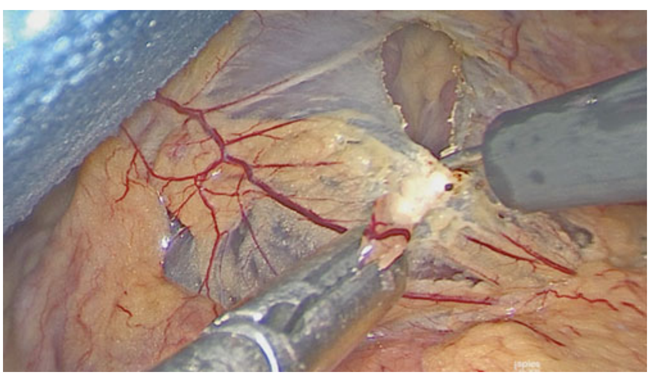

Fig. 6.3 Division of the gastrohepatic ligament

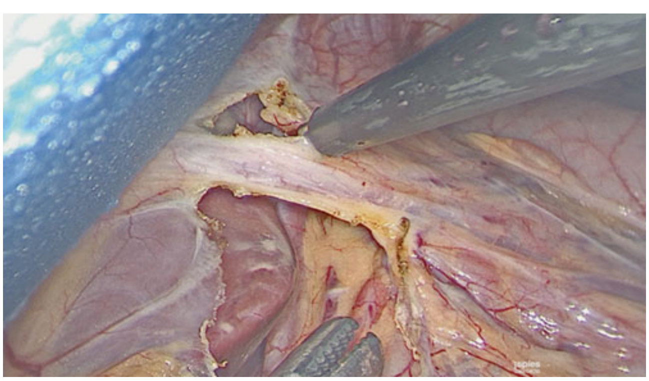

Fig. 6.4 Division of the gastrohepatic ligament

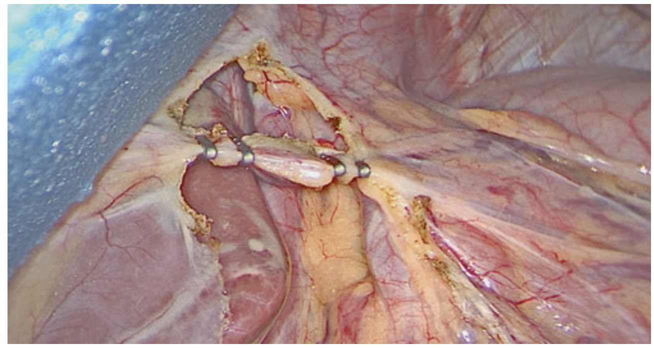

Fig. 6.5 The right crus of the diaphragm is identified

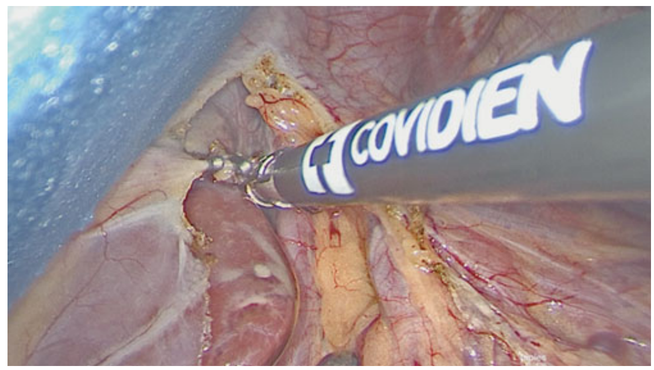

Fig. 6.6 Dissection of the right crus

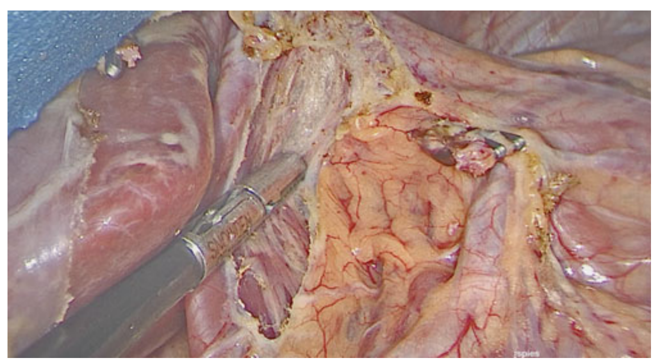

Fig. 6.7 Dissection of the right crus

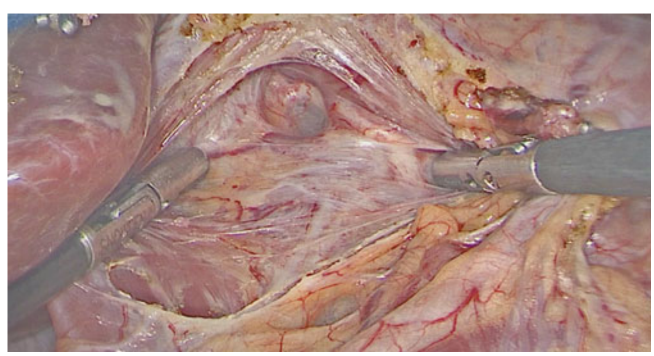

Fig. 6.8 Dissection of the right crus

Step 2 *Division of peritoneum and phrenoesophageal membrane above the esophagus; identification of the left crus of the diaphragm and anterior vagus nerve* (Figs. 6.9 and 6.10)

- The peritoneum and the phrenoesophageal membrane above the esophagus are transected with the electrocautery, with identification of the anterior vagus nerve. To avoid injury to the anterior vagus nerve or the esophageal wall, the nerve should be left attached to the esophageal wall, and the peritoneum and the phrenoesophageal membrane should be lifted from the wall by blunt dissection before they are divided.
- The left crus of the diaphragm is dissected bluntly downward toward the junction with the right crus.

Step 3 *Division of short gastric vessels* (Figs. 6.11 and 6.12)

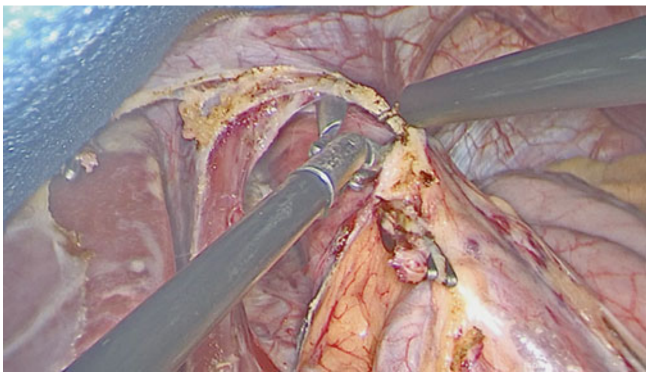

Fig. 6.9 Transection of the peritoneum and the phrenoesophageal membrane above the esophagus

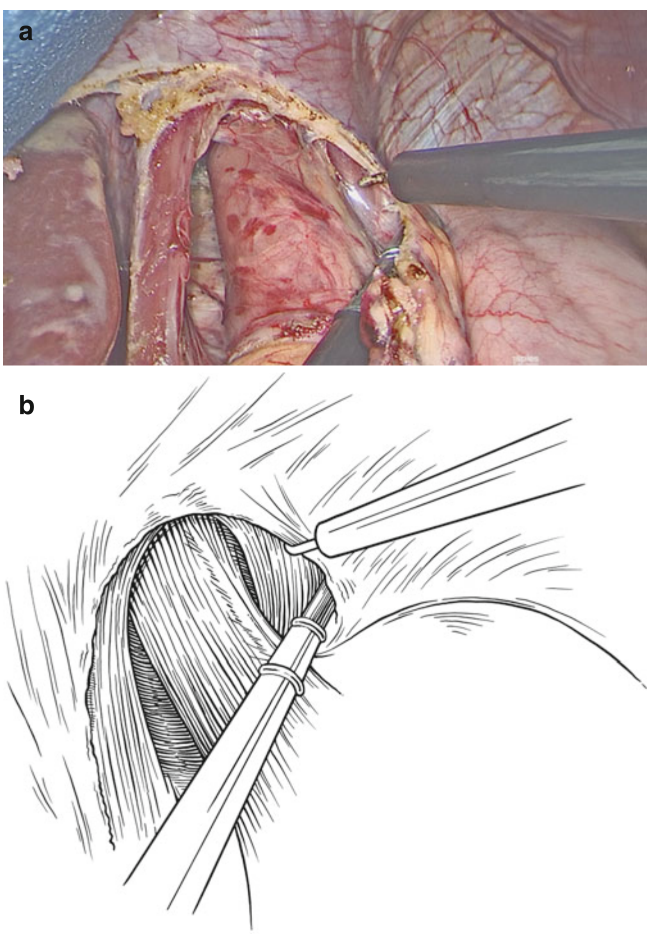

Fig. 6.10 (**a**) and (**b**), Dissection of the left crus of the diaphragm

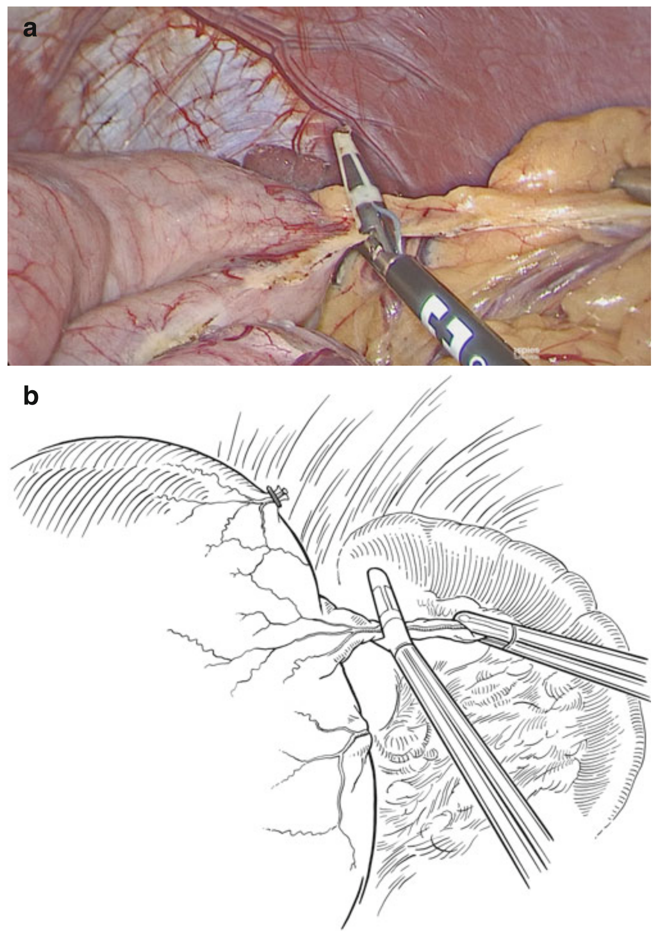

Fig. 6.11 (**a**) and (**b**), Taking down the short gastric vessels

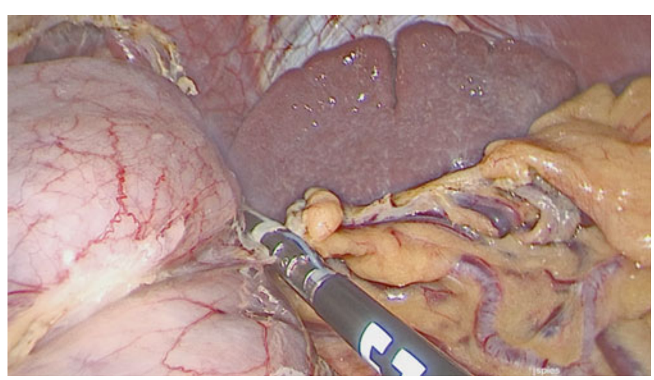

Fig. 6.12 Taking down the short gastric vessels

- The short gastric vessels are taken down all the way to the left pillar of the crus, starting at the level of the middle portion of the gastric body and continuing upward until the most proximal short gastric vessel is divided.

Possible complications during this step of the procedure are bleeding, either from the short gastric vessels or from the spleen, and damage to the gastric wall.

Step 4 *Creation of a window between gastric fundus, esophagus, and diaphragmatic crura; placement of Penrose drain around the esophagus* (Figs. 6.13, 6.14, and 6.15)

A Babcock clamp is applied at the level of the esophagogastric junction and the esophagus is retracted upward.

A window is opened by a blunt and sharp dissection under the esophagus, between the gastric fundus, the esophagus, and the left pillar of the crus.

The window is then enlarged, and a Penrose drain is passed around the esophagus, incorporating both the anterior and the posterior vagus nerves.

The two main complications that can occur during this part of the procedure are creation of a left pneumothorax and perforation of the gastric fundus.

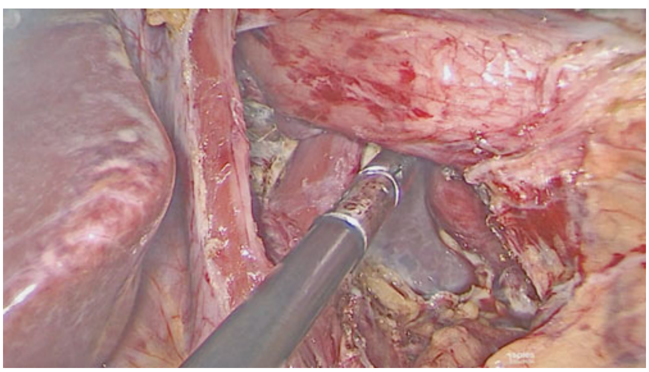

Fig. 6.13 A window is opened under the esophagus, between the gastric fundus, the esophagus, and the left pillar of the crus

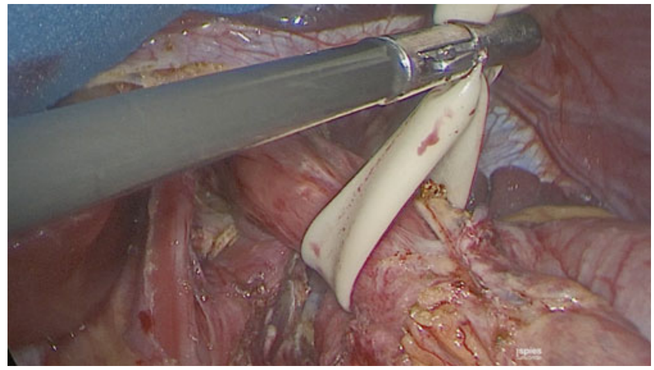

Fig. 6.14 A Penrose drain is passed around the esophagus, incorporating both the anterior and posterior vagus nerves

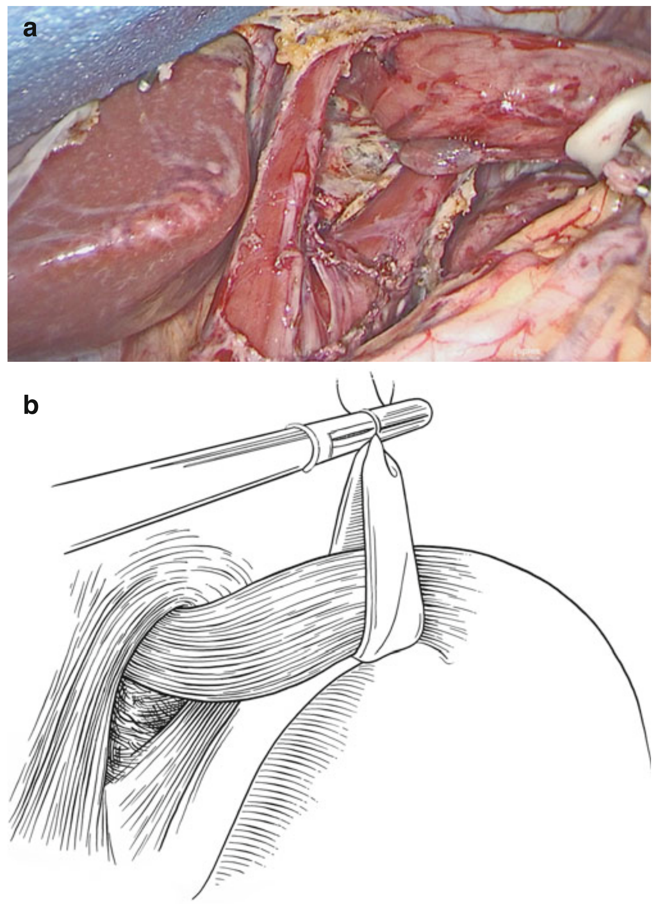

Fig. 6.15 (**a**) and (**b**), A Penrose drain is passed around the esophagus

Step 5 *Approximation of the left and right pillars of the crus* (Figs. 6.16 and 6.17)

- Interrupted 2-0 silk sutures are tied intracorporeally to close the diaphragmatic crura.
- Retraction of the esophagus upward and toward the patient's left with the Penrose drain is essential to provide proper exposure.
- 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.

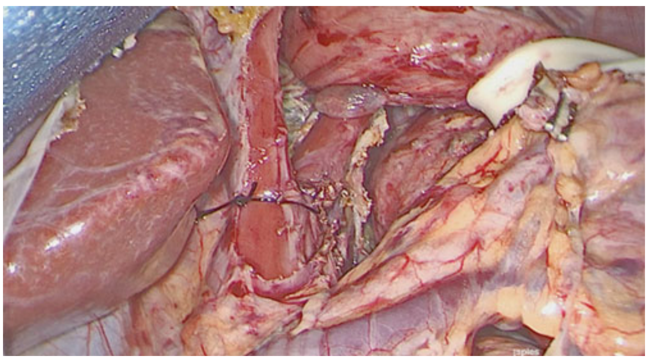

Fig. 6.16 Interrupted silk sutures are used to close the diaphragmatic crura. The first stitch should be placed just above the junction of the two pillars

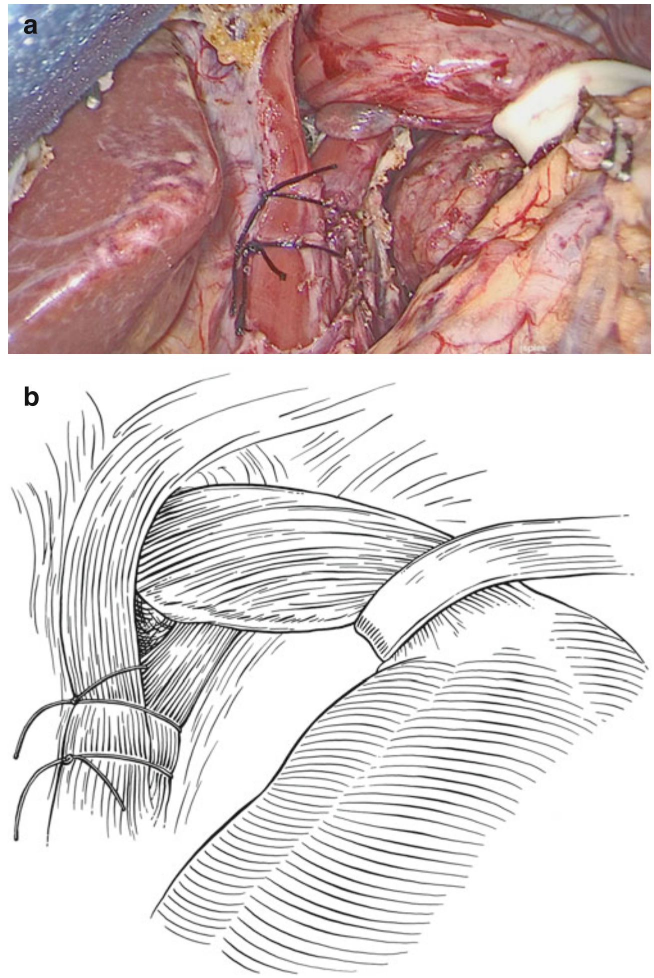

Fig. 6.17 (**a**) and (**b**), Additional stitches are placed 1 cm apart. Retraction of the esophagus with the Penrose drain is essential to provide proper exposure

Step 6 *Insertion of the bougie into esophagus and across the esophageal junction* (Fig. 6.18)

After removal of the orogastric tube, a lubricated 56 French bougie is inserted down the esophagus through the esophagogastric junction by the anesthesiologist. Lubrication of the bougie and slow advancement of the bougie reduce the risk of esophageal perforation.

The crura must be snug around the esophagus but not too tight: a closed grasper should slide easily between the esophagus and the crura.

Step 7 *Wrapping of gastric fundus around the lower esophagus* (Figs. 6.19, 6.20, and 6.21)

- The surgeon gently pulls the gastric fundus under the esophagus with two graspers. The use of atraumatic graspers during this step of the procedure reduces the risk of damage to the gastric wall. Delivering the fundus under the esophagus and checking for the origins of the transected short gastric vessels helps in evaluating whether the wrap will be floppy. If the wrap remains to the right side of the esophagus and does not retract back to the left, then it is floppy, and suturing can be performed. If not, the surgeon must make sure that the upper short gastric vessels have been transected and the posterior dissection has been completed. A "shoeshine maneuver" is performed to be sure that there is no redundant fundus and that no fundus will be left above the completed wrap.
- The left and right sides of the fundus are wrapped above the esophagogastric junction. A Babcock clamp introduced through trocar 2 is used to hold the two flaps together during placement of the first stitch.
- The two edges of the wrap are secured to each other by three 2-0 silk sutures placed 1 cm from each other. The wrap should be no longer than 2–2.5 cm.

The instruments and the trocars are removed from the abdomen under direct vision, and the trocar sites are closed.

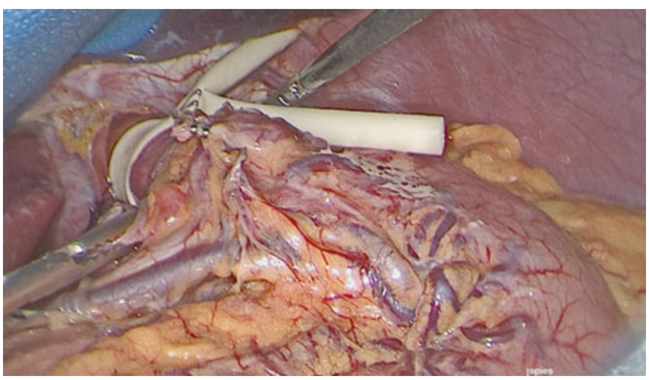

Fig. 6.18 The crura must be snug around the esophagus but not too tight

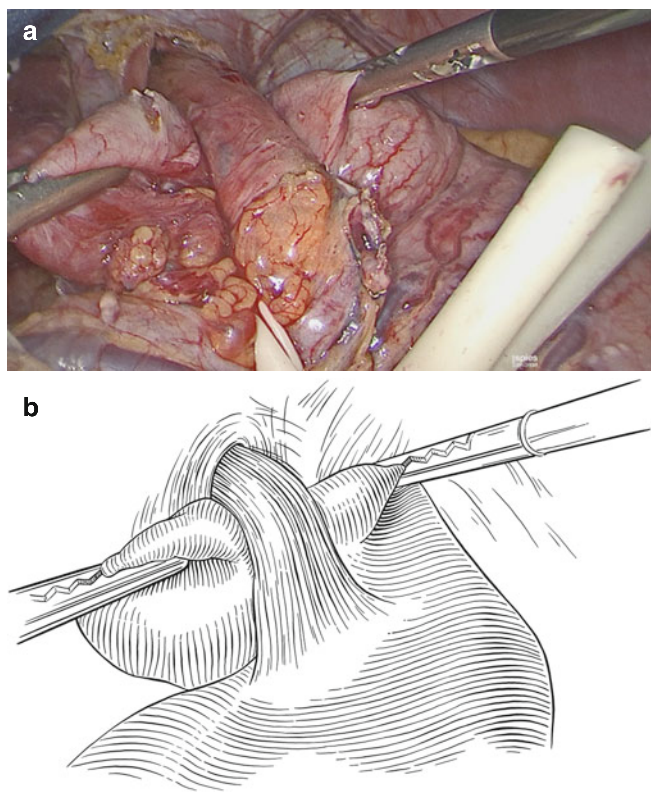

Fig. 6.19 (**a**) and (**b**), The surgeon gently pulls the gastric fundus under the esophagus with two graspers

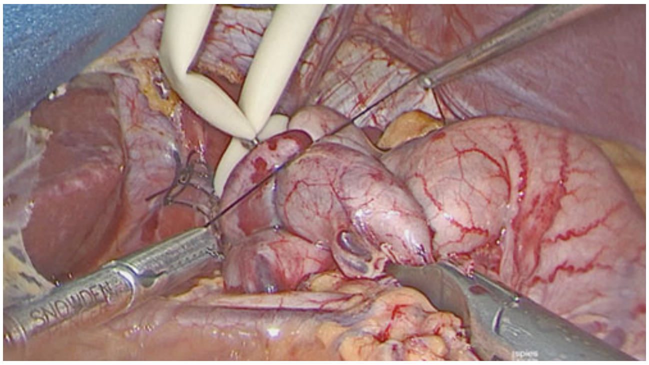

Fig. 6.20 The left and right sides of the fundus are wrapped above the esophagogastric junction. A Babcock clamp is used to hold the two flaps together during placement of the first stitch

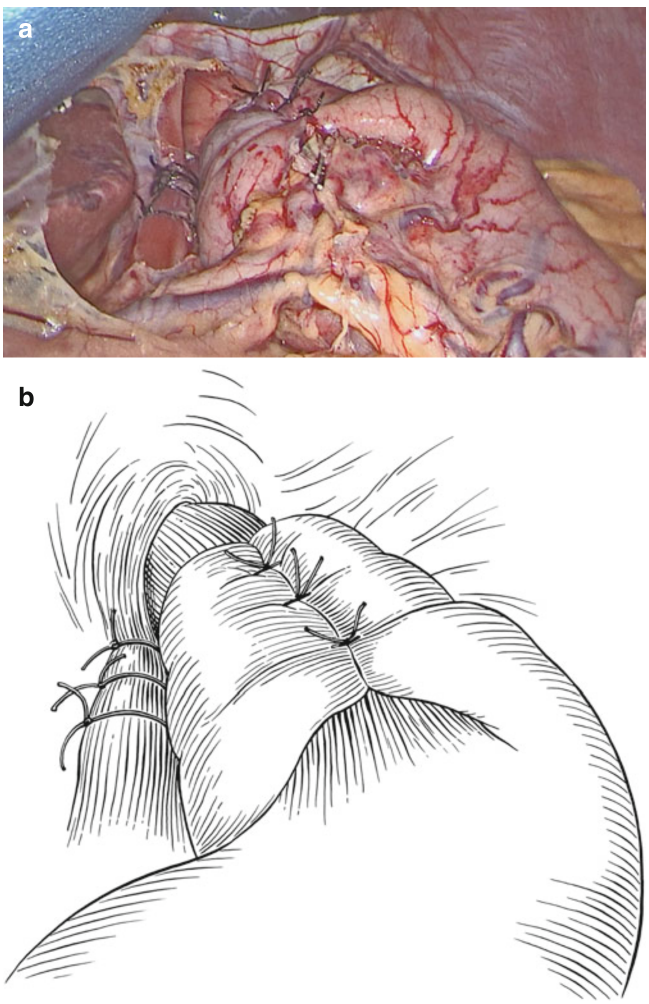

Fig. 6.21 (**a**) and (**b**), The two edges of the wrap are secured to each other by three 2-0 silk sutures placed 1 cm from each other

6.3 Laparoscopic Partial Posterior Fundoplication (220–280°)

The first six steps are identical to those of a laparoscopic total fundoplication.

Step 7 *Partial posterior fundoplication* (Figs. 6.22, 6.23, 6.24, 6.25, 6.26, and 6.27)

The delivered gastric fundus is gently pulled under the esophagus using two graspers.

Three 2-0 silk sutures are placed on each side of the wrap between the muscular layers of the esophageal wall and the gastric fundus, leaving 80–140° of the anterior esophageal wall uncovered. The resulting wrap measures about 220–280°.

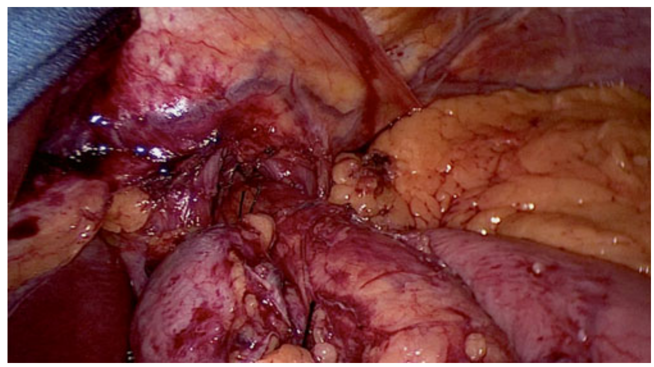

Fig. 6.22 Three 2-0 silk sutures are placed on each side of the wrap between the muscular layers of the esophageal wall and the gastric fundus

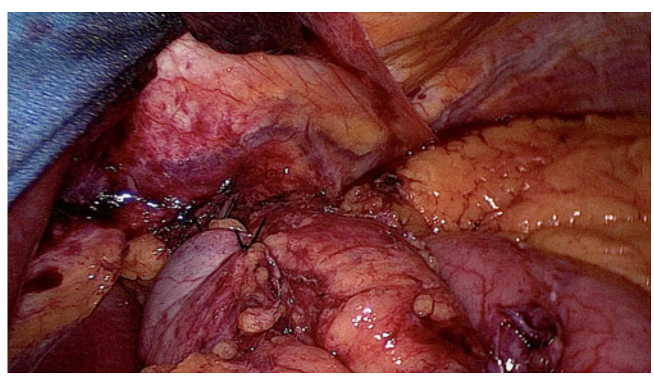

Fig. 6.23 About 80–140° of the anterior esophageal wall is left uncovered

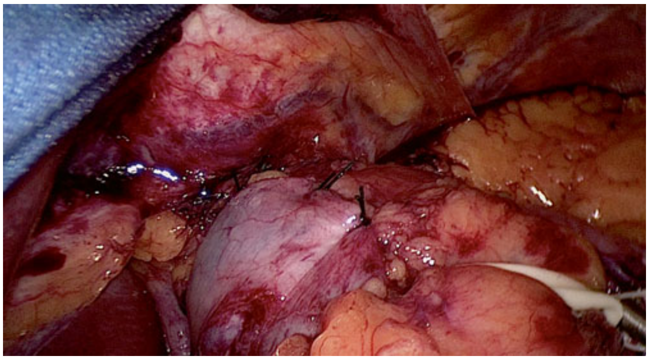

Fig. 6.24 Three 2-0 silk sutures are placed on each side of the wrap between the muscular layers of the esophageal wall and the gastric fundus

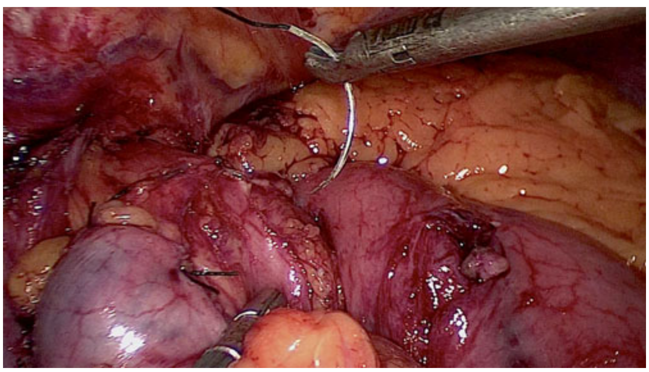

Fig. 6.25 Three 2-0 silk sutures are placed on each side of the wrap between the muscular layers of the esophageal wall and the gastric fundus

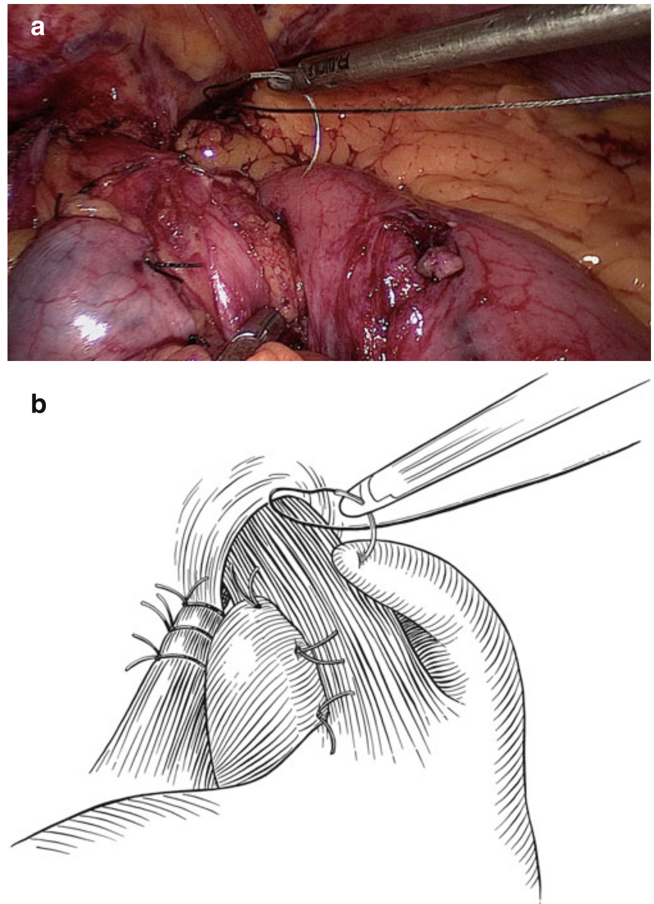

Fig. 6.26 (**a**) and (**b**), Three 2-0 silk sutures are placed on each side of the wrap between the muscular layers of the esophageal wall and the gastric fundus

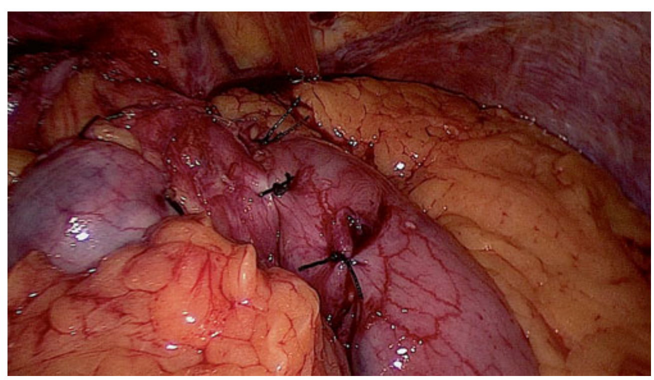

Fig. 6.27 Three 2-0 silk sutures are placed on each side of the wrap between the muscular layers of the esophageal wall and the gastric fundus

6.4 Laparoscopic Partial Anterior Fundoplication (180°)

The first six steps are identical to those of a laparoscopic total fundoplication.

Step 8 *Partial anterior fundoplication* (Fig. 6.28)

Two rows of sutures (2-0 silk) are used. The first row is on the left side of the esophagus, and consists of three stitches. The top stitch incorporates the fundus of the stomach, the left side of the esophageal wall, and the left pillar of the crus. The second and third stitches incorporate the gastric fundus and the muscular layer of the left side of the esophagus.

The fundus is then folded over the esophagus so that the greater curvature of the stomach is next to the right pillar of the crus.

The second row of sutures, on the right side of the esophagus, consists of three stitches between the fundus and the right pillar of the crus.

Finally, two additional stitches are placed between the fundus and the rim of the esophageal hiatus to eliminate any tension from the fundoplication.

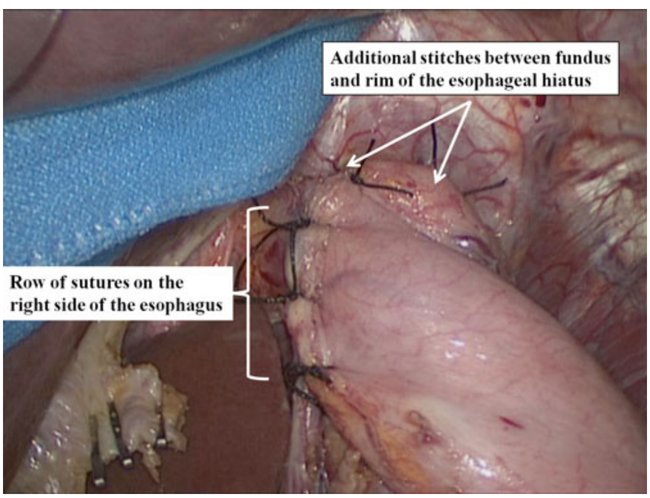

Fig. 6.28 The sutures on the right side of the esophagus consist of three stitches between the fundus and the right pillar of the crus. Two additional stitches are placed between the fundus and the rim of the esophageal hiatus

6.5 Postoperative Course

The patient was extubated in the operating room at the end of the operation. He spent the first night in the intensive care unit for monitoring. The following morning, the supplemental oxygen was discontinued. He had a soft diet for breakfast and lunch, and he was discharged.

During the 12 months after the laparoscopic fundoplication, the patient had complete resolution of the heartburn and the regurgitation. Bronchoscopy showed absence of pepsin in the bronchoalveolar lavage. His pulmonary function tests and his exercise tolerance improved significantly. Esophageal manometry showed that the LES had normal pressure, and ambulatory pH monitoring showed normalization of the reflux profile, with no episodes of reflux in the proximal esophagus.

Acknowledgement Images taken with SPIES system. Courtesy of Storz.

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7 Laparoscopic Pyloroplasty

P. Marco Fisichella and Anahita Jalilvand

7.1 Clinical History

The patient is a 26-year-old woman with cystic fibrosis who began complaining of progressive heartburn and regurgitation soon after her bilateral lung transplantation. Her evaluation included these findings:

- Barium swallow: normal anatomy
- Endoscopy: severe esophagitis, Los Angeles grade C
- Esophageal manometry: normal peristalsis and normal resting pressure and relaxation of the lower esophageal sphincter
- Esophageal pH monitoring: pathologic amount of gastroesophageal reflux, with a DeMeester score of 78 (normal <14.7)
- Gastric emptying scan: severely delayed emptying; only 6 % of the tracer exited the stomach over 4 h

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7.2 Operation

7.2.1 Preoperative Evaluation

All patients who are potential candidates for laparoscopic surgical correction of gastroesophageal reflux disease (GERD) undergo a preoperative assessment that includes a symptomatic evaluation, a barium swallow, an upper endoscopy, and a gastric emptying nuclear scan, when indicated. Because gastroparesis has been shown to be implicated in the pathogenesis of GERD and is associated with aspiration and allograft compromise, we prefer to perform a pyloroplasty at the time of laparoscopic antireflux surgery in the lung transplant patient with objectively identified GERD and symptomatic, severe gastric atony (which we define as <10 % of radiolabeled gastric contents emptied into the small bowel within 90 min) and failure to respond to prokinetic agents.

7.2.2 Operative Planning

Before induction, the patient is positioned with a beanbag on the operative table. Pneumatic compression stockings are always used as prophylaxis against deep vein thrombosis. Preoperative antibiotics are administered prior to skin incisions. A Foley catheter is usually inserted. When a laparoscopic pyloroplasty is planned, the patient is asked to maintain a liquid diet for the preceding 2–3 days. Even if the patient has electively fasted for more than 8 h prior to the procedure, a totally empty state can never be guaranteed, especially in those with gastric atony. Therefore, the anesthesiologist performs a rapid sequence intubation technique to quickly secure the airway. Further measures are also employed to diminish gastric volume and increase the pH of gastric fluid. After intubation, the beanbag is inflated and the lower extremities are placed in stirrups, and the surgeon stands between them. The abdomen is then prepped and draped and the patient is positioned in steep reverse Trendelenburg.

7.2.3 Port Placement

Figure 7.1 shows the position of the operative ports in order of placement when performing a laparoscopic Nissen fundoplication: (1) optical port, 14 cm below the xiphoid process; (2) left working port, below the left costal margin in the midclavicular line; (3) epigastric port for the Nathanson retractor; (4) right working port, below the right costal margin in the midclavicular line; (5) assisting port, on the left anterior axillary line at the level of the optical port. Figure 7.2 shows the port placement and rearrangement for a pyloroplasty. Port 6 is placed at the right midclavicular line at the level of the transverse umbilical line. This port holds an 11-mm optical trocar. Port 1 is then converted to a working port. Finally, a 5-mm working port (Port 7) is placed at the right anterior axillary line, triangulating with Port 1 for combined manipulation of the suturing instruments. Special attention must be given to proper port placement, because if the ports are placed too high, the angle of suturing becomes too wide and suturing becomes difficult.

7.2.4 Pyloroplasty Procedure

Once the pylorus is identified, electrocautery is employed to score the anterior surface of the pylorus and the first portion of the duodenum (Fig. 7.3). The pylorus is then entered and a 5-cm longitudinal enterotomy is carried distally in the duodenum and proximally in the antrum with the hook cautery or Ligasure™ (Fig. 7.3). Anchoring sutures are placed at the top and bottom of the enterotomy with interrupted 2-0 silk stitches with a V-20 needle and intracorporeally. To prevent incorporation of the posterior wall of the pylorus during closure, a rolled piece of Gelfoam (created by placing 2-0 silk ties at both ends) is introduced into the lumen of the pylorus (Fig. 7.4) and left in place to later dissolve. The longitudinal enterotomy is then closed transversely in a single layer over the Gelfoam roll with interrupted 2-0 silk sutures, which are placed a few millimeters apart, starting from the ends and progressing towards the middle (Fig. 7.5). These sutures are tied intracorporeally (Fig. 7.6). A Maryland dissector is then used to assess for gaps between the sutures, and simple 2-0 silk stitches are placed where appropriate. Finally, two metallic clips are placed on the top and the bottom of the pyloroplasty to help in locating the pyloroplasty on a subsequent barium swallow.

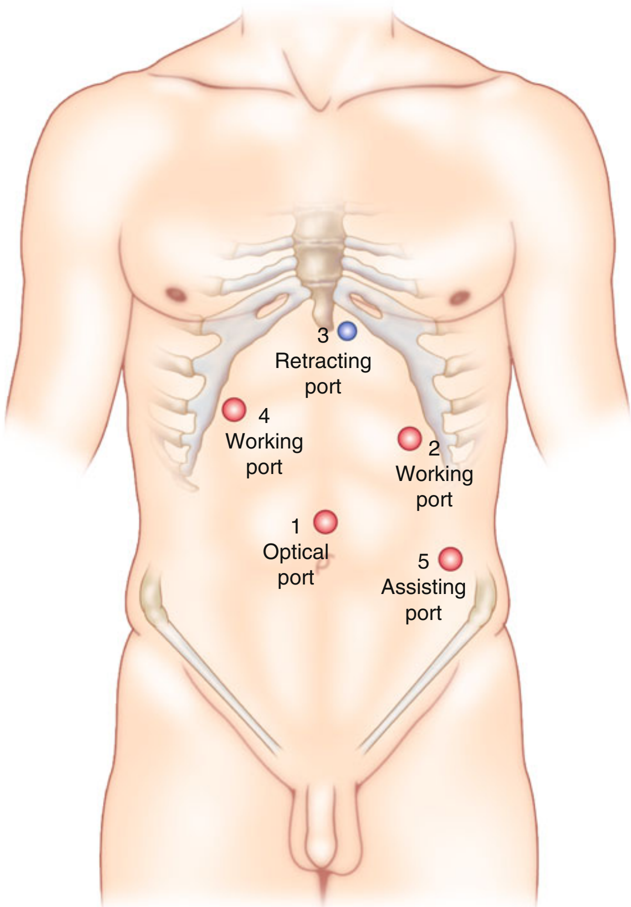

Fig. 7.1 Operative ports in order of placement for a laparoscopic Nissen fundoplication

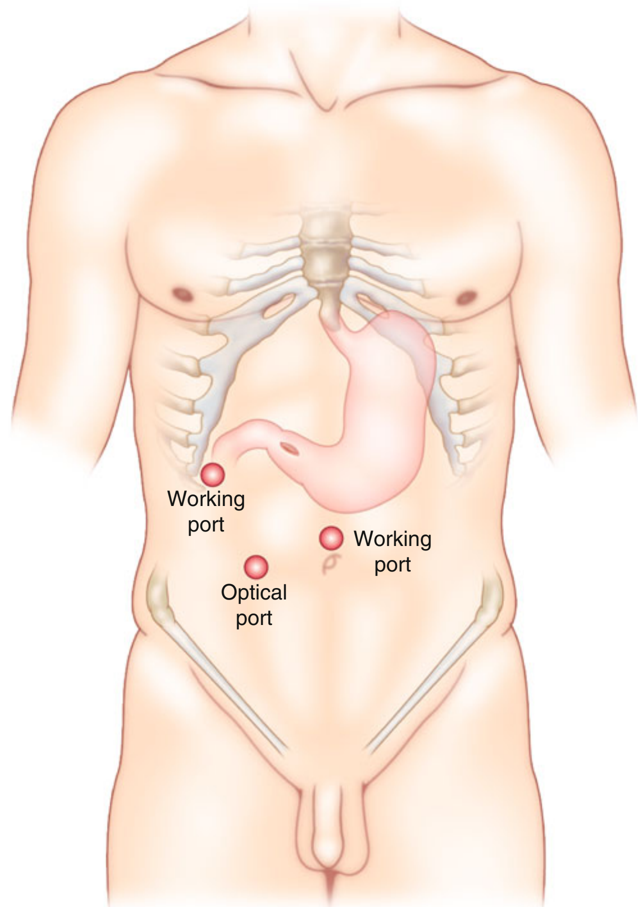

Fig. 7.2 Port placement and rearrangement for a pyloroplasty

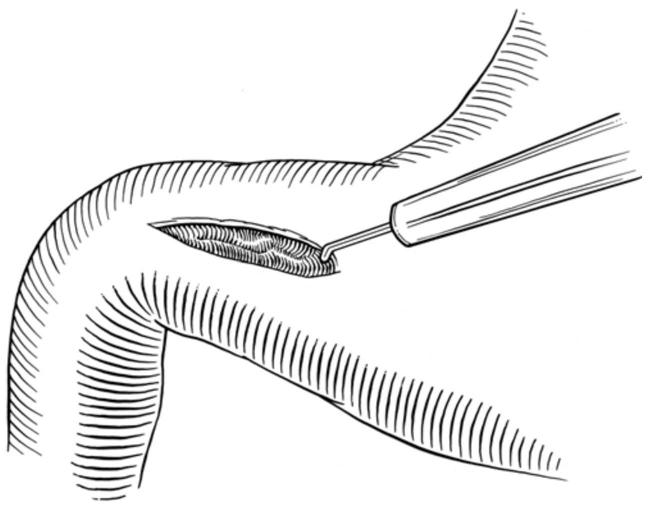

Fig. 7.3 The pylorus is entered and a 5-cm longitudinal enterotomy is carried distally in the duodenum and proximally in the antrum

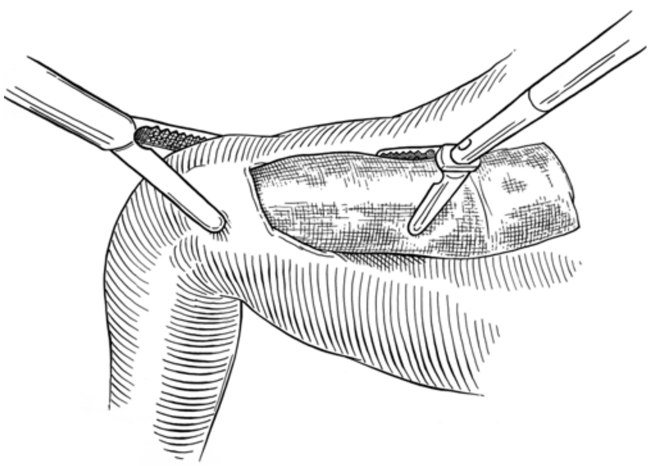

Fig. 7.4 A rolled piece of Gelfoam is introduced into the lumen of the pylorus to prevent incorporation of the posterior wall of the pylorus during closure

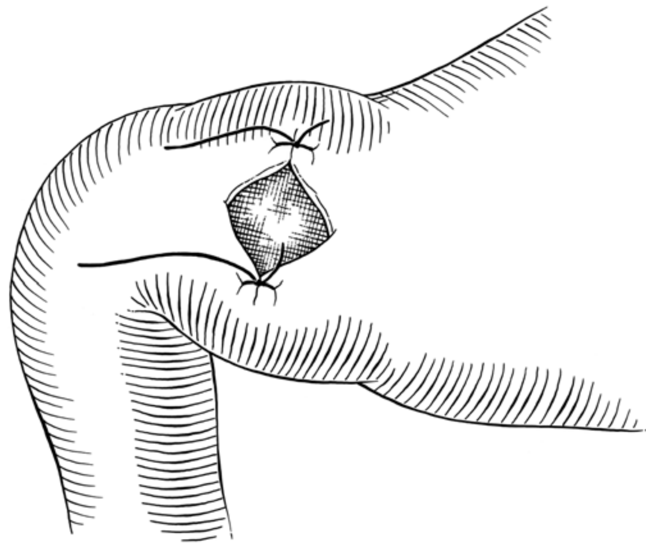

Fig. 7.5 The enterotomy is closed transversely with interrupted 2-0 silk sutures, starting from the ends and progressing towards the middle

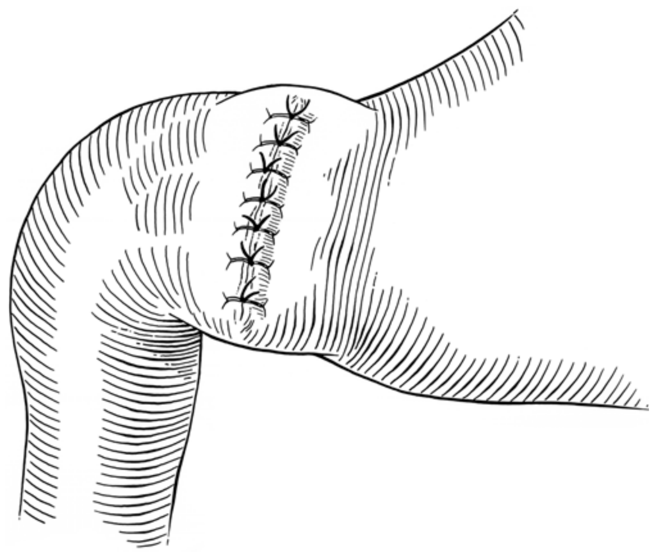

Fig. 7.6 The sutures are placed a few millimeters apart and are tied intracorporeally

7.3 Postoperative Care

A barium swallow is performed on postoperative day 1 to rule out a gastric leak. All patients are then started on a soft mechanical diet the morning of postoperative day 1 and are asked to keep this dietary regimen for the first 2 weeks postoperatively. Patients can then advance to more solid foods as tolerated.

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8 Paraesophageal Hernia Repair and Collis Gastroplasty

Jennifer Jolley, Tammy Kindel, and Dmitry Oleynikov

8.1 Laparoscopic Paraesophageal Hernia Repair

8.1.1 Case Presentation

The patient is a 52-year-old woman who presented to clinic with a history of melena and anemia secondary to a bleeding Cameron's ulcer. At an outside hospital, she had been previously found to have a hemoglobin of 3 g/dL and was admitted for resuscitation. A large hiatal hernia with an associated Cameron's ulcer was found on upper endoscopy. She reported associated dizziness with walking, epigastric fullness, and reflux. She had no significant past surgical history but did have a longstanding smoking history. She had been prescribed a proton pump inhibitor; in order to better control her symptoms and prevent progression of her disease, its frequency was increased to twice daily, Carafate was added, and smoking cessation was strongly encouraged. Further evaluation of her hiatal hernia and ulcer produced the following findings:

- Barium swallow: a large hiatal hernia and associated reflux
- Repeat upper endoscopy: a 5-cm hiatal hernia and healing of the Cameron's ulcer with no evidence of bleeding (Figs. 8.1 and 8.2)
- Esophageal manometry: preserved peristalsis of the esophageal body and normal lower esophageal pressure profile and relaxation

After completion of these studies, the patient was evaluated preoperatively for other comorbidities and consented for laparoscopic paraesophageal hernia repair with mesh and creation of a Nissen fundoplication.

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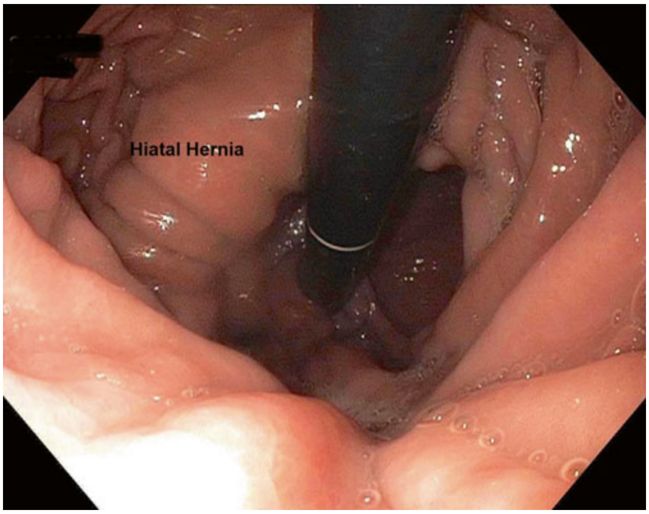

Fig. 8.1 Hiatal hernia viewed on upper endoscopy

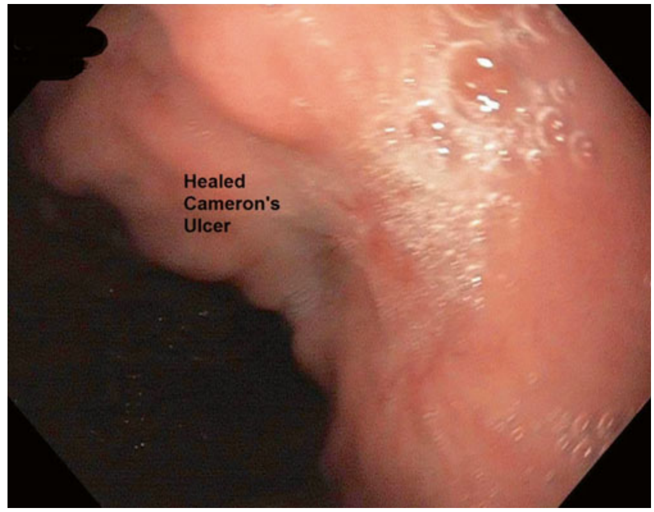

Fig. 8.2 Healed Cameron's ulcer on upper endoscopy

8.1.2 Operation

8.1.2.1 Patient Positioning

Place the patient in a supine position with both arms tucked and padded. A Foley catheter is necessary for measurement of intraoperative urine output. A footboard and a waist belt strap are used to accommodate steep reverse Trendelenburg positioning. Prior to the beginning of the operation, antibiotics and chemical and mechanical venous thromboembolism prophylaxis are given, and an orogastric tube is inserted for stomach decompression.

8.1.2.2 Port Placement

The ports are placed with the purpose of having proper triangulation of the patient's esophageal hiatus, keeping in mind that the hiatus is located slightly to the patient's left and tends to be much more cephalad after pneumoperitoneum insufflation. We enter the abdomen with a Veress needle in the left upper quadrant (LUQ), and then proceed by placing an 11-mm visualization trocar between the xiphoid and the umbilicus. Three more working ports are placed as shown in Fig. 8.3 (two 11-mm trocars in the left upper quadrant and a 5-mm trocar in the right upper quadrant). A Nathanson liver retractor is inserted in the epigastrium.

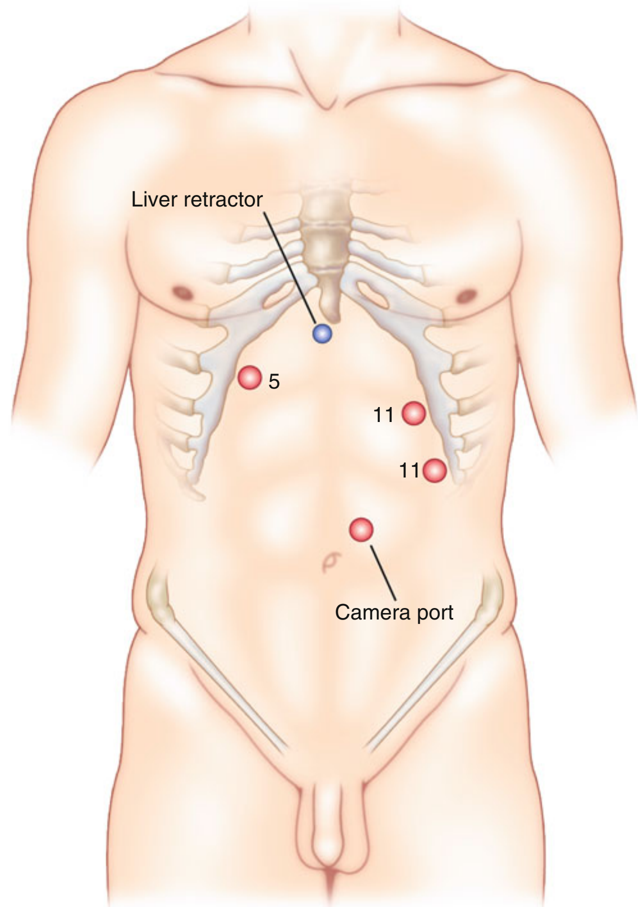

Fig. 8.3 Port placement for laparoscopic paraesophageal hernia repair

8.1.2.3 Operative Procedure

Step 1 *Reduce the hernia sac*

Place the patient in steep reverse Trendelenburg and right-side-down positioning and start pulling the contents of the hernia sac out of the mediastinum (Fig. 8.4a). We use the bipolar energy device to divide the short gastric vessels, just starting at the inferior margin of the spleen. Then continue to dissect out the left crus at the angle of His and enter the avascular plane in the mediastinum just anterior to the aorta (Fig. 8.4b). As the dissection is continued anteriorly, it is important to identify the left pleura and the anterior vagus nerve (Fig. 8.4c). Once the medial edge of the right crus is identified, we then move our dissection to that side in order to begin dividing the gastrohepatic ligament and further identify the right crus. We identify the posterior vagus nerve and then make our retroesophageal window in order to insert a Penrose drain for better retraction on the esophagus and stomach for the mediastinal dissection.

Step 2 *Obtain 3 cm of intra-abdominal esophagus through extensive mediastinal dissection*

Remove the orogastric tube and continue to retract the esophagus and the stomach with the Penrose drain at the gastroesophageal junction (GEJ). We use hook electrocautery to dissect higher in the mediastinum, to avoid bleeding from the vascular attachments to the esophagus (Fig. 8.5).

Step 3 *Create a tension-free posterior cruroplasty*

Once we have achieved enough esophageal length to have at least 3 cm of intra-abdominal esophagus, we then proceed to place our interrupted sutures to plicate the crura posterior to the esophagus (Fig. 8.6a). We place these sutures approximately every 5–8 mm until we have closed the crura, leaving only enough space for an instrument. We then use an absorbable mesh to reinforce this cruroplasty, placing it securely to the crura as an overlay in a U-shaped fashion (Fig. 8.6b).

Step 4 *Create an antireflux fundoplication*

An antireflux fundoplication is then created, using either a complete or partial wrap. The choice between creating a Nissen or a Toupet fundoplication is made before going to the operating room, based on the results of the preoperative esophageal manometry study. Patients with poor motility are given a Toupet fundoplication in order to limit potential postoperative dysphagia (Fig. 8.7). In this patient, with preserved peristalsis, a Nissen fundoplication was performed. We located the GEJ and then found a location to grasp on the greater curvature of the stomach approximately 3 cm distal and posterior to the GEJ. This location was marked with a clip, which is then used to help guide the “shoeshine” maneuver and create a floppy, symmetrical wrap. The Nissen fundoplication is completed by connecting the opposing sides of the stomach with two interrupted sutures about 2 cm apart. (The sides of the stomach are connected to the esophagus in a Toupet fundoplication.) The wrap is then further secured to the hiatus at both crura on either side of the esophagus.

Step 5 *Perform completion endoscopy*

We perform an endoscopy at the end of each operation in order to directly confirm that we have completed a symmetric wrap and have an easy entry at the GEJ (Fig. 8.8).

8.1.3 Postoperative Course

The patient is given a clear liquid diet after the operation and is advanced to a mechanical soft diet the next day. We do not feel that an upper GI series is indicated, and patients are usually discharged home on postoperative day 1. They maintain their soft diet for 2 weeks until their follow-up clinic visit, and their diet is advanced appropriately at that time. Patients are always seen again for follow-up at 6 months and 12 months after their operation.

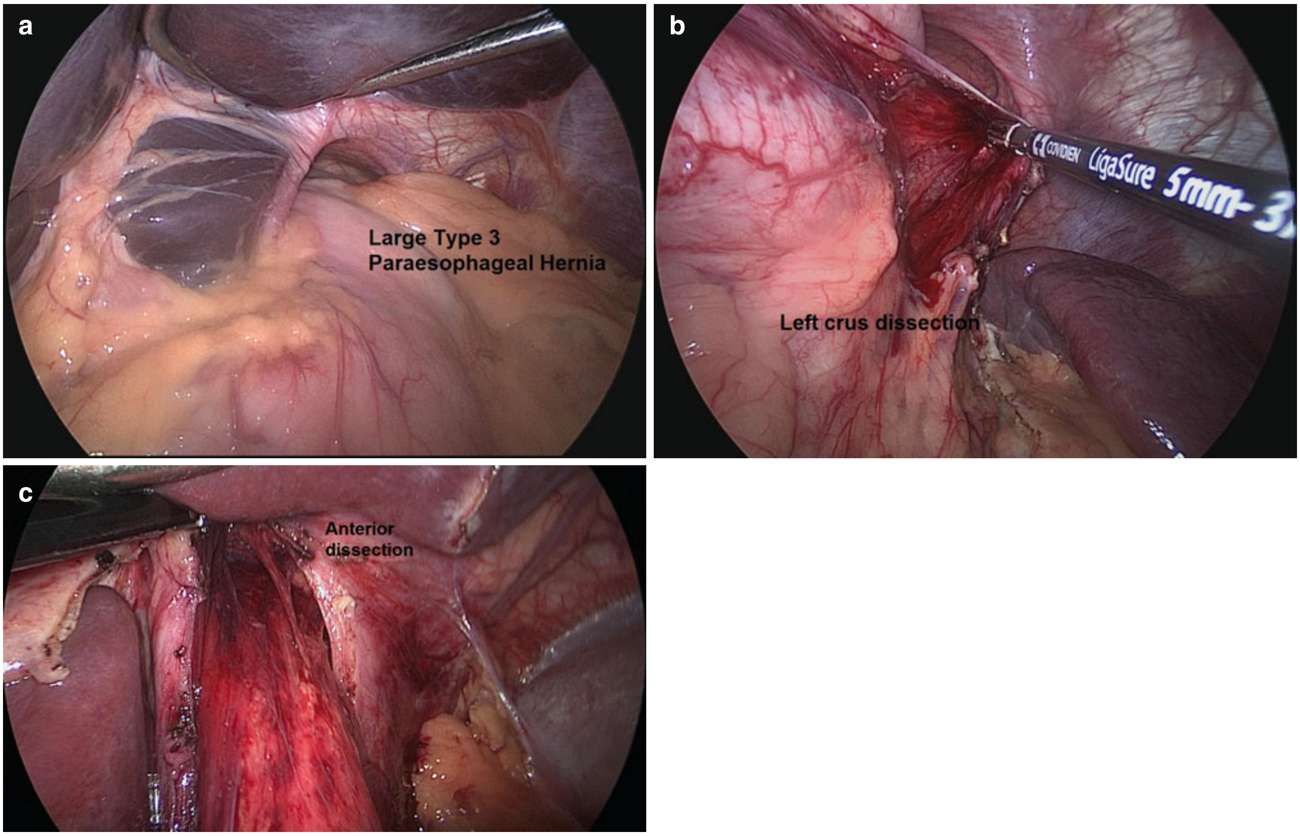

Fig. 8.4 (**a**) Pulling the contents of the hernia sac out of the mediastinum. (**b**) Dissection of the left crus. (**c**) Continuing anterior dissection, identifying the left pleura and the anterior vagus nerve

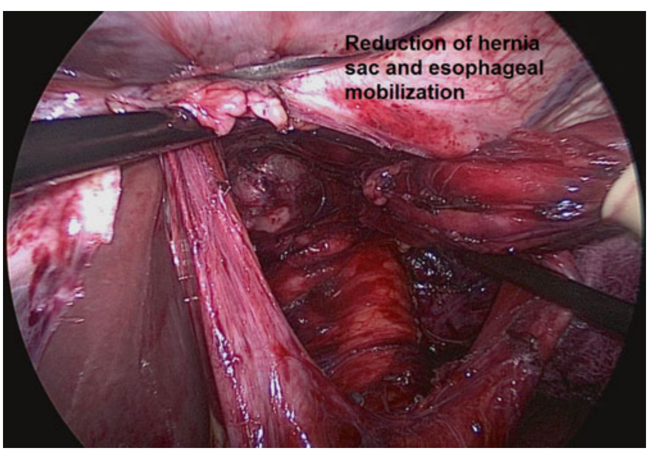

Fig. 8.5 Esophageal mobilization

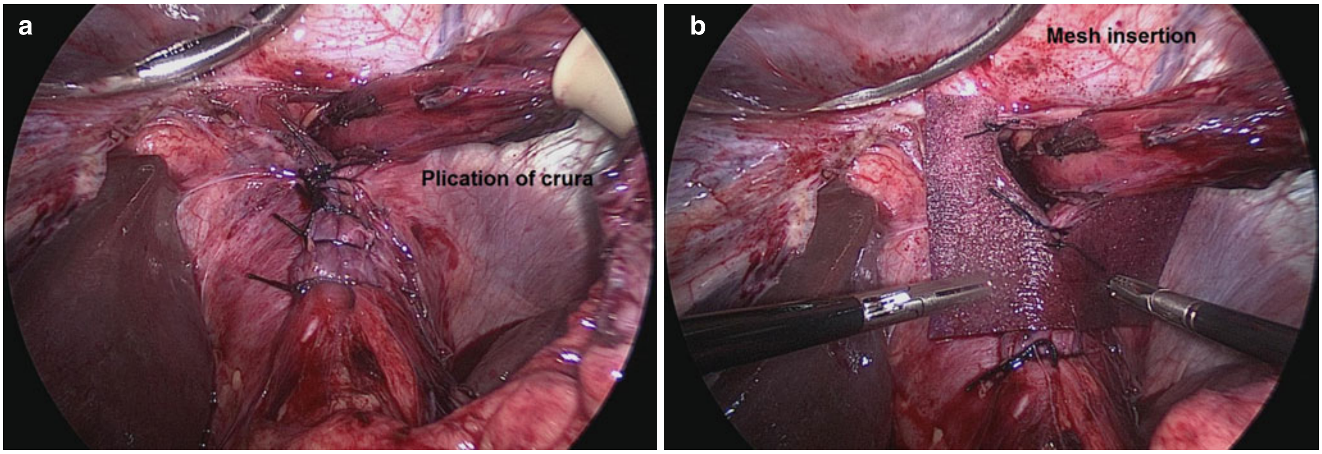

Fig. 8.6 (**a**) Plication of the crura posterior to the esophagus. (**b**) Insertion of absorbable mesh to reinforce cruroplasty

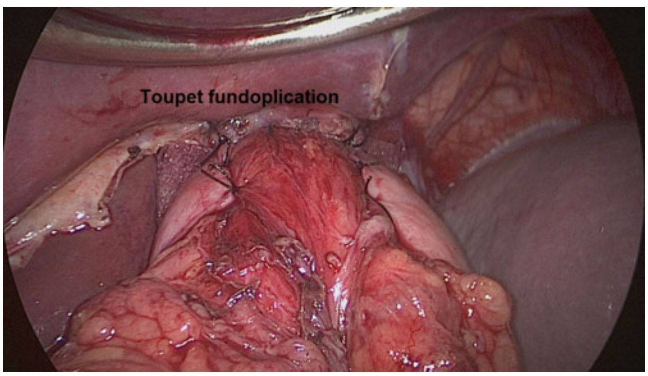

Fig. 8.7 Toupet fundoplication to limit postoperative dysphagia in patients with poor esophageal motility

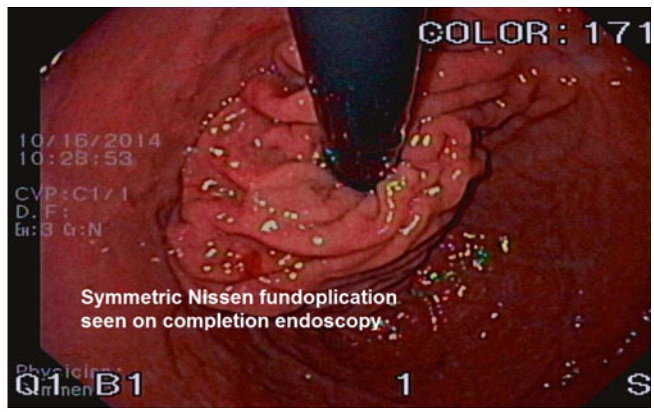

Fig. 8.8 Completion endoscopy confirming symmetric Nissen fundoplication

8.2 Collis Gastroplasty

8.2.1 Case Presentation

The patient is a 70-year-old woman with a past medical history of worsening symptoms of heartburn, regurgitation, and dysphagia for the past month. She has a past surgical history of a laparoscopic hiatal hernia repair with nonabsorbable mesh and Nissen fundoplication. Given her prior surgical history with recurrent symptoms of gastroesophageal reflux disease, a workup of recurrent hiatal hernia was performed:

- Barium swallow: large hiatal hernia with mild to moderate narrowing of the proximal stomach at the diaphragmatic hiatus and a dilated distal esophagus (Fig. 8.9)
- Endoscopy: Los Angeles grade C esophagitis, with Z line at 29 cm. A 6-cm hiatal hernia with no evidence of an intact fundoplication (Fig. 8.10).
- Esophageal manometry: hypotensive lower esophageal sphincter and ineffective esophageal motility; 40 % of swallows were peristaltic, with decreased amplitudes

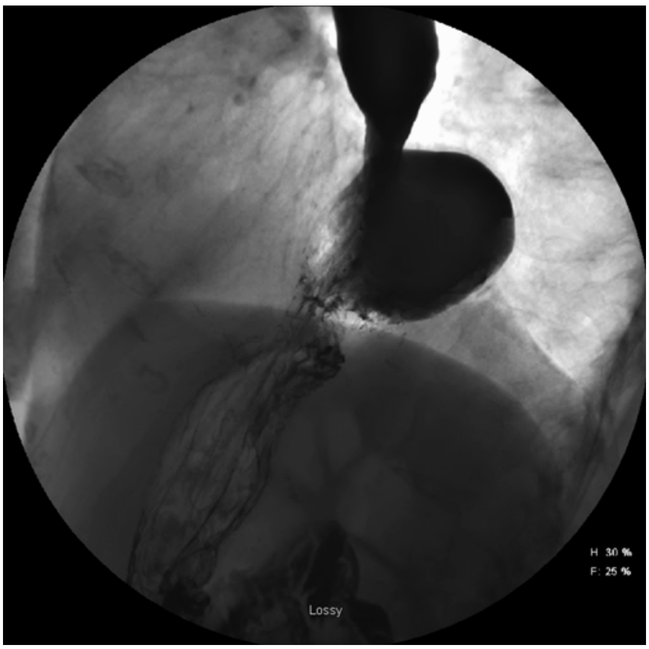

Fig. 8.9 Dilated distal esophagus with large hiatal hernia on barium swallow

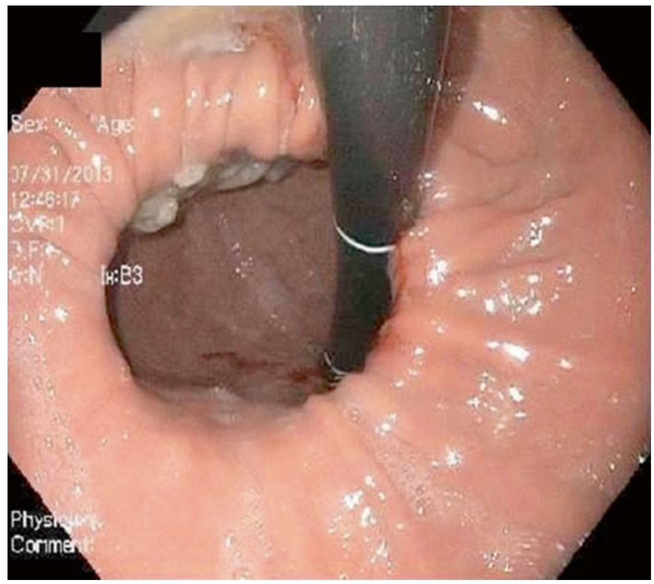

Fig. 8.10 Endoscopy showing esophagitis and hiatal hernia

8.2.2 Operation

The initial dissection is completed as described for laparoscopic paraesophageal hernia repair. With extensive mediastinal dissection, adequate intra-abdominal esophageal length can generally be obtained. Even in patients with a large hiatal hernia (>5 cm), prior hiatal surgery, an esophageal stricture, or Barrett's esophagus, adequate intra-abdominal esophageal length can generally be obtained with a full mediastinal dissection. If it is not possible to obtain at least 2.5 cm of tension-free intra-abdominal esophagus, however, a Collis gastroplasty should be performed. The description here is of a laparoscopic "wedge" Collis gastroplasty.

Step 1 *Mobilize the esophagus*

Following circumferential dissection of the esophagus, a Penrose drain is placed around the esophagus at the gastroesophageal junction to aid in identification of the hiatus in relation to the GEJ and for retraction of the GEJ during the lengthening procedure (Fig. 8.11). The epiphrenic fat pad or hernia sac often obscures the location of the GEJ. This is dissected off the stomach, being careful to avoid injuring the anterior vagus nerve. An intraoperative endoscopy can also be helpful in identifying the exact location of the GEJ.

Step 2 *Place horizontal staple line*

Once the decision is made to proceed with a lengthening procedure, a 48 F bougie is placed under direct visualization past the GEJ into the stomach. The greater curve of the stomach is retracted laterally. A 4.5-mm articulating endostapler is placed through the left lateral 12-mm trocar and positioned perpendicular to the greater curve at a distance to give 2.5 cm of intra-abdominal neo-esophageal length. The stapler is closed and fired up to the bougie marking the inferior aspect of the neo-esophagus (Fig. 8.12).

Step 3 *Place vertical staple line*

The stapler is articulated towards the hiatus to create the neo-esophagus, following the bougie (Fig. 8.13a–d). Several staple loads may be required. Care should be taken during the last firing to avoid stapling directly on the GEJ, to reduce the risk of stricture and postoperative perforation. Figure 8.13e illustrates a Collis gastroplasty after the "V" wedge has been stapled out.

Step 4 *Test the staple line seal*

The staple line seal is tested with intraoperative endoscopy and a leak test.

Step 5 *Perform fundoplication*

The completed staple line of the neo-esophagus should lie towards the patient's left. Regardless whether a partial or complete fundoplication is used (based on the preoperative manometric findings), the fundoplication should cover the neo-esophageal staple line (Fig. 8.14). After fundoplication, the horizontal staple line of the stomach should be located posterior to the neo-esophagus if oriented correctly.

8.2.3 Postoperative Course

The patient had an uneventful postoperative course. An upper GI series on postoperative day 1 was negative for a leak. At that point, a liquid diet was started. Her diet was advanced from pureed to solid food by 2 weeks postoperatively, and she experienced significant long-term improvement in her symptoms of heartburn and dysphagia. An upper GI exam at 1 year showed no recurrent hiatal hernia and an intact Toupet fundoplication (Fig. 8.15).

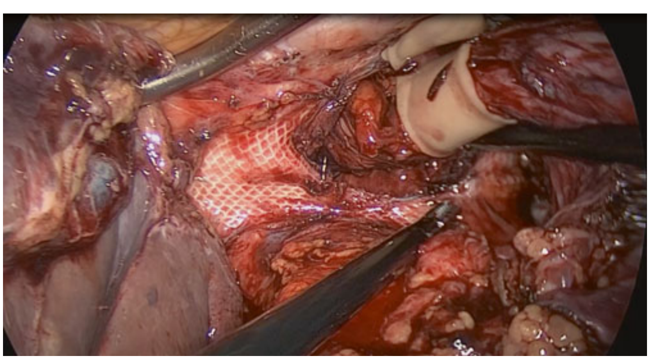

Fig. 8.11 Mobilization of the esophagus

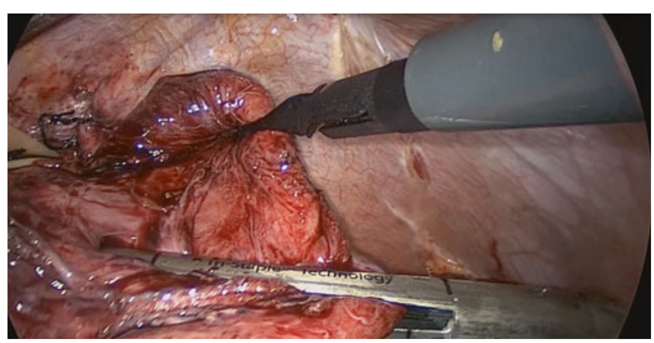

Fig. 8.12 Placement of horizontal staple line

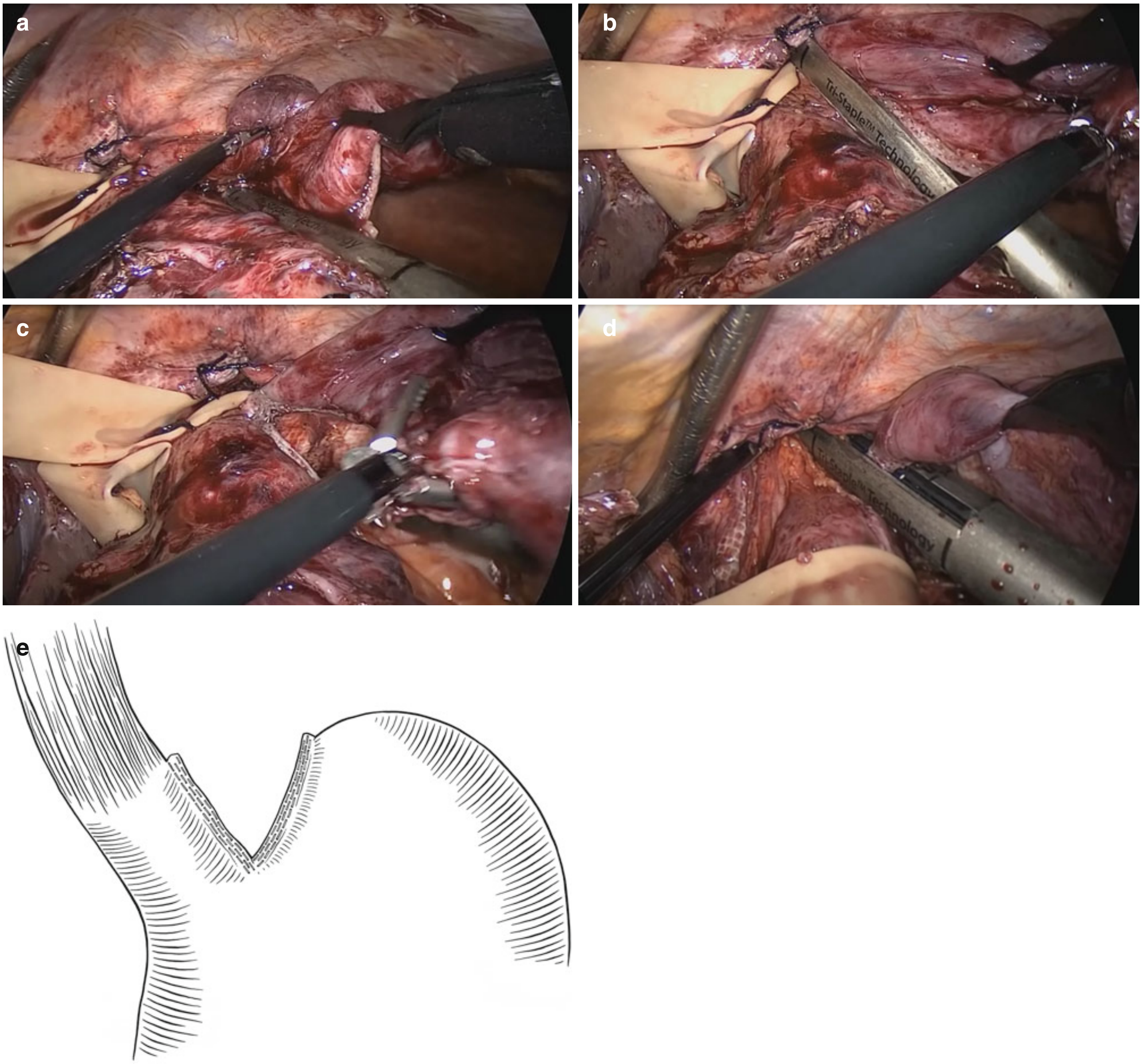

Fig. 8.13 (**a–d**) Creation of the neo-esophagus with placement of a vertical staple line. (**e**) Collis gastroplasty after the "V" wedge has been stapled out

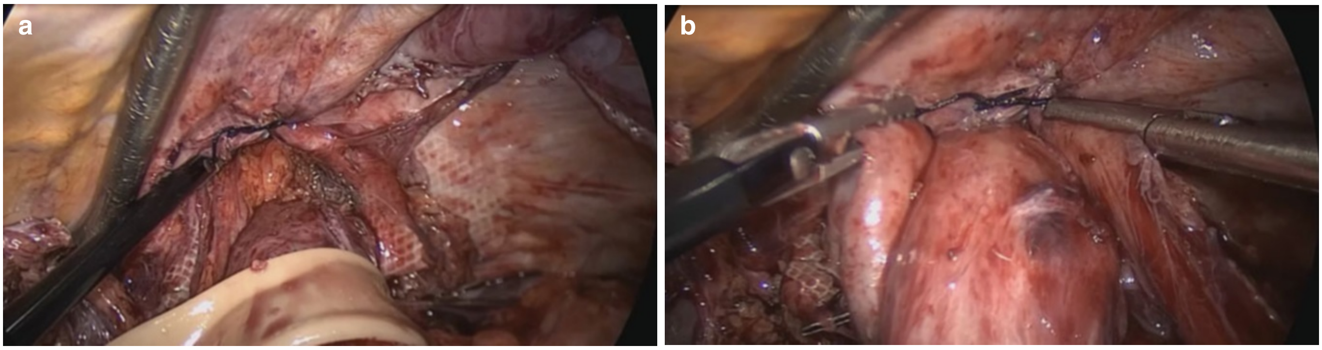

Fig. 8.14 (**a**, **b**) Toupet fundoplication following Collis gastroplasty

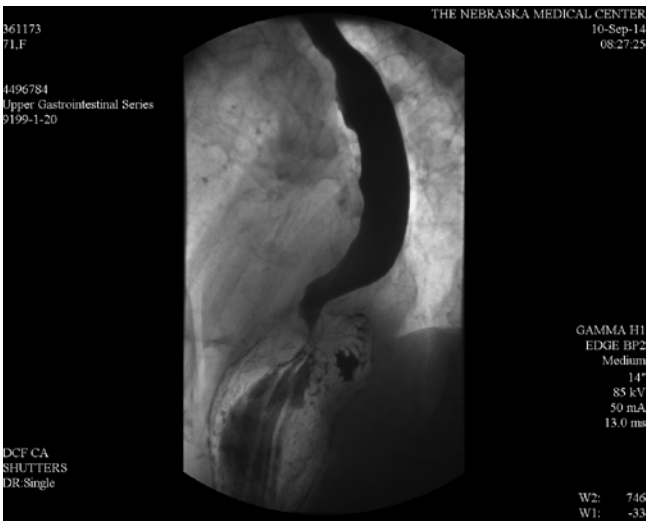

Fig. 8.15 Upper GI series 1 year after surgery, showing intact fundoplication and no hiatal hernia

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9 Operations for Achalasia

Bernardo Borraez and Marco G. Patti

This chapter describes the preoperative work-up, operative planning, and the technique of a laparoscopic Heller myotomy and partial fundoplication.

9.1 Clinical History

The patient is a 32-year-old man. He has been complaining for about 2 years of dysphagia, regurgitation, heartburn, and cough. He was initially treated with proton pump inhibitors on the assumption that gastroesophageal reflux was the cause of his symptoms. Because of the lack of response to these medications, an extensive workup was performed and revealed the presence of achalasia:

- Barium swallow: distal esophageal narrowing, an air-fluid level, and very slow emptying of barium from the esophagus into the stomach (Fig. 9.1).

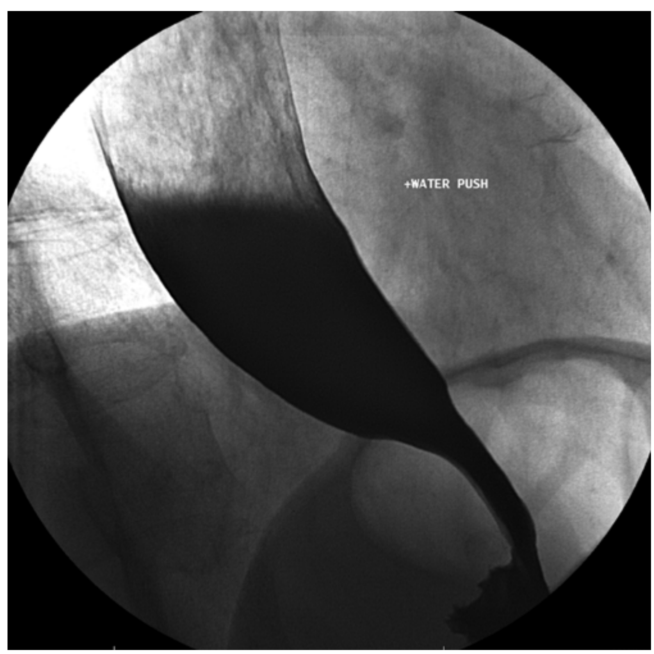

Fig. 9.1 Barium swallow showing distal esophageal narrowing, an air-fluid level, and very slow emptying of barium from the esophagus into the stomach

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P.M. Fisichella, M.G. Patti (eds.), *Atlas of Esophageal Surgery*, DOI 10.1007/978-3-319-13015-6_9

- Endoscopy: retained food in the esophageal lumen, and confirmation that the distal esophageal narrowing seen on the barium swallow was not due to a peptic stricture or cancer (Fig. 9.2).
- Esophageal manometry: type II achalasia according to the Chicago classification (Fig. 9.3). The lower esophageal sphincter showed normal resting pressure but absent relaxation in response to swallowing.

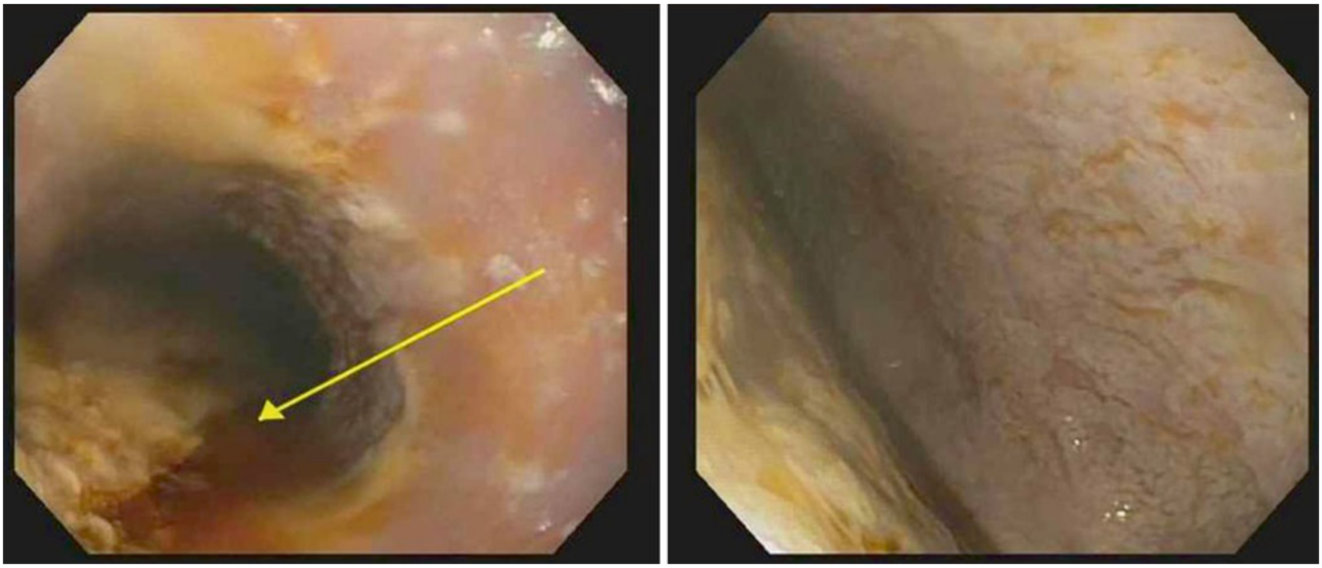

Fig. 9.2 Endoscopy showing retained food in the esophageal lumen (*arrow*), and confirmation that the distal esophageal narrowing on Fig. 9.1 was not due to a peptic stricture or cancer

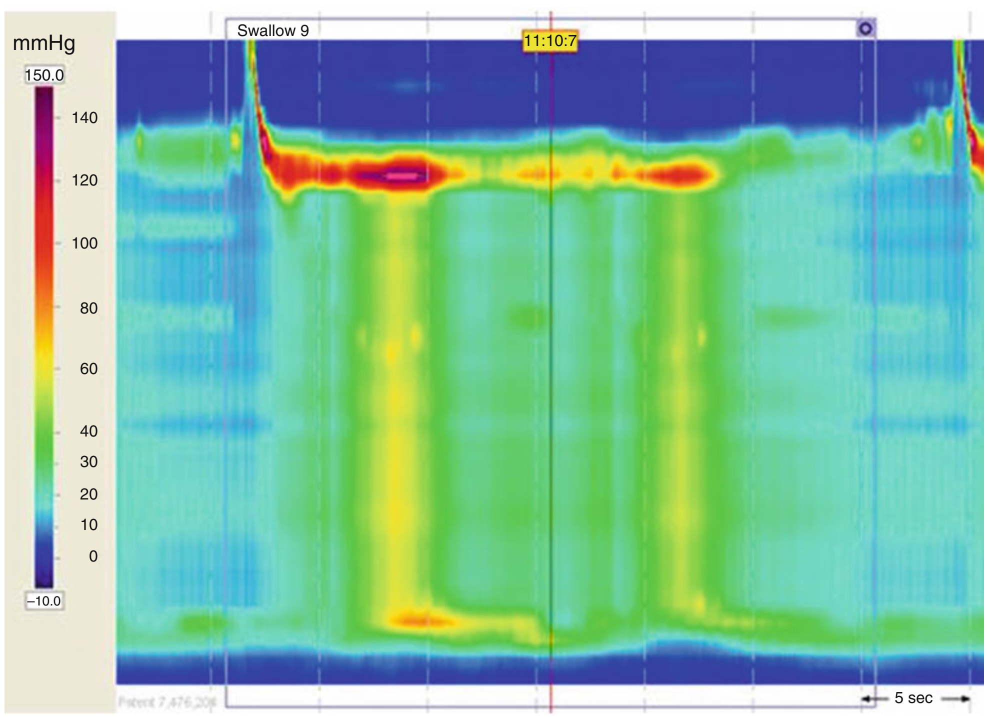

Fig. 9.3 Esophageal manometry showing type II achalasia (Chicago classification)

9.2 Operation

9.2.1 Patient Position and Placement of Trocars

The patient was positioned supine on the operating room table and the legs were extended on stirrups. Five trocars were inserted into the peritoneal cavity, as discussed in Chap. 5 (Fig. 9.4). The surgeon performs the procedure standing between the patient's legs.

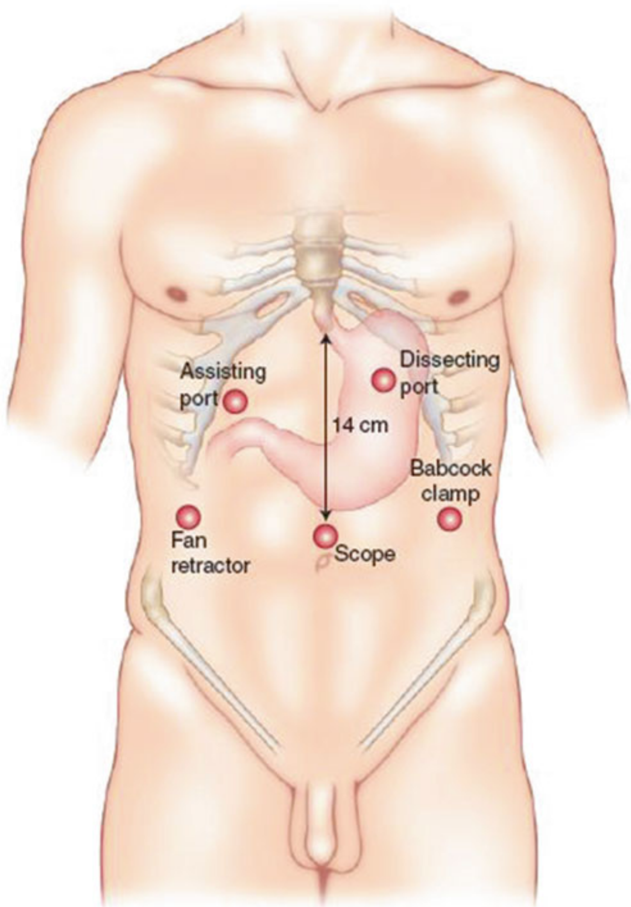

Fig. 9.4 Location of trocars for laparoscopic operations for achalasia

9.2.2 Operative Procedure: Heller Myotomy and Dor Fundoplication

Step 1 *Divide the gastrohepatic ligament*

The gastrohepatic ligament is divided (Fig. 9.5), beginning above the caudate lobe of the liver, all the way to the right pillar of the crus. An accessory left hepatic artery (from the left gastric artery) is frequently present in the gastrohepatic ligament and should be clipped to have proper exposure.

Step 2 *Identify the right crus of the diaphragm and posterior vagus nerve*

After opening the gastrohepatic ligament, the right pillar of the crus is separated from the right side of the esophagus by blunt dissection (Fig. 9.6). The posterior vagus nerve is identified.

Step 3 *Divide the peritoneum and phrenoesophageal membrane above the esophagus*

The peritoneum and the phrenoesophageal membrane above the esophagus are transected with the electrocautery, and the anterior vagus nerve is identified (Fig. 9.7). The left crus of the diaphragm is dissected downward toward the junction with the right crus.

Step 4 *Divide the short gastric vessels*

The short gastric vessels are divided using a bipolar instrument (Figs. 9.8 and 9.9). This step allows full mobilization of the fundus of the stomach to avoid any tension when the partial fundoplication is constructed.

Step 5 *Perform esophageal dissection in the mediastinum*

Using the bipolar instrument, further dissection is done in the posterior mediastinum in order to have about 4 cm of esophagus below the diaphragm without any tension (Figs. 9.10 and 9.11). No posterior dissection is performed.

Step 6 *Excise the fat pad and expose the esophageal wall*

It is important to excise the fat pad in order to have clear exposure of the gastroesophageal junction (Fig. 9.12). This maneuver is started just proximal to the first branch of the left gastric artery. Subsequently the esophageal wall is cleared in order to show the longitudinal fibers (Fig. 9.13).

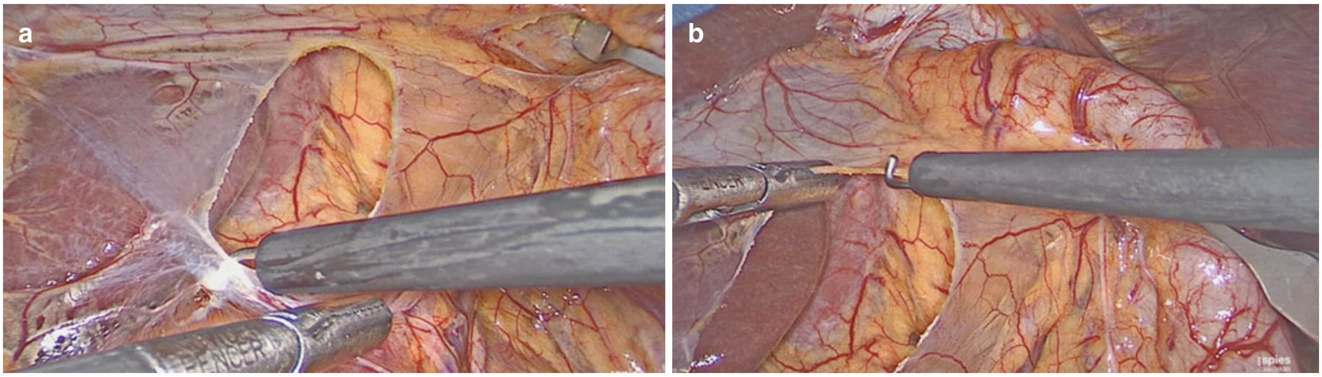

Fig. 9.5 (**a**, **b**) Division of the gastrohepatic ligament

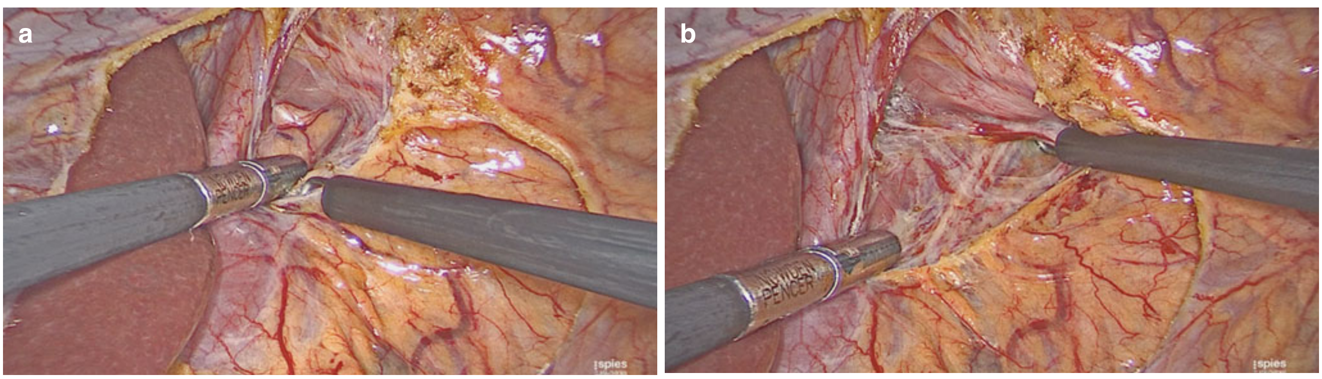

Fig. 9.6 (**a**, **b**) Identification of the right crus of the diaphragm and posterior vagus nerve

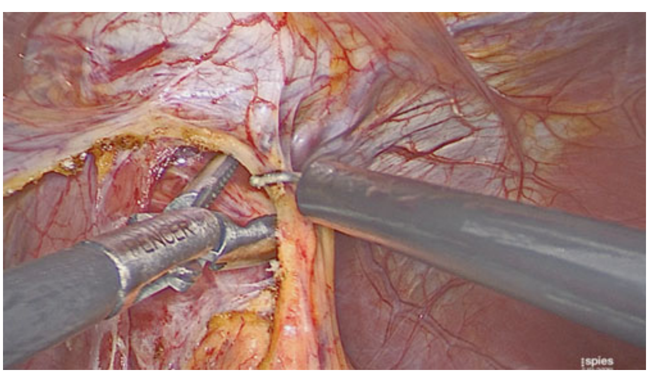

Fig. 9.7 Division of peritoneum and phrenoesophageal membrane above the esophagus

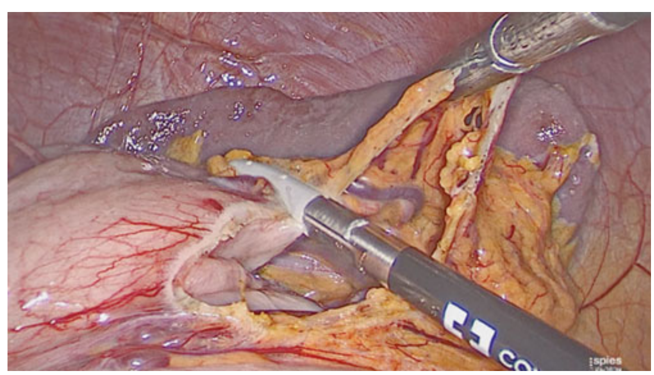

Fig. 9.8 Division of short gastric vessels

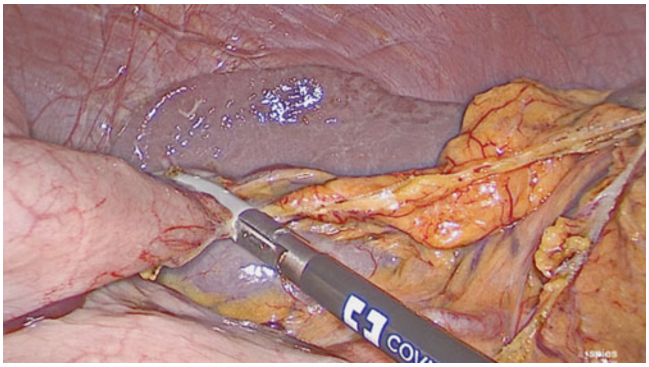

Fig. 9.9 Division of short gastric vessels

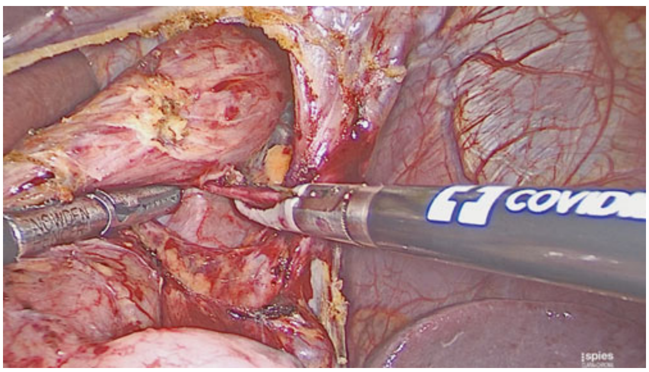

Fig. 9.10 Esophageal dissection in the mediastinum

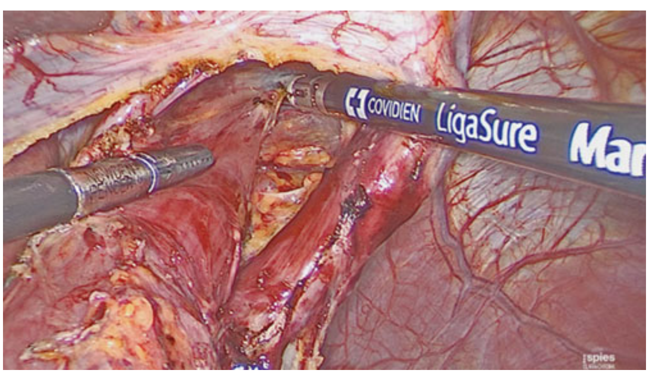

Fig. 9.11 Esophageal dissection in the mediastinum

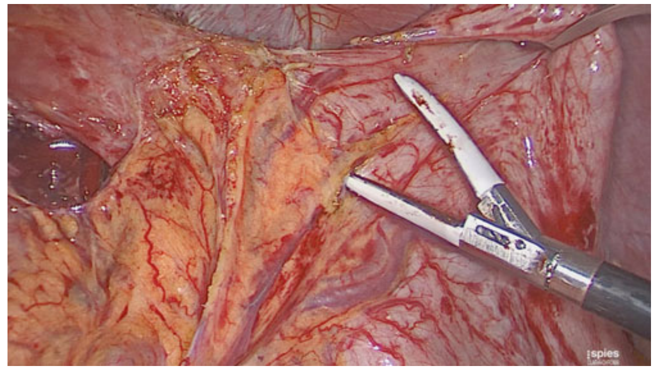

Fig. 9.12 Excision of the fat pad to achieve clear exposure of the gastroesophageal junction

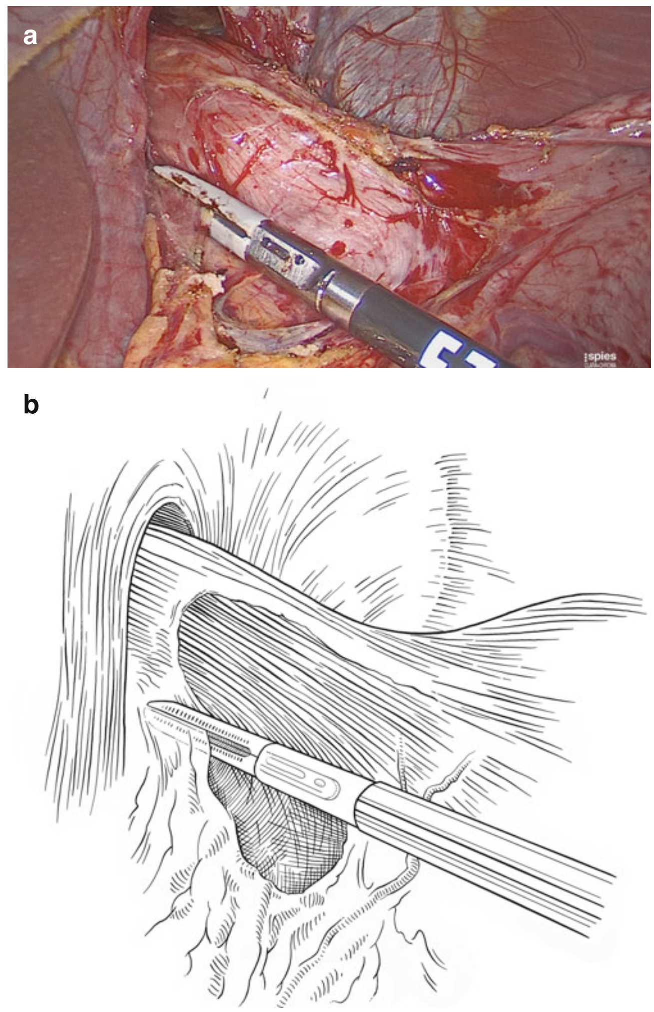

Fig. 9.13 (**a**, **b**) Clearing of the esophageal wall to show the longitudinal fibers

Step 7 *Perform esophageal myotomy*

The myotomy is performed using the hook cautery in the 11 o'clock position (Fig. 9.14). We start the myotomy just proximal to the gastroesophageal junction, and then we extend it for about 6 cm upward and 2.5–3 cm onto the gastric wall. The myotomy has a "hockey stick" configuration and it transects all the sling fibers. The muscle edges are then separated by blunt dissection in order to have the mucosa clearly exposed (Figs. 9.15 and 9.16). It is important to be very careful in patients previously treated with endoscopic procedures (botulinum toxin and/or dilations), as fibrosis can be present, with consequent loss of the normal anatomic planes.

Step 8 *Perform Dor fundoplication*

The Dor (anterior partial) fundoplication has two rows of sutures, one on the left and one on the right. The left row has three stitches. The uppermost stitch is triangular and M the fundus, the left side of the esophageal wall and the left pillar of the crus (Fig. 9.17). The second and third stitches are placed 1.0–1.5 cm from each other and incorporate the fundus of the stomach and the left side of the esophageal wall (Fig. 9.18). The fundus of the stomach is then folded over the exposed mucosa so that the greater curvature with the transected short gastric vessels is next to the right pillar of the crus (Fig. 9.19). The right row of sutures has three stitches that incorporate the fundus and the right pillar of the crus (Figs. 9.20 and 9.21). Finally, two stitches are placed between the fundus of the stomach and the rim of the esophageal hiatus in order to avoid tension on the right row of sutures.

Step 9 *Perform final inspection of the myotomy*

Before removing the trocars, a final inspection of the myotomy is made (Fig. 9.22). If there is any question about a possible perforation, the myotomy can be covered with saline and air can be insufflated with an orogastric tube or an endoscope. Alternatively, a sterile dye can be injected through the orogastric tube. If a perforation is detected, it should be immediately closed using absorbable material.

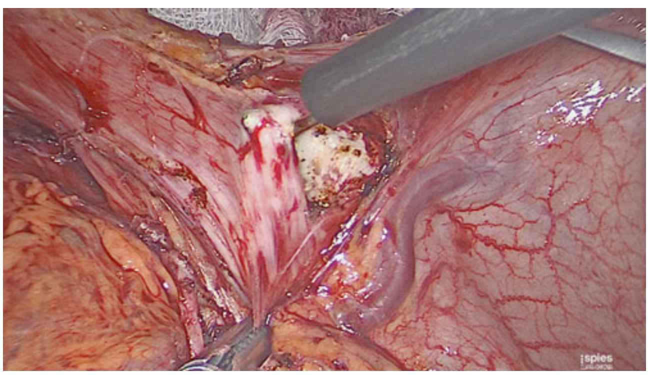

Fig. 9.14 Esophageal myotomy is started onto the esophagus

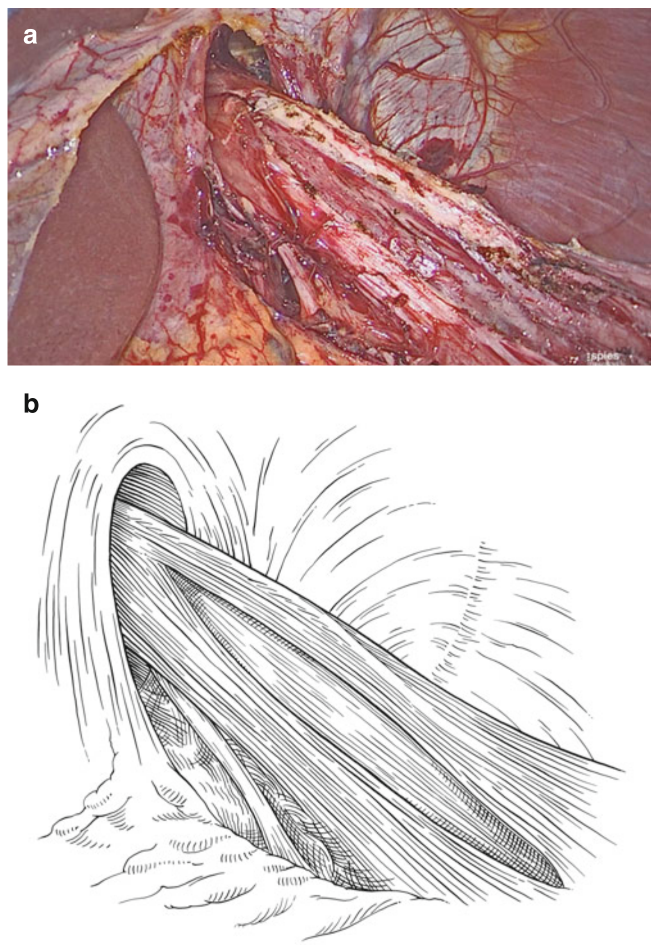

Fig. 9.15 (**a**, **b**) Completed esophageal myotomy

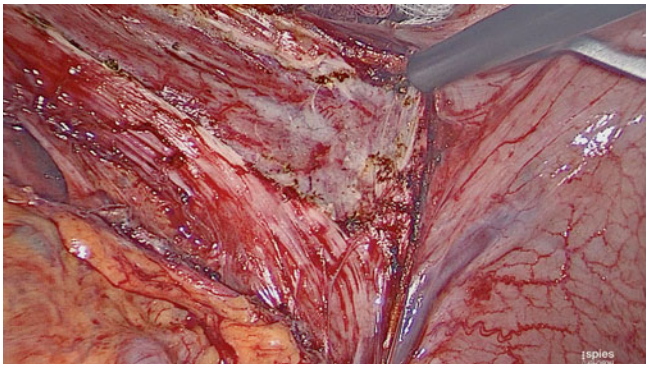

Fig. 9.16 Esophageal myotomy—distal extent

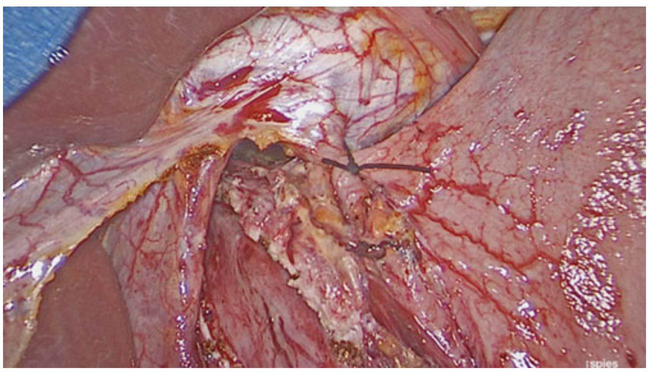

Fig. 9.17 In a Dor fundoplication, the uppermost stitch in the left row incorporates the fundus, the left side of the esophageal wall and the left pillar of the crus

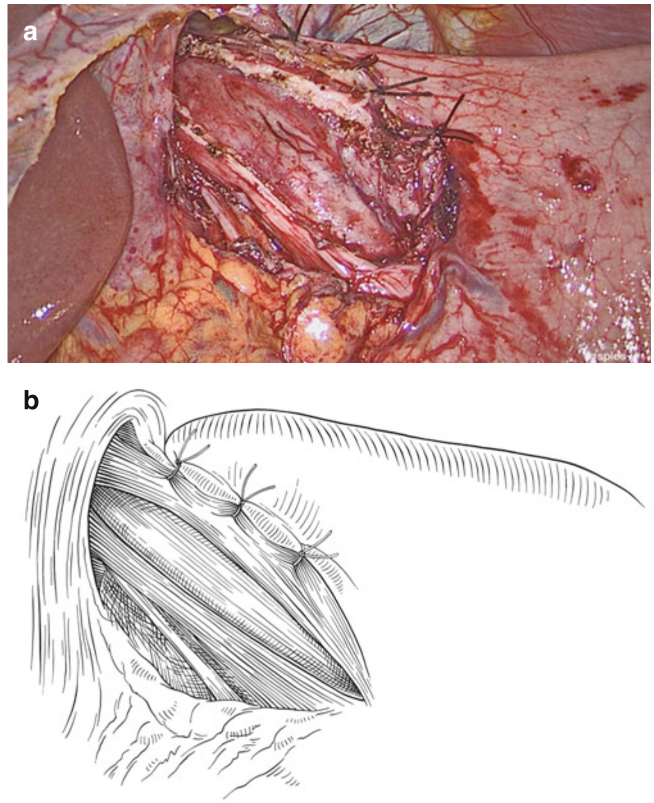

Fig. 9.18 (**a**, **b**) The second and third stitches incorporate the fundus and the left side of the esophageal wall

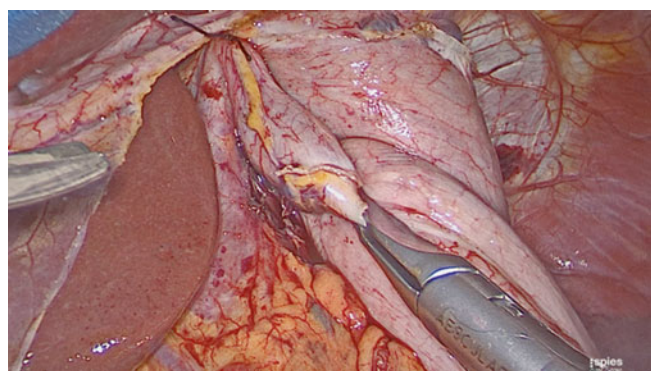

Fig. 9.19 The fundus of the stomach is folded over the exposed mucosa

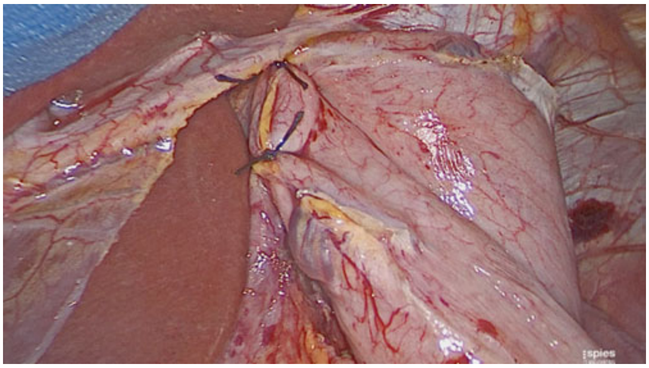

Fig. 9.20 Stitches incorporating the fundus and the right pillar of the crus

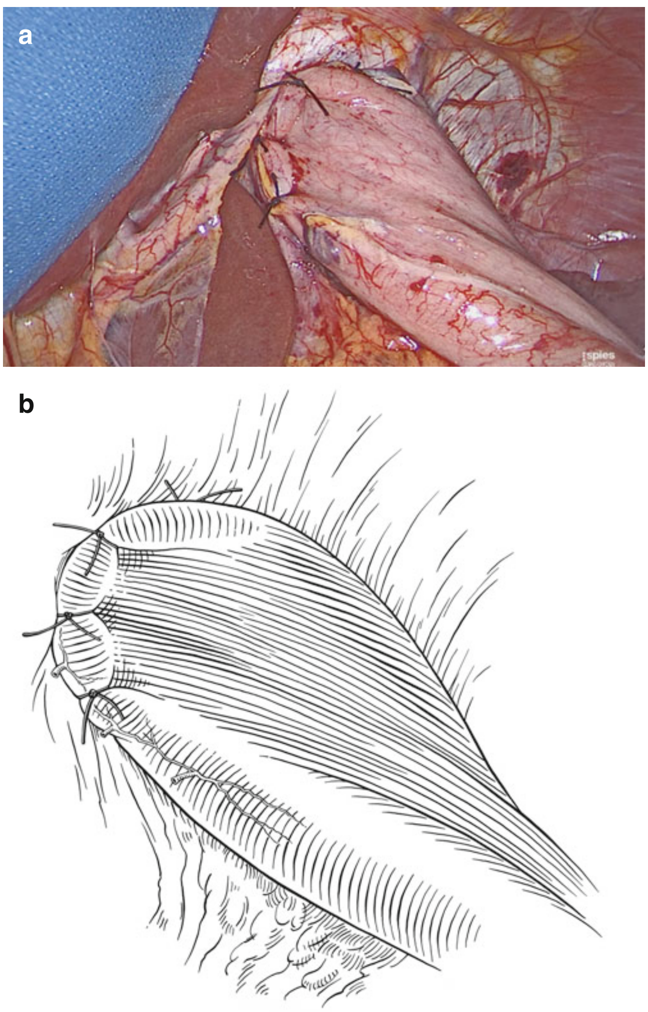

Fig. 9.21 (**a**, **b**) The right row of sutures, with three stitches incorporating the fundus and the right pillar of the crus

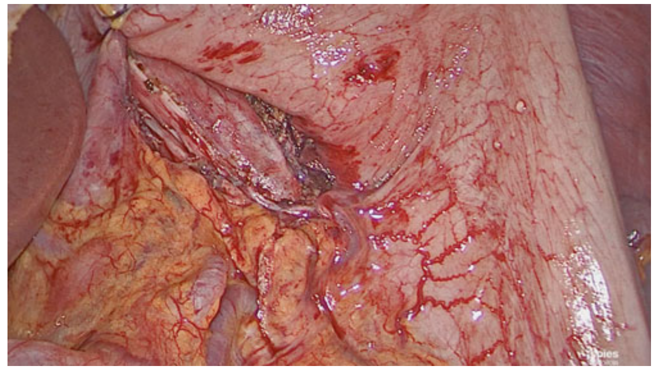

Fig. 9.22 The completed myotomy

9.3 Postoperative Course

The patient stayed overnight in the hospital. On the morning of the first postoperative day, a clear liquid diet was started. He had a soft diet for lunch and left in the afternoon. He was seen in follow-up 2 and 4 weeks after the operation, and has been contacted by e-mail every 3 months. Fifteen months after the operation, he is asymptomatic and has had complete resolution of his cough, suggesting that it was due to aspiration of the food retained in the esophagus.

Acknowledgement Images taken with SPIES system. Courtesy of Storz.

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10 Peroral Endoscopic Myotomy (POEM)

Eric S. Hungness and Rym El Khoury

This chapter describes preoperative work-up, operative planning, and the technique of a peroral endoscopic myotomy for achalasia, as well as troubleshooting difficult situations.

10.1 Clinical History

A 56-year-old woman presented in clinic with a 5-year history of chest pain, heartburn, and dysphagia. She was initially diagnosed with gastroesophageal reflux disease and put on a proton-pump inhibitor. Her symptoms did not resolve with anti-acid medication, and a subsequent esophagogastroduodenoscopy (EGD) was negative for esophagitis.

As her dysphagia progressed from solids to liquids, a complete work-up for esophageal motility disorder was performed:

- Repeat EGD: dilated and tortuous esophagus without mucosal-based lesions, suspicious for achalasia (Fig. 10.1)
- Timed barium esophagram: smooth tapering of the distal esophagus and a persistent contrast column of 10.2 cm at 5 min, indicative of bolus retention (Fig. 10.2)
- High-resolution impedance manometry (HRIM): elevated mean 4-s integrated relaxation pressure (IRP) of 32.4 mmHg, 10 failed swallows, and panesophageal pressurization consistent with type II achalasia according to the Chicago Classification (Fig. 10.3)

She was presented with three treatment options: pneumatic dilation, laparoscopic Heller myotomy, and peroral endoscopic myotomy (POEM). She chose to undergo POEM.

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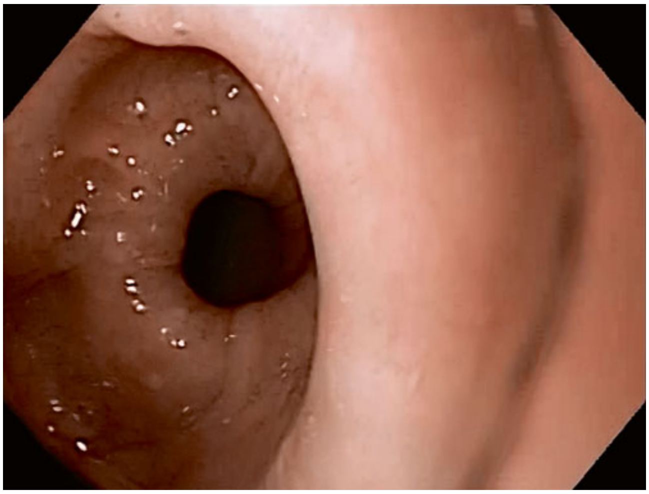

Fig. 10.1 Preoperative upper endoscopy: dilated and tortuous esophagus

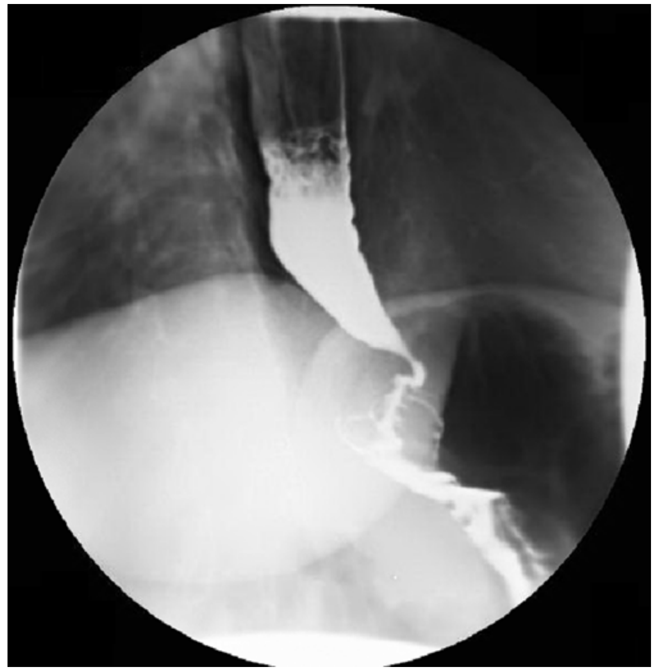

Fig. 10.2 Preoperative esophagram: retained contrast column and narrowing at the esophagogastric junction (EGJ)

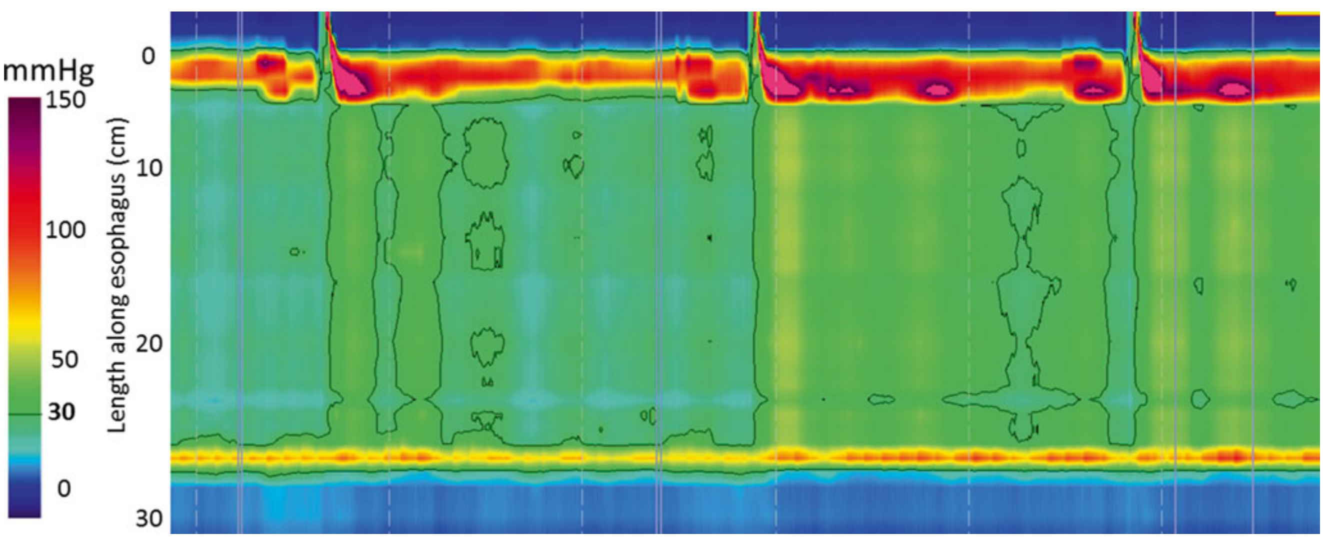

Fig. 10.3 Preoperative HRIM showing elevated integrated relaxation pressure (IRP) and panesophageal pressurization consistent with type II achalasia

10.2 Operation

10.2.1 Patient Preparation and Operative Setup

Prior to surgery, the patient was kept on a clear liquid diet for 48 h and completed a 5-day course of oral nystatin for *Candida* prophylaxis.

The patient was positioned supine with the right arm abducted and the left arm tucked at the side, with the abdomen prepped in case needle decompression was required for the presence of capnoperitoneum (Fig. 10.4). The POEM was performed under general anesthesia with endotracheal intubation and skeletal muscle paralysis. Special care was taken at the time of anesthesia induction and endotracheal intubation to prevent aspiration.

Fig. 10.4 Operative setup

10.2.2 Operative Procedure

Step 1 *Initial endoscopy*

Initial endoscopy was performed using a single-channel, high-definition gastroscope with CO_2 insufflation. The air insufflation was confirmed to be turned off. The esophagus and stomach were aspirated of any retained fluid and food, the stomach was desufflated, and the esophageal body was examined for *Candida* or stasis esophagitis. The endoscope was then fitted with an oblique transparent cap (longer end of bevel posterior) and the distance from the squamo-columnar junction to the incisors was measured on the scope shaft (Fig. 10.5).

Step 2 *Mucosotomy and entry into the submucosal space*

A submucosal bleb was created in the esophageal wall 12 cm proximal to the esophagogastric junction (EGJ) at the 1 o'clock position, using a sclerotherapy needle containing a solution of 0.9 % saline, 10 mL of indigo carmine (0.2 mg/mL), and dilute epinephrine (5 μg/mL) (Fig. 10.6). An endoscopic cautery knife was used to create a 2-cm longitudinal mucosotomy over the submucosal bleb (Fig. 10.7). The submucosal areolar tissue was cleared to expose the circular muscle layer. The endoscope was then bluntly maneuvered into the submucosal space, utilizing the oblique scope cap.

Step 3 *Creation of the submucosal tunnel*

Creation of the anterior submucosal tunnel required a combination of electrocautery (Fig. 10.8) and hydrodissection using a solution of saline and indigo carmine without epinephrine (Fig. 10.9). The orientation was checked periodically by evaluating the meniscus of injected fluid within the tunnel. The tunnel was extended 3 cm distal to the EGJ. Narrowing of the submucosal tunnel and the appearance of palisading vessels and aberrant muscle bundles (Fig. 10.10), as well as markings of the shaft of the endoscope, signified transition to the EGJ. The patient's systolic blood pressure was kept under 120 mmHg to avoid bleeding during progression of the submucosal tunnel. The epinephrine-containing solution was used again in the distal portion of the tunnel. After completion of the submucosal tunnel (Fig. 10.11), the scope was withdrawn from the tunnel and advanced through the esophageal body to the gastric lumen. Blanching of the gastric cardia mucosa, seen upon retroflexion, was recognized as a sign of extension of the submucosal tunnel onto the stomach (Fig. 10.12).

Step 4 *Myotomy*

A selective anterior myotomy of the inner circular muscle layer was started at 6 cm above the EGJ, using electrocautery to divide individual fibers and extended to the end of the submucosal tunnel (Fig. 10.13). Special attention was taken to protect the mucosa during myotomy progression (Fig. 10.14); splaying of longitudinal muscle fibers rarely occurred. The scope was withdrawn from the tunnel and advanced into the gastric lumen to observe patency of the EGJ.

Step 5 *Mucosotomy closure*

Finally, the scope was advanced into the tunnel, which was irrigated with a solution of bacitracin. The scope was withdrawn into the true esophageal lumen and the mucosotomy was closed with seven endoscopic clips (Figs. 10.15 and 10.16). A Veress needle was used to relieve capnoperitoneum. The stomach was intubated one last time, aspirated, and desufflated before withdrawal of the endoscope.

Fig. 10.5 Initial endoscopy showed a narrow EGJ. The endoscope was fitted with an oblique transparent cap, and the location of the squamo-columnar junction was measured on the endoscope shaft

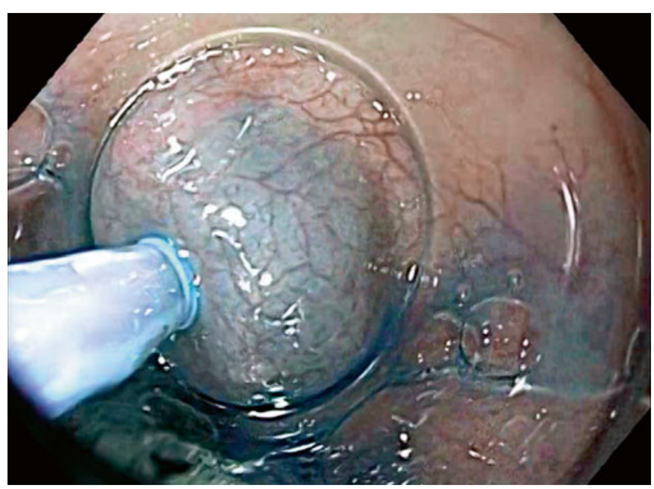

Fig. 10.6 Submucosal bleb created with a solution of saline, indigo carmine, and dilute epinephrine

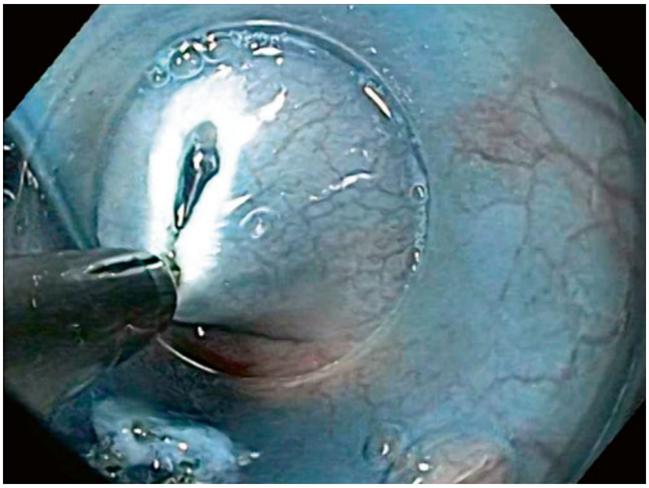

Fig. 10.7 Longitudinal mucosotomy performed by electrocautery over the submucosal bleb

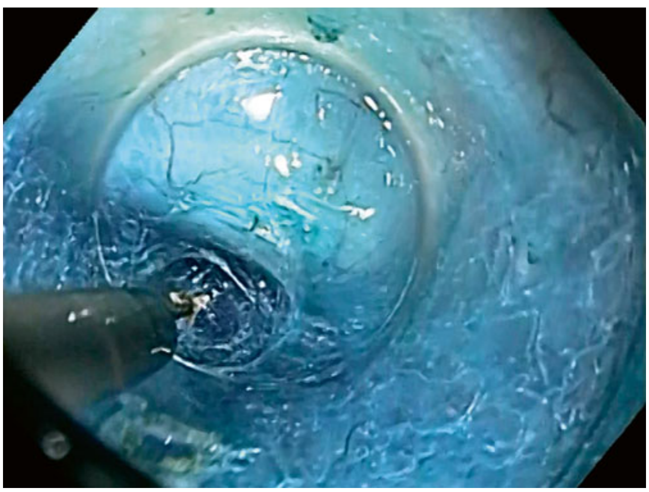

Fig. 10.8 Division of the submucosal tissue using electrocautery. The circular muscle layer can be seen in the background

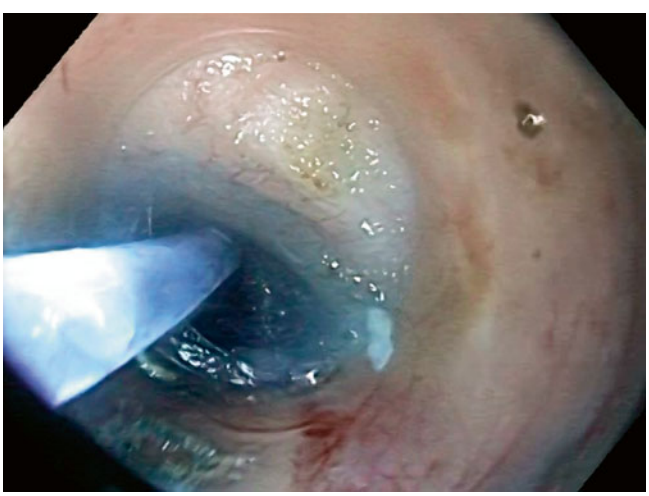

Fig. 10.9 Hydrodissection with saline and indigo carmine solution during the creation of the submucosal tunnel

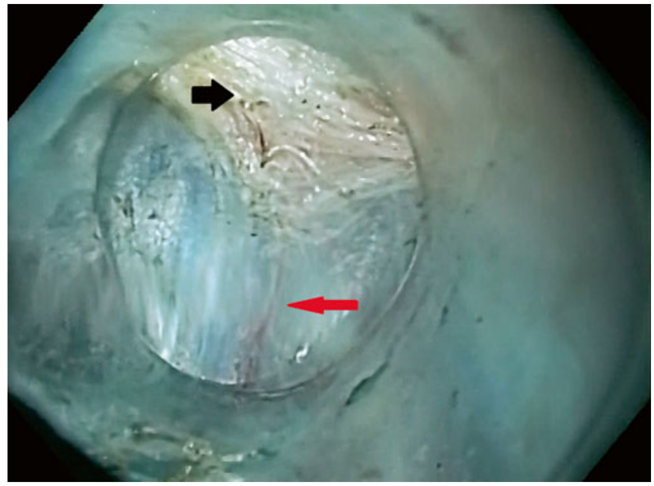

Fig. 10.10 Submucosal tunnel appearance approaching the EGJ, including palisading vessels (*red arrow*) and oblique muscle-fiber bundles (*black arrow*)

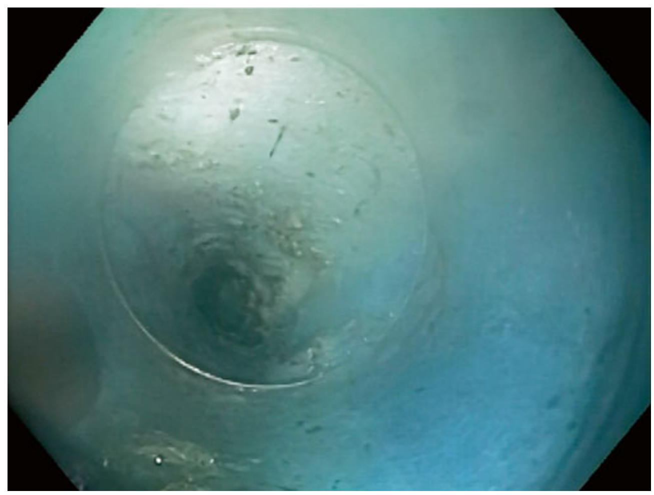

Fig. 10.11 Inside view of completed submucosal tunnel

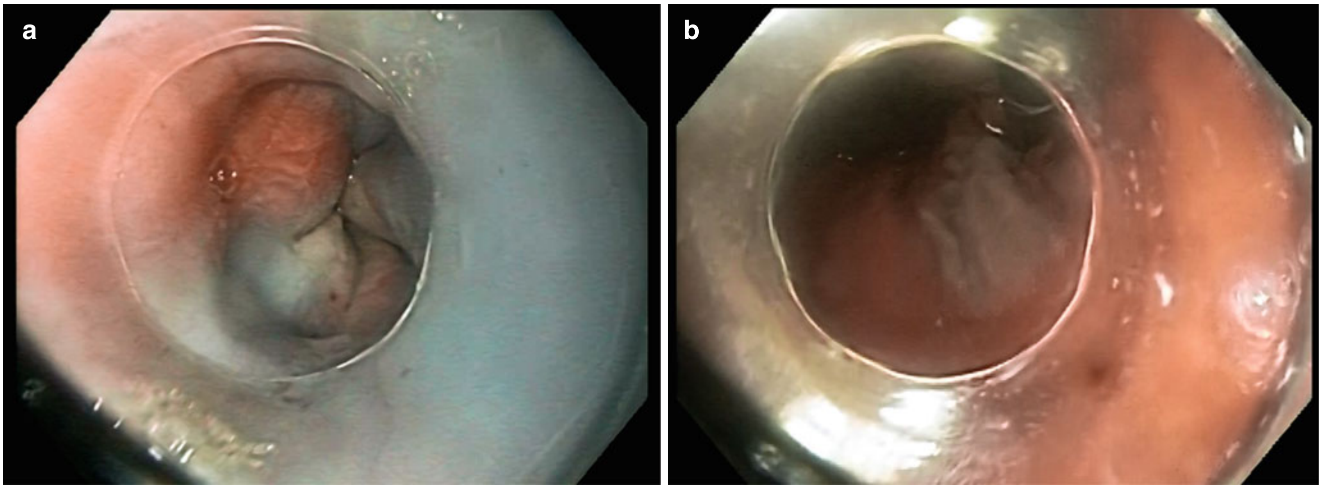

Fig. 10.12 (**a**) Mucosal blanching after submucosal tunnel extension onto the stomach. (**b**) Blanching of the gastric cardiac mucosa seen upon retroflexion at the end of the submucosal tunnel creation

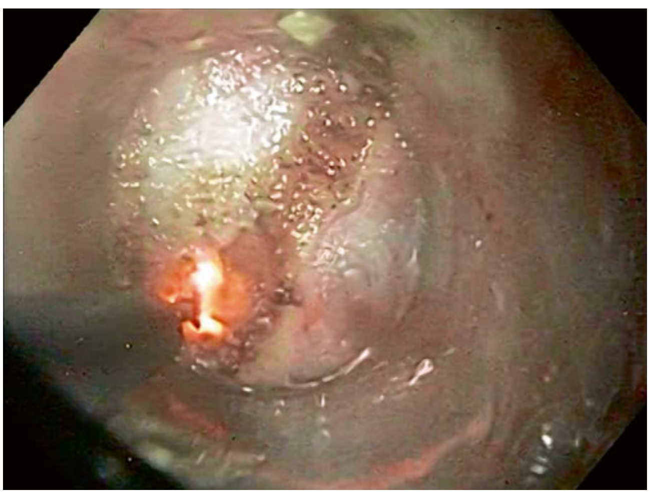

Fig. 10.13 Circular muscle division using electrocautery

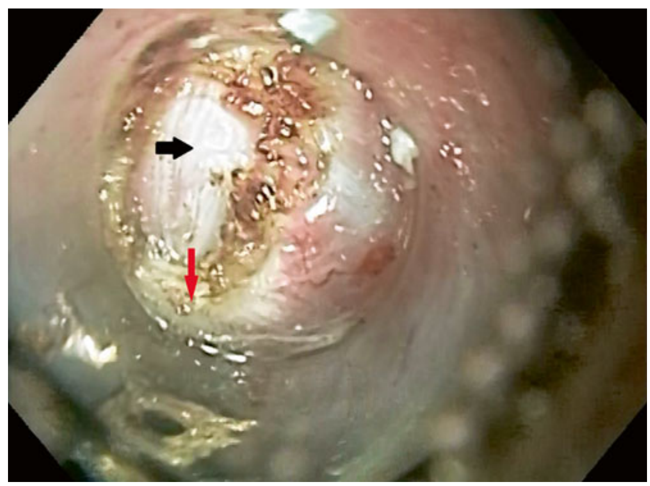

Fig. 10.14 Myotomy progression. Longitudinal muscle fibers (*black arrow*) are seen in the background during progression of the selective circular muscle division distally (*red arrow*)

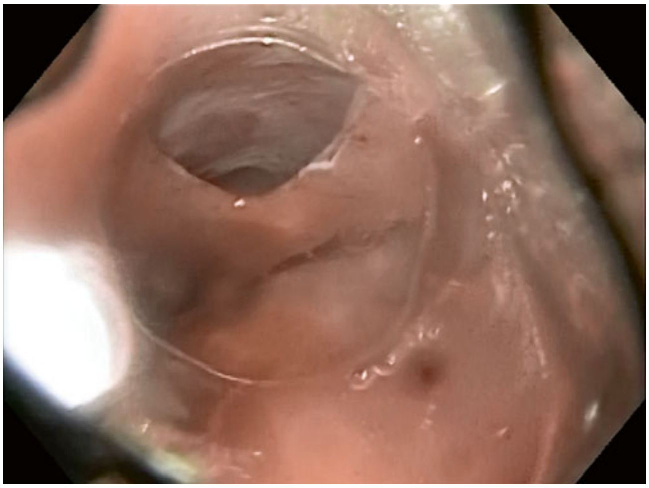

Fig. 10.15 Mucosotomy before clip closure

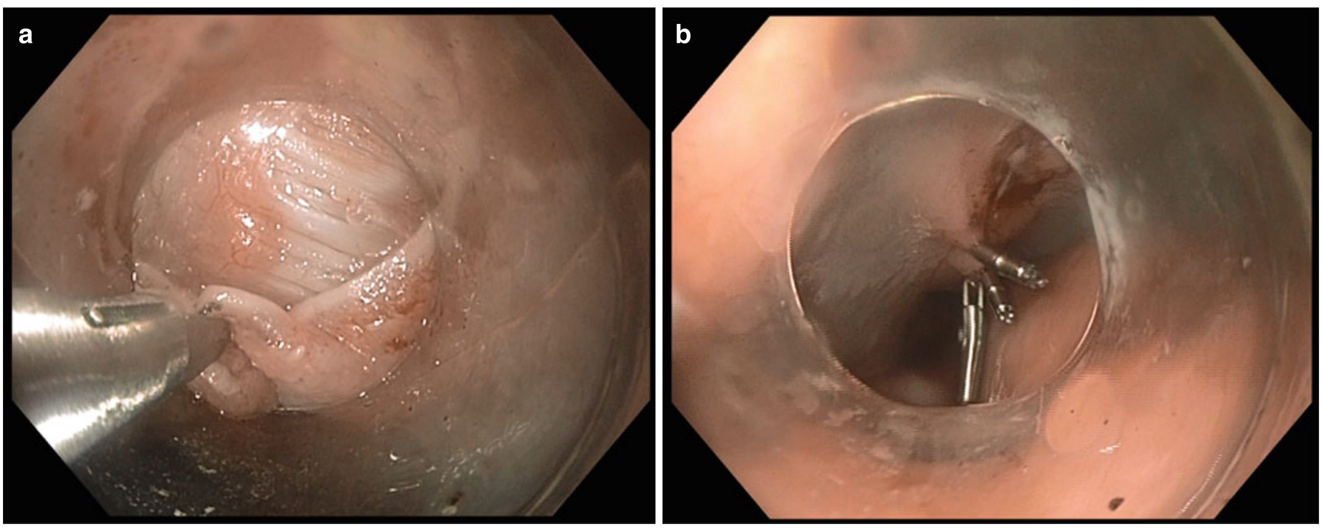

Fig. 10.16 (**a**) First clip applied to close the mucosotomy. (**b**) Mucosotomy clip closure in progress

10.3 Troubleshooting

POEM is a safe surgical option for the treatment of achalasia, but it requires advanced endoscopic and surgical skills. Initial endoscopy can be difficult in the context of food impaction or retention. This situation can be prevented by giving a clear liquid diet 48 h prior to surgery. In cases of severe esophageal stasis, extensive lavage and aspiration are often required before mucosotomy.

Preoperative treatment with antifungals (nystatin or fluconazole) is recommended to prevent *Candida* esophagitis, which has a high prevalence in patients with achalasia.

Esophageal muscle circular thickening, sigmoid esophagus, and severe esophageal dilatation can add technical difficulty to POEM. A decision to proceed with POEM in a patient with these findings should be at the discretion of the operating surgeon.

After longitudinal mucosotomy, the endoscope is bluntly maneuvered into the submucosal space. In patients with type III achalasia, Jackhammer esophagus, or esophageal spasms, this step can be technically challenging.

Additionally, bleeding can occur in the submucosal tunnel, particularly when approaching the EGJ, because of the robust blood supply in this area. Bleeding can be controlled by directly coagulating injured vessels (away from mucosa) or applying indirect pressure onto the tunnel with the endoscope positioned in the esophageal true lumen. A systolic blood pressure goal under 120 mmHg is also recommended during this step of the procedure.

Mucosal injury can occur during initial endoscopy or submucosal tunnel creation, but it usually can be repaired by clips. Depending on the extent and location of the mucosal defect, the procedure can be aborted, continued, or performed at an orientation other than the anterior position.

The current recommendation for spastic achalasia is an extended proximal myotomy ablating the entire spastic segment. In these patients, the submucosal tunnel and myotomy are started more proximally in the esophageal body.

Sparing of longitudinal muscle fibers is not always possible. Limited areas of full-thickness myotomy are acceptable in POEM.

Capnoperitoneum may require decompression with a Veress needle. Capnoperitoneum should not be considered as a complication, but rather as a normal consequence of the procedure, given that CO_2 can easily dissect through tissue planes.

Finally, mucosal redundancy and infoldings can add to the difficulty of mucosotomy clip closure. Various types of clips can be used to facilitate this last step.

10.4 Postoperative Course

Postoperatively, the patient was extubated and transferred to the postanesthesia care unit for observation. She stayed overnight and was kept nil per os. She received standing intravenous (IV) antiemetics, pain medication, and IV narcotics as needed.

A routine esophagram was performed on the morning of postoperative day 1 to rule out esophageal leak. (This systematic esophagram has since then been eliminated from our practice.) She was started on clear liquids, advanced to full liquids, and discharged on the afternoon of postoperative day 1 on anti-acid medication. The full liquid diet was maintained for 2 weeks and then gradually increased to include soft foods.

She was seen at 2 weeks postoperatively and showed great improvement in her symptoms. Subsequently, she was advanced to a regular diet and scheduled for long-term physiologic follow-up studies.

At 9 months, she was complaining of minimal heartburn on anti-acid medication. The EGD showed Los Angeles grade A reflux esophagitis. The HRIM showed absent peristalsis with eight failed swallows without panesophageal pressurization, and an IRP of 11 mmHg. At 18 months after the POEM procedure, her Eckardt score had decreased to 0 from a preoperative score of 5.

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11 Operations for Zenker's Diverticulum

Vishnu R. Kannabiran, John Gooey, and P. Marco Fisichella

Zenker's diverticulum is a false diverticulum or pseudodiverticulum of the esophageal mucosa and submucosa occurring at Killian's dehiscence, which lies at the junction between the oblique fibers of the cricopharyngeus muscle and the transverse fibers of the inferior pharyngeal constrictor (Fig. 11.1). The Zenker's diverticulum is a pulsion diverticulum thought to occur as a result of inadequate coordination between these muscle fibers, with a resultant increased pharyngoesophageal intraluminal pressure. The advent of endoscopic techniques has transformed the surgical treatment of Zenker's diverticula. Although the treatment paradigm has shifted to minimally invasive approaches with repair assisted by endoscopic stapling or lasers, traditional transcervical procedures can still play a role in selected cases. This chapter illustrates our tailored approach to patients with Zenker's diverticulum and demonstrates the open surgical and endoscopic techniques.

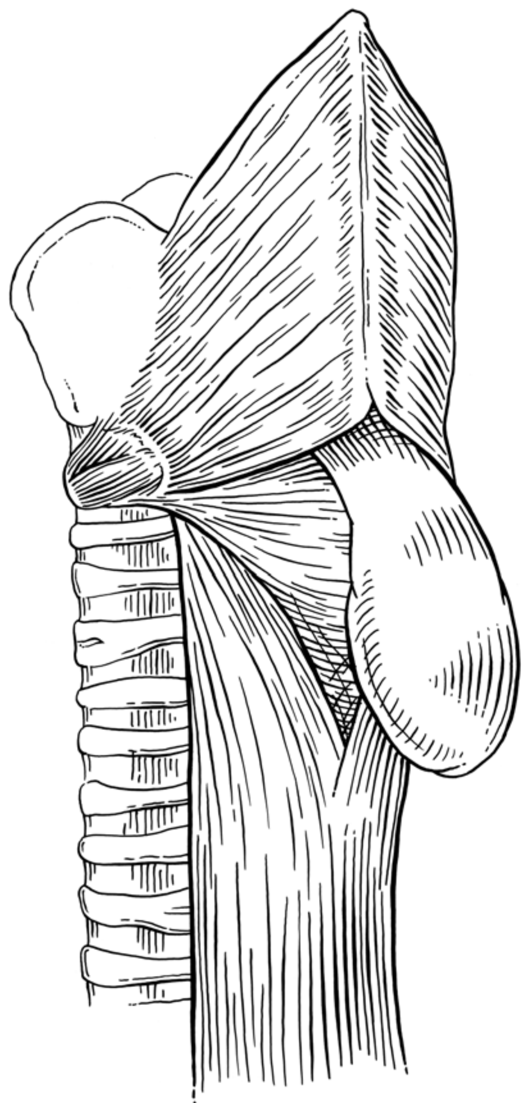

Fig. 11.1 Zenker's diverticulum, at the junction between the oblique fibers of the cricopharyngeus muscle and the transverse fibers of the inferior pharyngeal constrictor

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11.1 Clinical Scenario #1

A 55-year-old woman presented with progressive dysphagia for solids, with a gradual onset 2 years ago. She stated that sometimes she felt as if food got stuck in her neck. She had no odynophagia and no dysphonia, but had nocturnal coughing spells from aspiration of liquid in her trachea. Her husband said that she always has bad breath. A barium swallow showed a 5-cm Zenker's diverticulum. The patient is otherwise healthy.

11.2 Clinical Scenario #2

A 92-year-old man presented with progressive dysphagia for solids, with a gradual onset 2 years ago. He stated that sometimes he felt as if food got stuck in his neck. He had no odynophagia and no dysphonia, but he has been hospitalized numerous times for chronic aspiration. He has terrible breath odor. A barium swallow showed a 5-cm Zenker's diverticulum. The patient has had four-vessel coronary artery bypass grafting. He maintains an ejection fraction of 13 % and is on 3 L of oxygen at rest and 6 L when he walks around his house.

11.3 Workup and Choice of Approach

Barium swallow is the diagnostic study of choice. The barium swallow not only can identify the Zenker's diverticulum (Fig. 11.2), but also can provide more accurate measurements of the distance between the top of the septum and the bottom of the diverticulum than flexible esophagoscopy. Therefore, a barium swallow should be performed in all patients to guide the most appropriate surgical approach.

In patients who also complain of symptoms of gastroesophageal reflux, such as regurgitation and heartburn, we perform esophageal function tests to detect reflux objectively. (During these tests, the catheters are inserted under fluoroscopy to avoid perforation of the diverticulum.) In these patients, we perform a laparoscopic fundoplication prior to addressing the Zenker's diverticulum, in order to stop the reflux and prevent serious episodes of aspiration, which may occur after the transection of the upper esophageal sphincter—the last protective barrier to the gastroesophageal reflux—during the cricopharyngeal myotomy.

The decision to undertake an endoscopic or a transcervical repair depends on the patient's anatomic characteristics, surgical risk, and the size of the diverticulum. Anatomic characteristics can limit the surgical exposure during the endoscopic repair of Zenker's diverticulum. A short neck, a short hyomental distance, and a high body mass index correlate significantly with failure of exposure during an endoscopic repair. Furthermore, maxillary dentition, trismus, and preexisting limited motion range of the cervical spine may adversely influence the surgical exposure of the esophagodiverticular septum (common party wall) with the use of the bulky Weerda diverticuloscope. Most patients with Zenker's diverticulum are in their seventh and eight decades of life and typically have multiple medical comorbidities and a varied degree of surgical risk. Endoscopic repair may be a valid alternative for high-risk patients if there is concern about a longer surgical time during an open surgical approach. Finally, the size of the diverticulum can influence the type of repair. Specifically, a Zenker's diverticulum with a distance between the top of the septum and the bottom of the diverticulum of less than 3 cm may not be amenable to stapled endoscopic repair because the distal end of the endoscopic stapler is 1.5 cm and is nonfunctional. Endoscopic stapling in these cases may result in an incomplete division of the party wall and an incomplete myotomy, but endoscopic laser myotomy is still feasible.

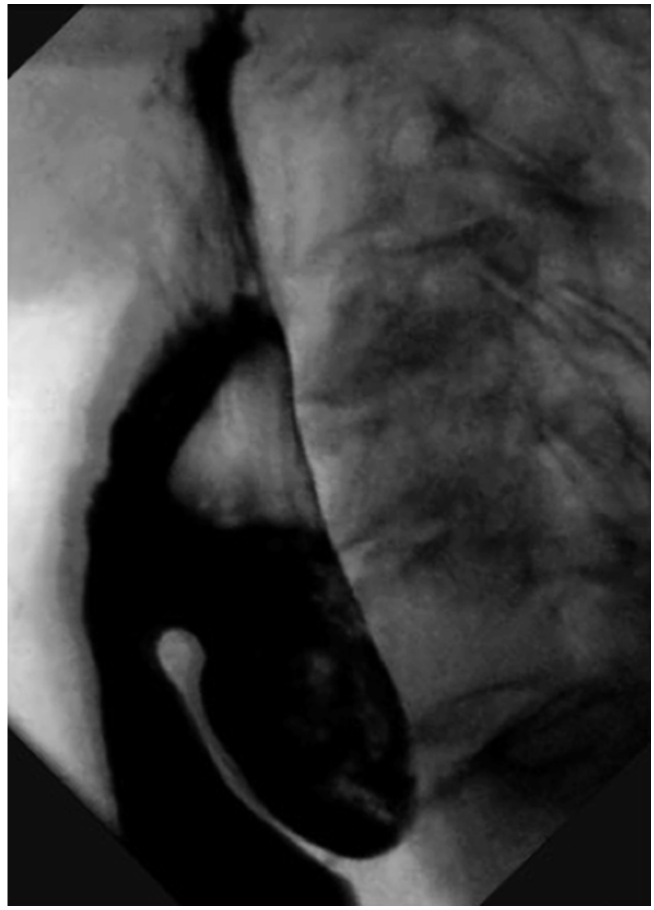

Fig. 11.2 Barium swallow identifying a Zenker's diverticulum

11.4 Operation

11.4.1 Operative Planning

In the operating room, the patient is positioned supine on the table and is placed in a 20° reverse Trendelenburg position. The neck is hyperextended by placing a shoulder roll. This maneuver facilitates the insertion of a rigid esophagoscope when an endoscopic approach is planned. If a transcervical approach is planned, the patient's head is also rotated opposite to the location of the diverticulum to facilitate the surgical exposure of the patient's neck. Preoperative antibiotics are given before instrumentation of the esophagus. Then, with protection of the maxillary alveolus with a dental guard or moist gauze, we perform a rigid or flexible esophagoscopy to confirm the location of the pouch (usually the left side) and to place a wire guide within the esophageal lumen. (We use the guide wire that is supplied with Savary esophageal dilators.) The wire guide facilitates the placement of the diverticuloscope during the endoscopic approach and can be useful to identify the esophagus in the transcervical approach.

When a transcervical approach is planned, we prefer to pass a 36 Fr Savary dilator over the wire to help identify the esophagus during the operation and to ensure that we do not narrow the lumen when resecting the diverticulum. Additionally, we pack the diverticulum with 1/4-inch ribbon gauze, using a laryngeal forceps inserted through the endoscope, to assist in identification of the diverticulum during the operation. The ribbon gauze is kept long, is taped to the patient's cheek, and is removed before the stapling of the diverticulum. If the diverticulum is large enough (>4 cm on the preoperative barium swallow), we use the inflated balloon of a 16 Fr Foley catheter (with its tip cut) to aid in the identification of the diverticulum in the operative field.

11.4.2 Transcervical Approach

The skin incision is made on the neck, along the anterior border of the sternocleidomastoid muscle. Subplatysmal flaps are elevated, followed by lateral retraction of the sternocleidomastoid and medial retraction of the strap muscles. The omohyoid is usually transected to improve the exposure of the surgical field. The middle thyroid vein is ligated, whereas the inferior thyroid artery usually can be preserved. Further dissection is carried out to retract the carotid sheath laterally and access the esophageal diverticulum, which lies anteromedially to the prevertebral fascia. The recurrent laryngeal nerve is found in the tracheoesophageal groove as it enters the cricothyroid muscle and should be identified and preserved. Careful medial retraction of the trachea and the thyroid is performed with the assistant's hands to avoid traction injury to the recurrent laryngeal nerve. The diverticulum is carefully pulled with an Allis clamp, and its neck is dissected off its adhesions from the muscle fibers until the point of herniation of the esophageal submucosa from the muscle fibers is evident. At this point, a cricopharyngeal myotomy, which is started with a right-angle instrument inserted in the extramucosal plane at the inferior neck of the diverticulum, is extended onto the muscularis propria of the cervical esophagus for a few millimeters. The myotomy is always performed, as it is essential in resolving the motor discoordination implicated in the pathophysiology of Zenker's diverticulum. If the diverticulum is small (<2 cm) we perform only a myotomy that also extends 1 or 2 cm cephalad onto the inferior pharyngeal constrictor. Conversely, if the diverticulum is larger than 2 cm, we elect to perform a diverticulectomy with a stapler.

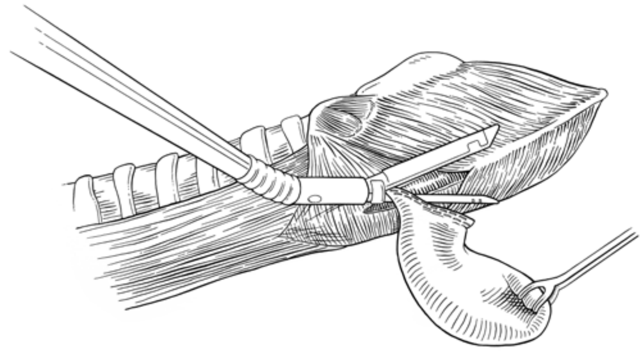

Fig. 11.3 Diverticulectomy with a stapler allows simultaneous resection of the Zenker's diverticulum and closure of its neck

We use the same stapler for both endoscopic and transcervical approach: the Endopath® 35-mm ETS Articulating Linear Cutter (Ethicon, Somerville, NJ). This device (with a blue cartridge) has an articulating head that can be applied close to the neck of the diverticulum in the limited exposure of the transcervical approach, and it is small enough to be used endoscopically to provide an adequate view of the party wall. Performing diverticulectomy with a stapler allows for the simultaneous resection of the diverticulum and closure of its neck (Fig. 11.3). The operation is concluded with a water leak test. A #10 flat Jackson-Pratt suction drain is placed in the operative field and the platysma and the skin are reapproximated and closed.

11.4.3 Endoscopic Approach

We initially perform a rigid cervical esophagoscopy to assess our ability to access the diverticulum and evaluate its precise location and size.

Next, we insert the Weerda diverticuloscope with adequate protection of the maxillary gingiva. The diverticuloscope is positioned with the anterior blade within the esophageal lumen and the posterior blade within the diverticulum (Fig. 11.4). This diverticuloscope can adjust the angle and the distance between the two blades while maintaining a fixed angle. The valves of the diverticuloscope are then widened to isolate the septum for its entire length. We then insert a zero-degree, 5-mm Hopkins® telescope (Karl Storz, Tuttingen, Germany) or a urological endoscope into the oral cavity to confirm adequate positioning. The diverticuloscope is then secured to the bed using a self-retaining instrument, such as the Riecker-Kleinsasser laryngoscope holder.

Once the patient is set up and the septum is isolated, we apply the Endopath® 35-mm ETS Articulating Linear Cutter (Ethicon) with a blue cartridge and orient the stapler cartridge "upside down" so that the longer lip with the cartridge lies within the esophageal lumen while the shorter lip is placed within the diverticulum (Fig. 11.5). This position ensures maximum division of the party wall upon firing of the stapler.

Once the adequate positioning of the stapler is confirmed with the telescope, the stapler is fired and the division of the party wall that includes the cricopharyngeal muscle is accomplished (Figs. 11.6 and 11.7). Two or more applications of the stapler may be necessary, depending on the size of the diverticulum. An internal cricopharyngeal myotomy is performed in this manner.

If the preoperative barium swallow has shown that the diverticular pouch is too small to accommodate a stapler, we have used a CO_2 laser to divide the party wall. The CO_2 laser has hemostatic properties and produces minimal surrounding thermal damage. The setup for this procedure (or to facilitate the positioning of the stapler in difficult cases), is the same as described above. We then place two temporary stay sutures of 2–0 silk through the party wall using an Endo Stitch™ (Covidien, Minneapolis, MN) to allow for lateral retraction while performing the laser diverticulotomy. We use an OPMI® Sensera operating microscope (Carl Zeiss, Jena, Germany) with a CO_2 laser micromanipulator at working distance of 400 mm and at a setting of 5–10 watts.

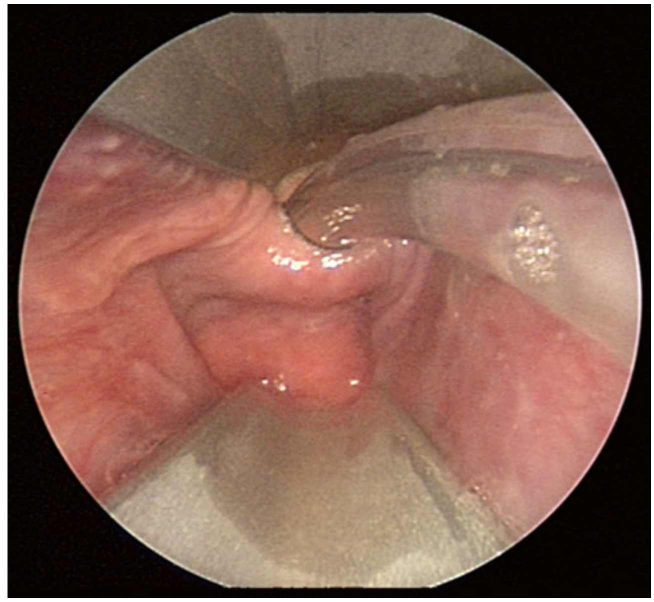

Fig. 11.4 Positioning of the Weerda diverticuloscope in an endoscopic approach to Zenker's diverticulum

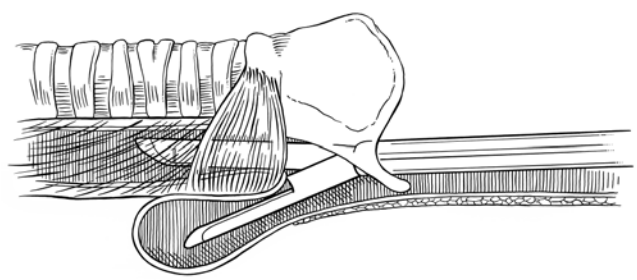

Fig. 11.5 The Endopath® 35 mm ETS Articulating Linear Cutter (Ethicon™) is oriented so that the longer lip with the stapler cartridge lies within the esophageal lumen and the shorter lip is placed within the diverticulum

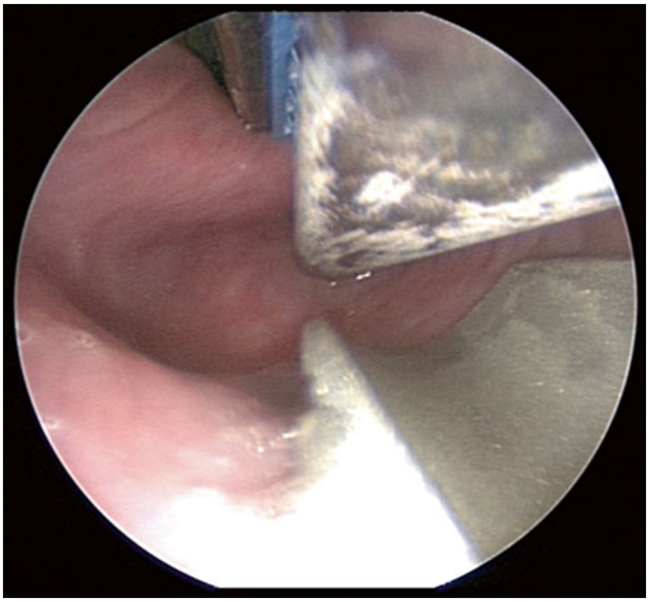

Fig. 11.6 Positioning of the stapler in the endoscopic approach to Zenker's diverticulum

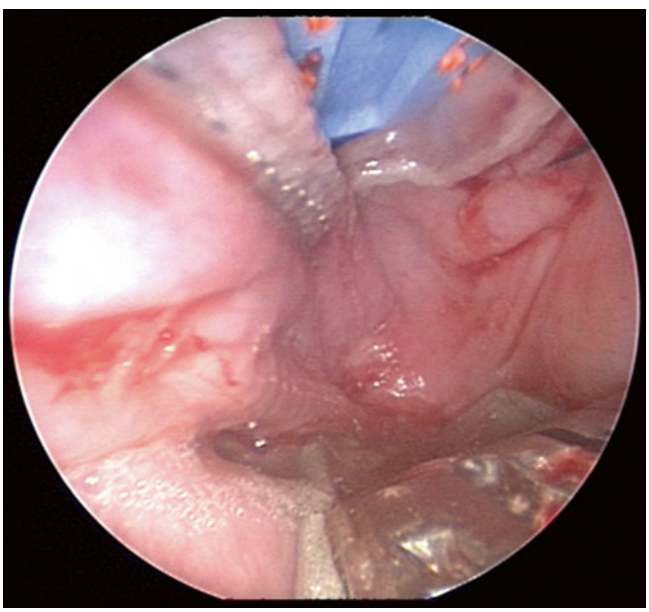

Fig. 11.7 Division of the party wall after firing of the stapler

11.5 Postoperative Care

Patients are admitted overnight and a contrast esophagram with either barium or a water-soluble agent such as Gastrografin is performed the next day to rule out a leak from the staple line. A regular diet is then started. If a drain is present, it is pulled prior to discharge, 24–48 h postoperatively.

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12 Laparoscopic Treatment of Epiphrenic Diverticula

P. Marco Fisichella and Anahita Jalilvand

The laparoscopic repair of epiphrenic diverticulum is today considered the standard surgical approach that has replaced the traditional repair through a left thoracotomy. The laparoscopic approach has in fact several advantages over a left thoracotomy or thoracoscopy: it allows a cardiomyotomy extending far onto the stomach, contralateral to the diverticular staple line; it allows a partial fundoplication that prevents gastroesophageal reflux and covers the cardiomyotomy; and it avoids the discomfort of a chest tube postoperatively. This chapter illustrates the preoperative work-up and choice of surgical technique.

12.1 Clinical History

The patient is a 73-year-old woman who has been complaining for about 5 years of progressive dysphagia and regurgitation of undigested food right after eating. An extensive work-up was performed and revealed the presence of achalasia:

- Barium swallow: distal esophageal narrowing, an air-fluid level, a slow emptying of barium into the stomach, and an epiphrenic diverticulum measuring 5×6 cm (Fig. 12.1)
- Endoscopy: confirmation that the distal esophageal narrowing was not due to a peptic stricture or cancer; identification of the neck of the diverticulum
- Esophageal manometry: achalasia, with normal resting pressure of the lower esophageal sphincter but absent relaxation in response to swallowing (Fig. 12.1)

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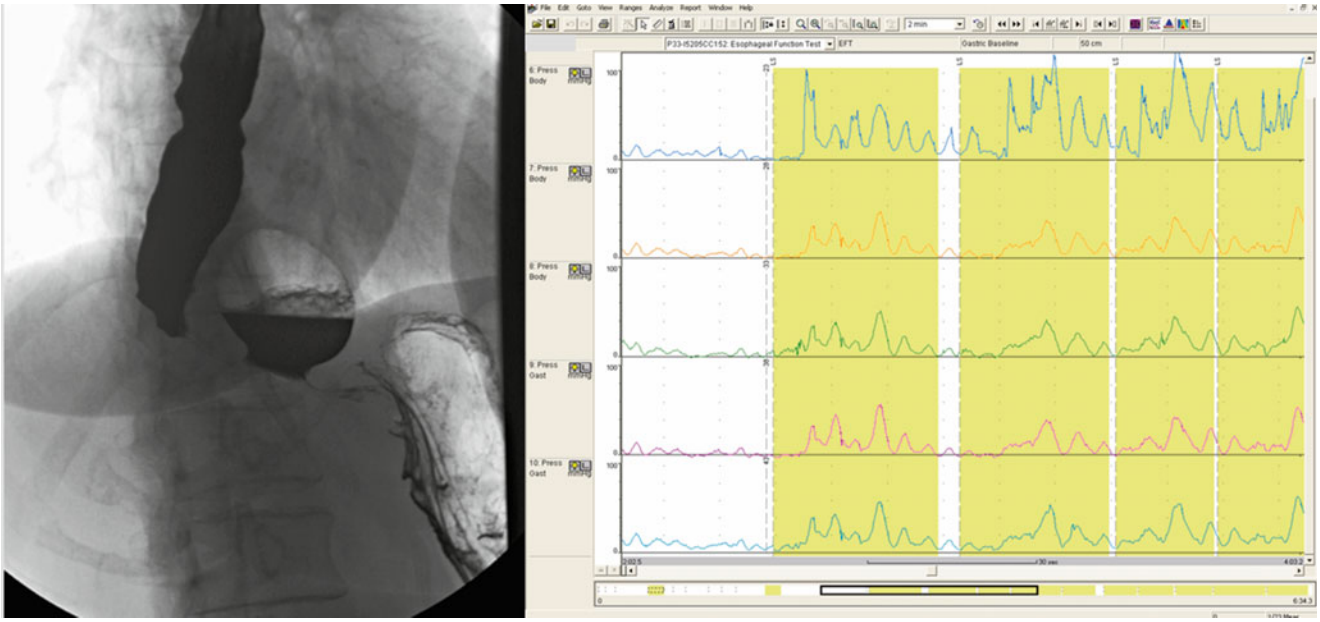

Fig. 12.1 *Left*, Barium swallow showing distal esophageal narrowing, an air-fluid level, slow emptying of barium into the stomach, and a 5×6-cm epiphrenic diverticulum. *Right*, Esophageal manometry showing achalasia, with normal resting pressure of the lower esophageal sphincter but absent relaxation in response to swallowing

12.2 Operation

12.2.1 Patient Positioning

The patient is positioned supine on a beanbag on the operative table. Pneumatic compression stockings are used as prophylaxis against deep vein thrombosis, and preoperative antibiotics are administered prior to skin incision. A rapid sequence induction is performed to prevent aspiration of particulate matter lodged inside the diverticulum or filling the esophageal lumen of patients with underlying esophageal motility disorders, such as achalasia. A Foley catheter is then inserted; the lower extremities are placed in stirrups; and the beanbag is inflated to support the patient in the reverse Trendelenburg. Finally, the abdomen is prepped and draped.

12.2.2 Ports and Instruments

A 1-cm transverse midline incision is made onto the skin approximately 1 inch above the umbilicus (Fig. 12.2). The fascia is grasped with a Kocher clamp and a nick is made with a #15 blade; a Veress needle is inserted; a water drop test is performed; the abdomen is insufflated to 14 mmHg; and an 11-mm trocar is inserted into the abdominal cavity under direct visualization using a 0°, 10-mm laparoscope. Then three trocars are placed. Ports B and C are 11-mm working ports through which the graspers, the laparoscopic LigaSure™ Vessel Sealing System (Covidien, Minneapolis, MN) and the suturing instruments are introduced. Port D is a 12-mm port used for manipulation of a laparoscopic atraumatic Allis clamp; the LigaSure™, to take down the short gastric vessels; and the insertion of a laparoscopic stapler. Finally, a 5-mm incision to the left of the xiphoid process is made to insert a Nathanson retractor, which retracts the left lobe of the liver medially and upwards and exposes the diaphragmatic hiatus and the gastroesophageal junction. The Nathanson retractor is at last secured to the operative table. The 0°, 10-mm laparoscope is exchanged for a 30- or 45°, 10-mm laparoscope, which is used for the entire procedure. Because of its angled lens, this laparoscope allows superior visualization, especially when working in the mediastinum during the mobilization of the cranial portion of the diverticular neck.

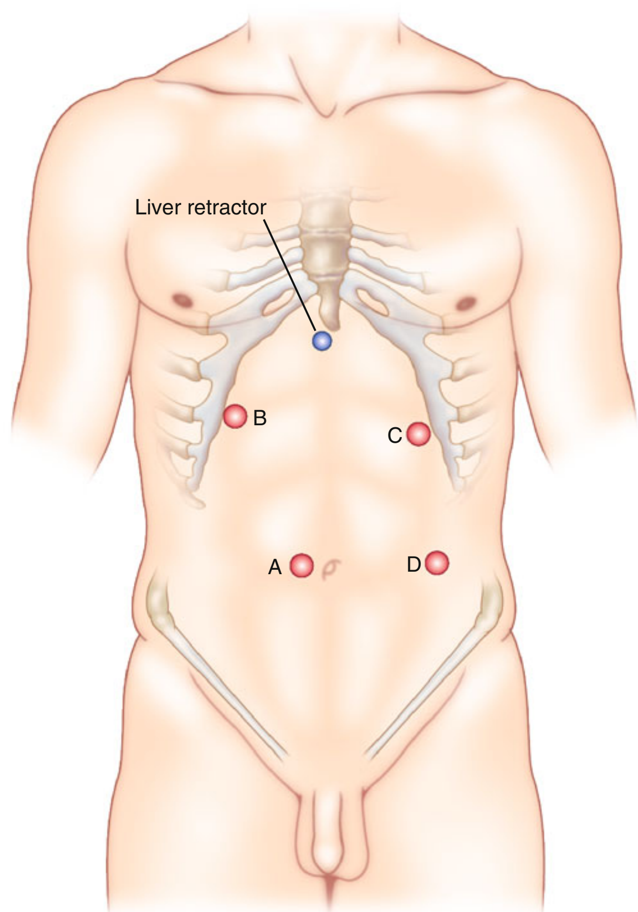

Fig. 12.2 Operative ports in order of placement for laparoscopic treatment of epiphrenic diverticula; port A must be in the midline above the umbilicus

12.2.3 Operative Procedure

Step 1 *Mobilization of the esophagus*

Once all ports are placed, the patient is positioned in steep reverse Trendelenburg. Applying a laparoscopic Allis clamp near the gastroesophageal junction anteriorly starts the operation. This maneuver tents up the gastrohepatic ligament, which is divided with the Ligasure™ until the right diaphragmatic crus becomes visible. The phrenoesophageal ligament is divided from the apex of the right crus to the apex of the left crus, and the anterior vagus nerve is identified. The esophagus is then bluntly dissected away from the right crus to provide access to the posterior mediastinum. The posterior vagus nerve is then identified. The left pillar of the crus is then visualized and a retroesophageal window is created. A Penrose drain is passed around the esophagus, encircling both vagi nerves; it is used to apply caudad traction to the distal esophagus, which makes it easier to deliver the diverticulum closer into the abdomen.

Step 2 *Exposing the neck of the diverticulum*

The dissection is continued into the posterior mediastinum, where the diverticulum is located. After the diverticulum is discovered, it is bluntly dissected off the pleura and the esophageal wall until its neck is clearly isolated, to provide a safe access for the stapler. The exposure of diverticular neck is completed only after the most cranial portion of the neck has been adequately dissected (Fig. 12.3). Occasionally, the diaphragm is split anteriorly to gain access to a large diverticulum in the mediastinum.

Step 3 *Stenting of the esophagus*

A tapered-tip bougie (54–58 F) is then placed carefully and under direct vision into the esophagus to stent its lumen and prevent stenosis by stapling an excess of the mucosa and submucosa of the diverticular neck. To prevent the inadvertent introduction of the bougie into the diverticulum, the diverticular neck may be gently and loosely closed with a grasper.

Step 4 *Stapling of the diverticulum*

Once the bougie is in place, the neck of the diverticulum is then stapled with a roticulating laparoscopic stapler equipped with a 2.5-mm vascular cartridge and oriented longitudinally to the esophageal axis (Fig. 12.4). The bougie is gently withdrawn before the stapler is fired, to avoid backward dragging of the stapled mucosa and submucosa. The bougie is then always taken out of the patient's esophagus.

Step 5 *Closure of the esophagus*

The defect of the esophageal musculature is then closed in one layer with a few intracorporeally tied, #2-0 silk interrupted sutures to imbricate the staple line (Fig. 12.5). The diverticulum is placed into a plastic bag and retrieved from one of the ports. Similarly, the Penrose drain is cut and removed.

Step 6 *Perform cardiomyotomy*

A cardiomyotomy is always performed contralateral to the stapled diverticulum. It extends approximately 7 cm cranially onto the esophagus and not less than 3 cm caudally onto the anterior wall of the stomach, until the first branch of the left gastric artery (Fig. 12.6). The cardiomyotomy is always started above the gastroesophageal junction and is continued distally onto the stomach; it is performed with a combination of blunt dissection with a laparoscopic Maryland dissector and division of the circular fibers with the Ligasure™. An intra-abdominally placed plastic ruler helps with the documentation of the execution of a cardiomyotomy of an appropriate length. The anterior vagus nerve is always preserved during this portion of the operation, as the cardiomyotomy is continued below it onto the anterior gastric wall.

Step 7 *Closure of the hiatus*

After the cardiomyotomy is completed, the hiatus is always closed with a few intracorporeally tied, interrupted #0 silk sutures. Gentle lateral traction of the stomach with a laparoscopic Allis clamp assists with this task. In closing the hiatus, it is important to be careful to avoid an extrinsic esophageal stenosis and prevent postoperative dysphagia. To avoid this complication (or a more dangerous leak of the staple line resulting from an outflow obstruction), the uppermost crural stitch is placed approximately 1 cm posterior to the esophagus. If the diaphragm was split anteriorly to gain better access into the posterior mediastinum, that defect is closed anteriorly with one or two intracorporeally tied, interrupted #0 silk sutures.

Step 8 *Addition of a partial fundoplication*

This step involves the division of the short gastric vessels with the Ligasure™ and the creation of a Dor (partial anterior) fundoplication. The fundoplication is fashioned by suturing the gastric fundus laterally to the apex of the left crus and the left edge of the myotomy. The stomach is then folded over the myotomy. Lastly, the gastric fundus is sutured superiorly along the diaphragmatic hiatus and then medially onto the right edge of the myotomy (Fig. 12.7). Intracorporeally tied, 2-0 silk interrupted sutures are used for this portion of the operation.

At the end of the operation, the Nathanson retractor and all trocars are removed under direct visualization. The fascia of the optical port and the 12-mm incision are closed with a figure-of-eight 2-0 absorbable suture. The Foley catheter is removed in the operating room before extubation.

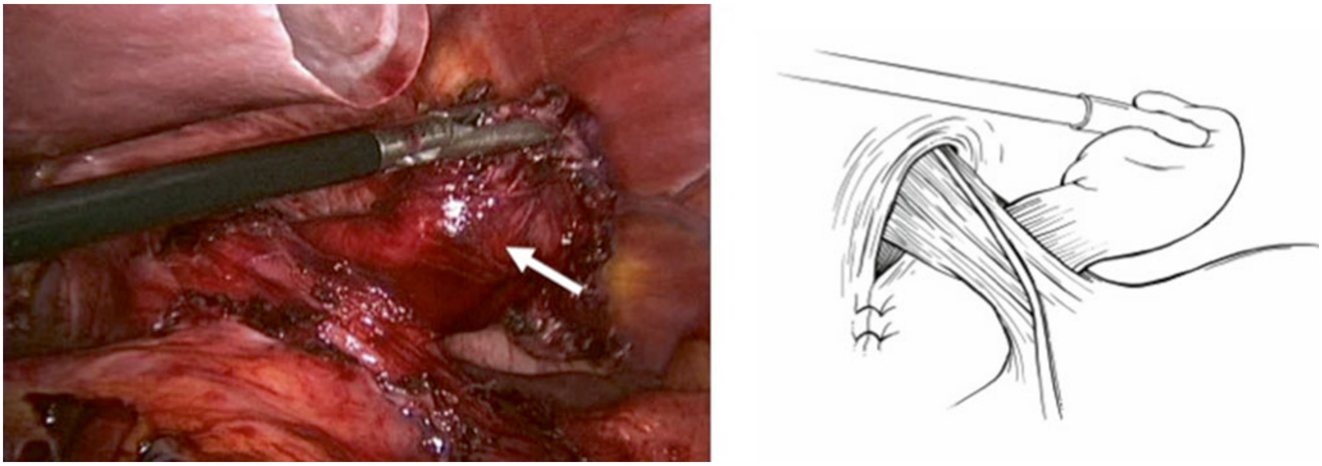

Fig. 12.3 Dissection and identification of the diverticulum (*arrow*)

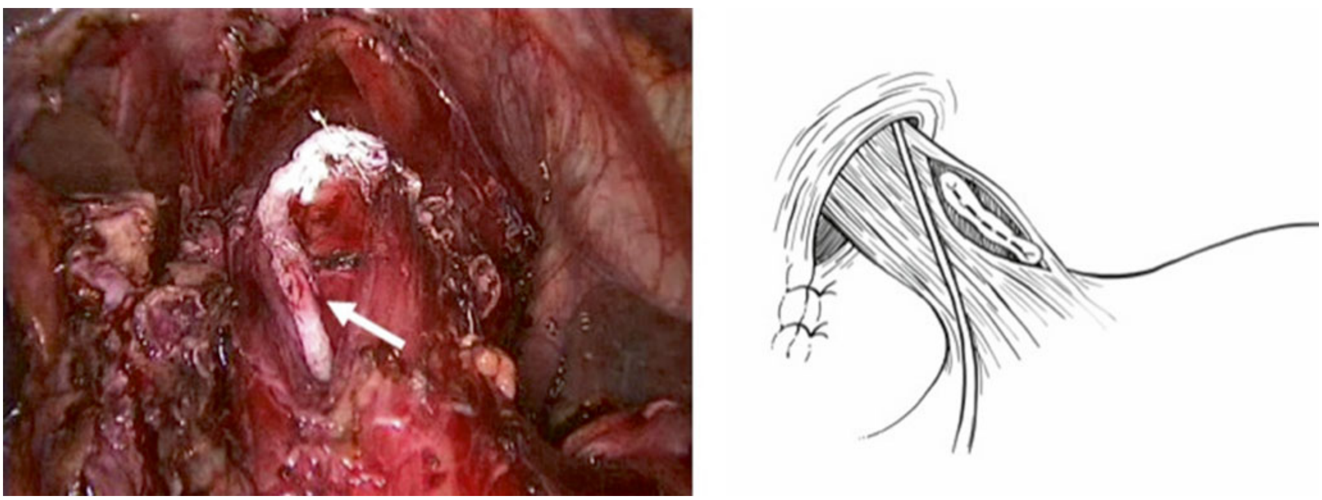

Fig. 12.4 Stapling of the diverticulum. *Arrow* indicates staple line in the esophageal submucosa

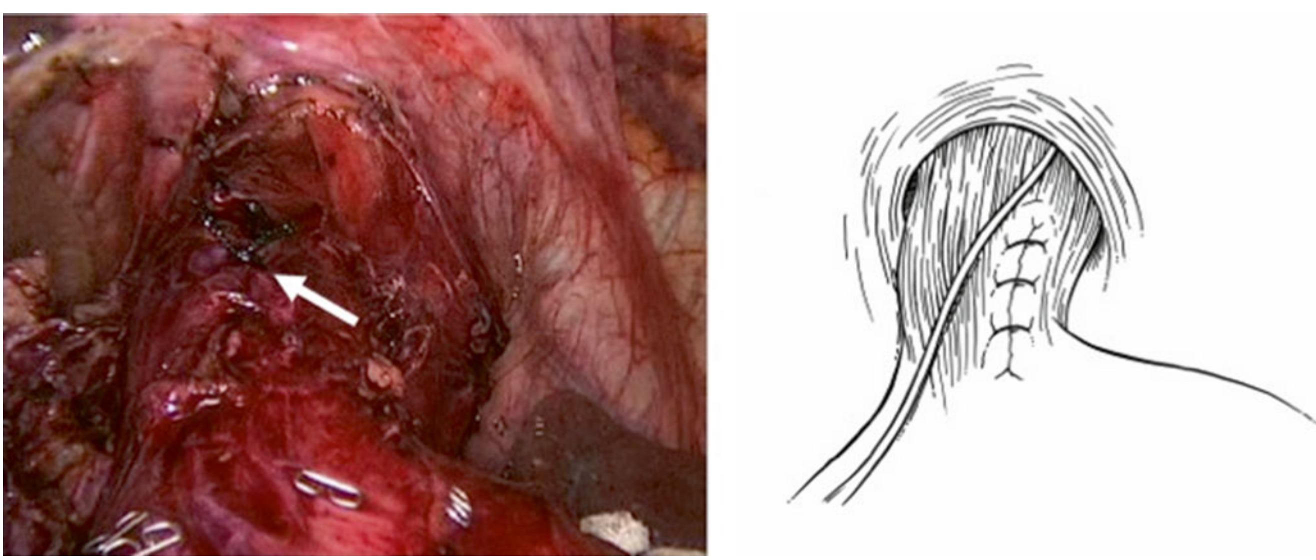

Fig. 12.5 Closure of the esophagus with a few interrupted sutures (*arrow*)

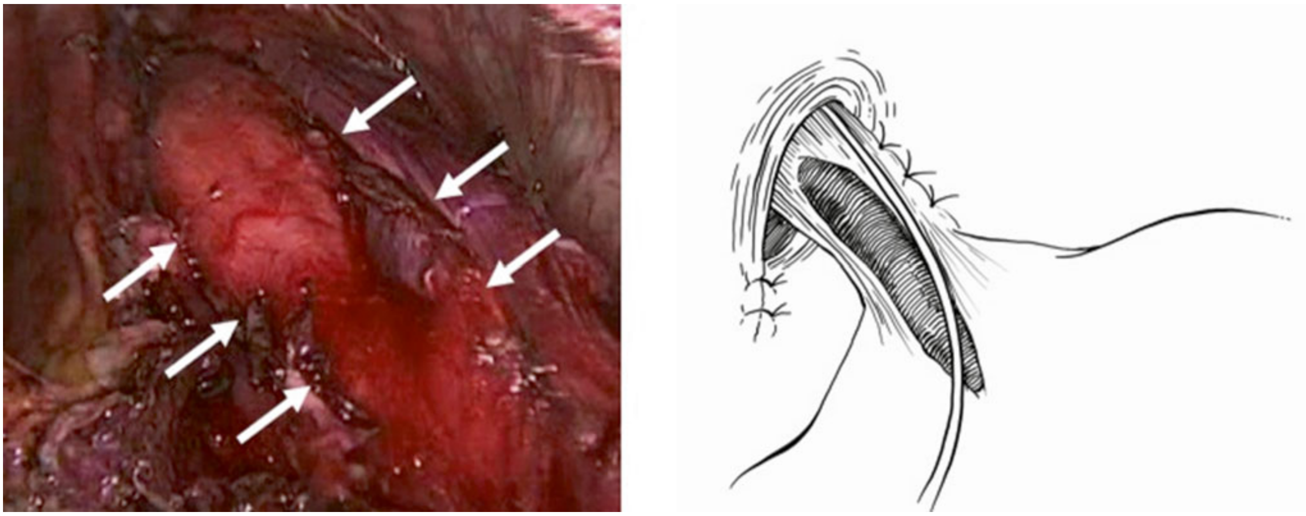

Fig. 12.6 Cardiomyotomy completed with the submucosa exposed between the edges of the myotomy (*arrows*)

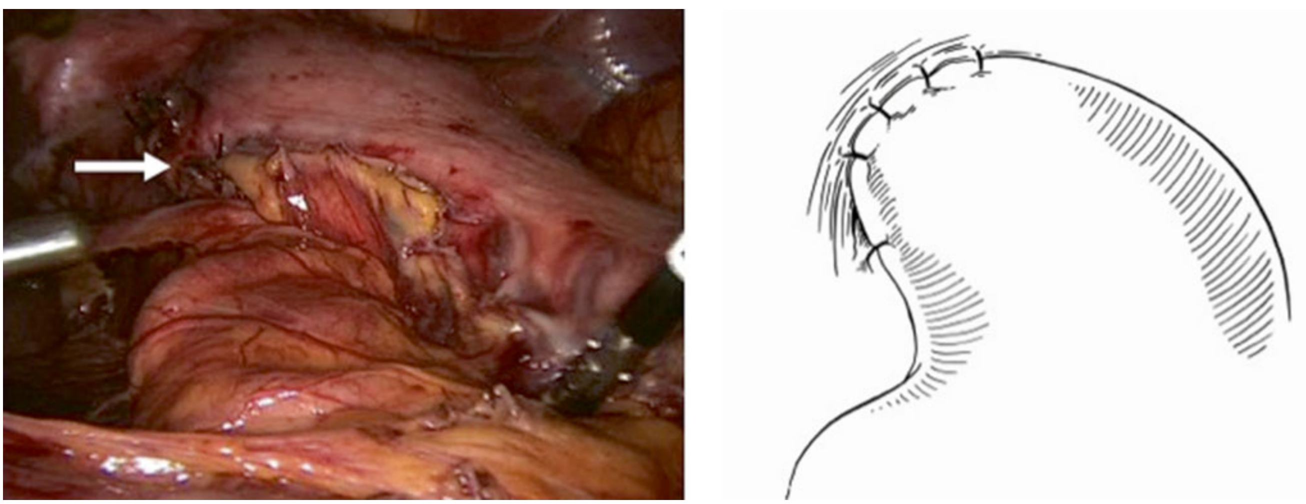

Fig. 12.7 Partial anterior fundoplication. The gastric fundus is sutured superiorly along the diaphragmatic hiatus and then medially onto the right edge of the myotomy (*arrow*)

12.3 Postoperative Care

Postoperatively, all patients are admitted overnight and started on a soft mechanical diet the morning of postoperative day 1, after a leak has been ruled out by Gastrografin and a barium swallow. They are then discharged home and asked to keep this dietary regimen for 1 week postoperatively, after which they are seen in clinics for their first follow-up and instructed to resume an unrestricted diet.

12.4 Tips and Troubleshooting

An orogastric tube is seldom placed for this operation. After induction, its blind positioning may risk forcing the tip of the tube against the wall of the diverticulum, perforating it. Moreover, a rapid sequence intubation usually prevents the overdistention of the stomach. Overdistention is rarely a concern during this operation, especially in patients with achalasia, in whom the nonrelaxing lower esophageal sphincter prevents gastric distention. Nevertheless, to further prevent aspiration on induction, all patients with achalasia are advised to keep a clear liquid diet for about a week before the operation, and an nasoesophageal tube is carefully placed preoperatively in those with a dilated esophagus (transverse diameter >6 cm on barium esophagogram) to evacuate longstanding undigested food mixed with salivary secretions. Occasionally, an orogastric tube is placed intraoperatively to decompress an overdistended stomach, but it is promptly removed, and the patient leaves the operating room without a gastric tube.

An upper endoscopy is seldom performed to assess the adequacy of the cardiomyotomy or the integrity of the staple line of the diverticular neck, but it is always performed in difficult cases, when a mucosal perforation is suspected. In these instances, the mucosa is submerged under saline during gentle insufflation. Perforations discovered are usually small (a few millimeters), and the mucosal tissue is immediately closed with one or two intracorporeally tied interrupted sutures (2-0 absorbable). Then, a Dor fundoplication allows ample coverage of the repaired perforation.

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13 Laparoscopic Operations for Esophageal Leiomyoma

Bernardo Borraez and Marco G. Patti

This chapter describes the preoperative work-up, operative planning, and the laparoscopic enucleation of esophageal leiomyoma.

13.1 Clinical History

The patient is a 38-year-old woman who started experiencing progressive dysphagia 6 months prior to her presentation. An endoscopy showed a submucosal mass in the distal esophagus. The mucosa overlying the mass was normal. An endoscopic ultrasound confirmed the presence of the mass in the distal esophagus and showed a similar mass in the proximal stomach along the lesser curvature. A CT scan confirmed the finding.

It was decided to attempt a laparoscopic excision of both the gastric and the esophageal masses. The preoperative tests were not able to determine whether there were two separate tumors or only one tumor.

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13.2 Operation

13.2.1 Patient Positioning

The patient lies supine on the table over a bean bag (inflated to prevent sliding in reverse Trendelenburg position). The legs are extended on stirrups, and the knees are flexed at an angle of 20–30°.

The surgeon performs the procedure standing between patient's legs, with two assistants on the right and left sides of the operating table (Fig. 13.1).

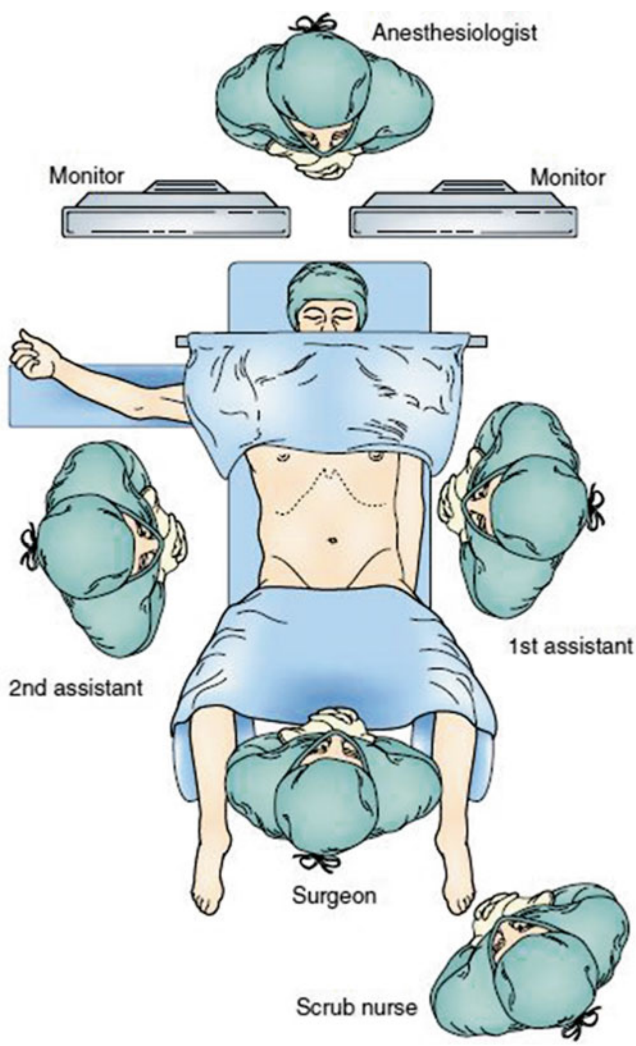

Fig. 13.1 Setup of the operating room

13.2.2 Ports and Instruments

Five trocars (Fig. 13.2) are used for the procedure:

- *Trocar 1:* Placed 14 cm inferior to the xiphoid process in the midline (or 1–2 cm to the left of the midline to be in line with the hiatus). It is used for a 30° camera.
- *Trocar 2:* Placed in the left mid clavicular line (at the same level as trocar 1). It is used for a Babcock clamp, a grasper to hold the Penrose drain, or an instrument used to divide the short gastric vessels.
- *Trocar 3:* Placed in the right mid-clavicular line (at the same level as the first two trocars). It is used for the insertion of a liver retractor.
- *Trocars 4 and 5:* Placed under the right and left costal margins. They are used for the suturing and dissecting instruments.

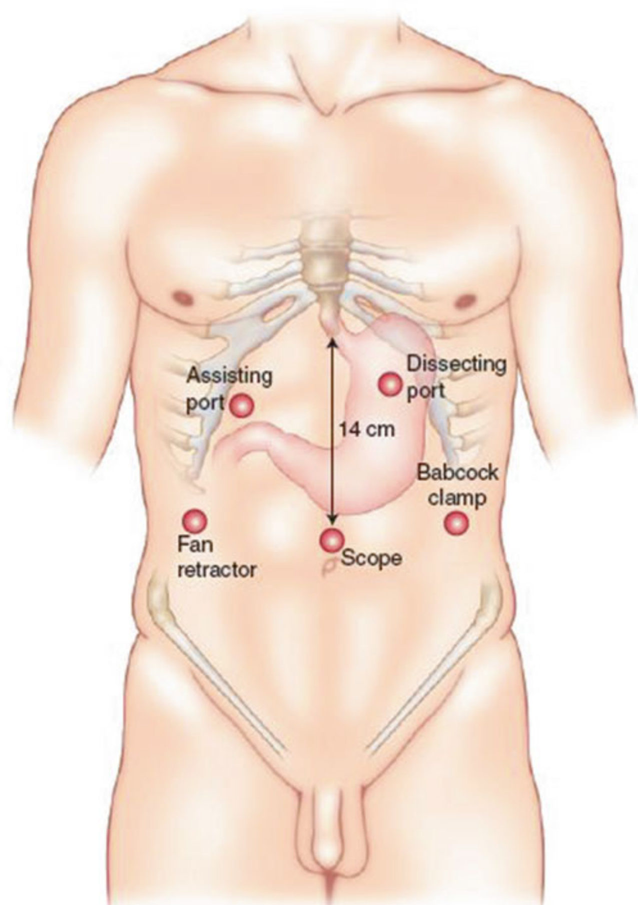

Fig. 13.2 The positions and functions of the five trocars

13.2.3 Operative Procedure

Step 1 *Division of the gastrohepatic ligament, peritoneum, and phrenoesophageal membrane*

The gastrohepatic ligament is divided, beginning above the caudate lobe of the liver (Figs. 13.3 and 13.4). The peritoneum and the phrenoesophageal membrane above the esophagus are transected with electrocautery, and the anterior vagus nerve is identified (Fig. 13.5). The left crus of the diaphragm is dissected downward toward the junction with the right crus (Fig. 13.6).

Step 2 *Dissection of the gastric component*

The gastric component of the tumor is identified (Figs. 13.7 and 13.8), and the short gastric vessels are divided with a bipolar instrument (Figs. 13.9 and 13.10).

The tumor is dissected using a combination of the electrocautery and the bipolar instrument (Figs. 13.11, 13.12, 13.13, 13.14, 13.15, 13.16, 13.17, 13.18, 13.19, and 13.20). It is possible to identify the characteristic "mother of pearl" appearance of the tumor capsule. Particular attention is given to avoiding a thermal or traction injury to the mucosa.

Step 3 *Dissection of the esophageal component*

The esophageal component of the tumor is carefully separated from the esophageal mucosa using a combination of blunt dissection, hook cautery, and a bipolar instrument (Figs. 13.21, 13.22, 13.23, 13.24, 13.25, 13.26, 13.27, 13.28, 13.29, and 13.30).

The esophageal mucosa is carefully inspected (Figs. 13.31 and 13.32). An orogastric tube is then placed just proximal to the diaphragm, and methylene blue is injected to rule out a hole in the mucosa.

Step 4 *Construct dor fundoplication*

After the excision of the tumor, the edges of the muscle layers in this patient were far apart, so we did not try to approximate them over the mucosa for fear of significantly narrowing the esophageal lumen. We decided to cover the exposed mucosa with a Dor fundoplication, similar to what we do after a Heller myotomy for achalasia.

An anterior partial fundoplication (Dor fundoplication) is constructed using two rows of sutures. The first row of sutures is on the left and has three stitches. The first stitch (superior) is triangular, and incorporates the gastric fundus, the left side of the esophageal wall, and the left pillar of the crus (Fig. 13.33). The second stitch and the third stitches incorporate the esophageal and the gastric wall (Fig. 13.34). The second row of sutures is on the right side. Usually three stitches are used, which incorporate the right pillar of the crus and the gastric fundus (Fig. 13.35). Finally, two or three stitches are placed in the apical portion between the gastric fundus and the rim of the esophageal hiatus (Fig. 13.36). The Dor fundoplication then completely covers the exposed mucosa (Fig. 13.37).

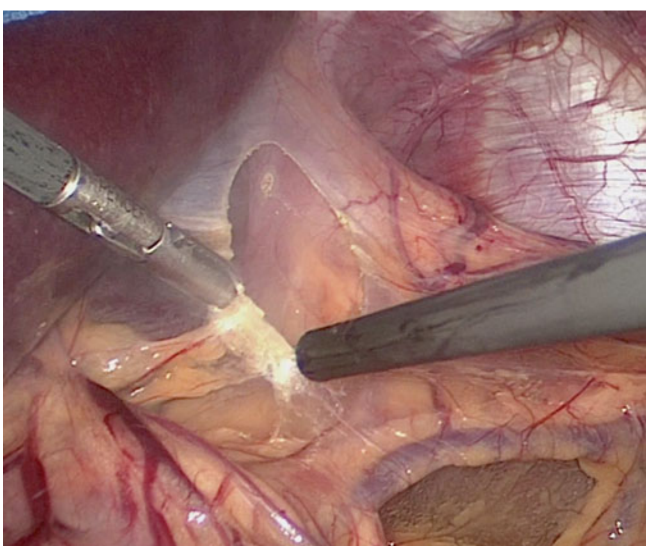

Fig. 13.3 Division of the gastrohepatic ligament

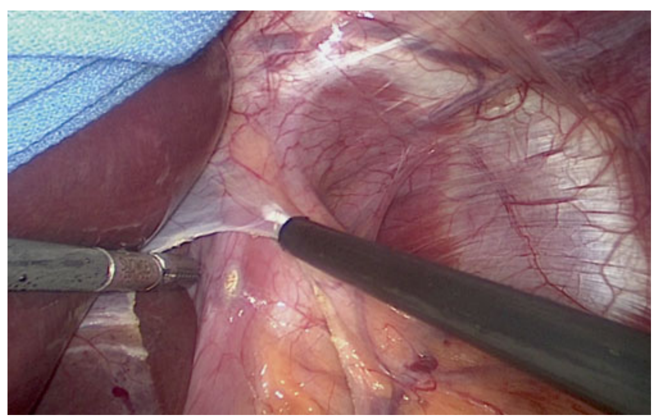

Fig. 13.4 Division of the gastrohepatic ligament

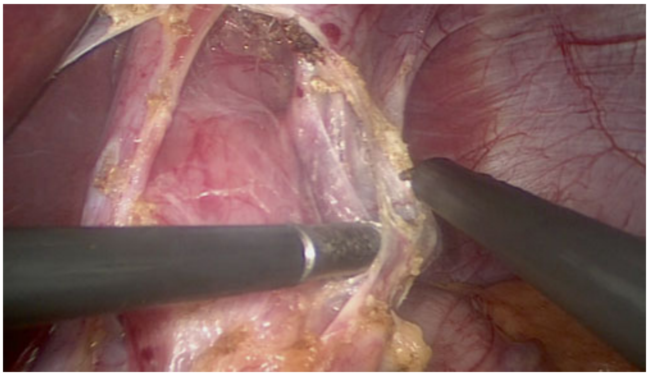

Fig. 13.5 Transection of the peritoneum and the phrenoesophageal membrane above the esophagus, using electrocautery

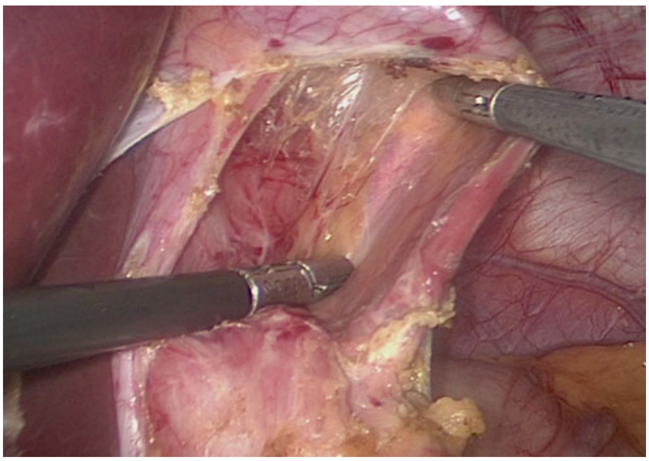

Fig. 13.6 The left crus of the diaphragm is dissected downward toward the junction with the right crus

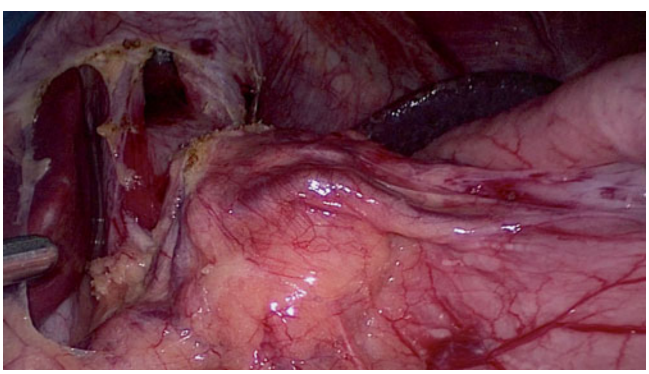

Fig. 13.7 Identification of the gastric component of the tumor

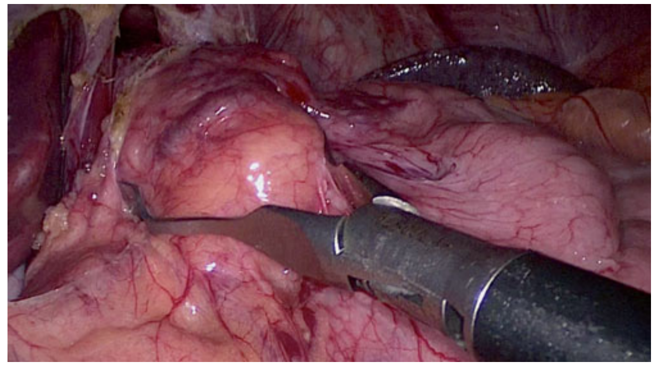

Fig. 13.8 Identification of the gastric component of the tumor

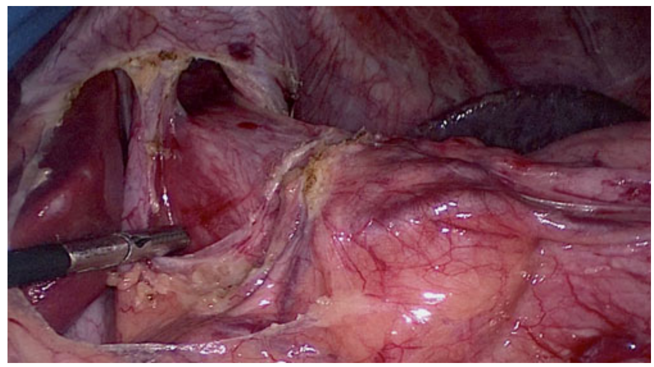

Fig. 13.9 Division of the short gastric vessels

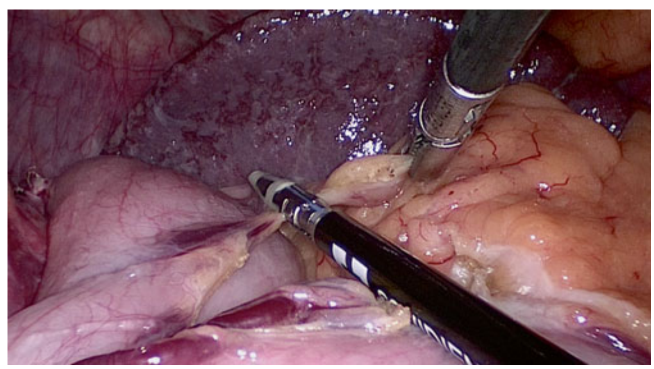

Fig. 13.10 Division of the short gastric vessels

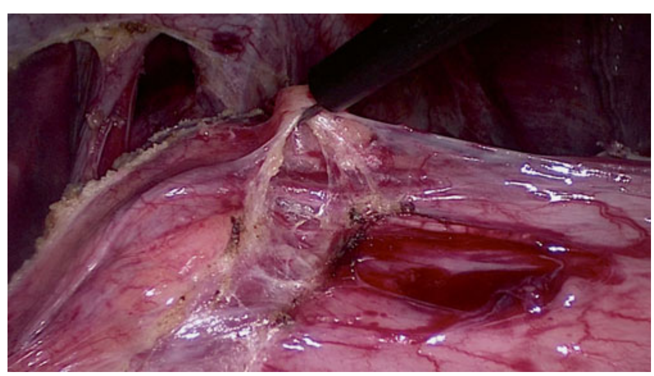

Fig. 13.11 Dissection of the gastric component of the tumor

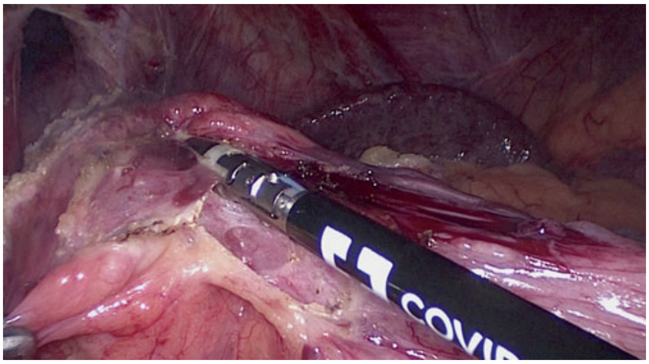

Fig. 13.12 Dissection of the gastric component of the tumor

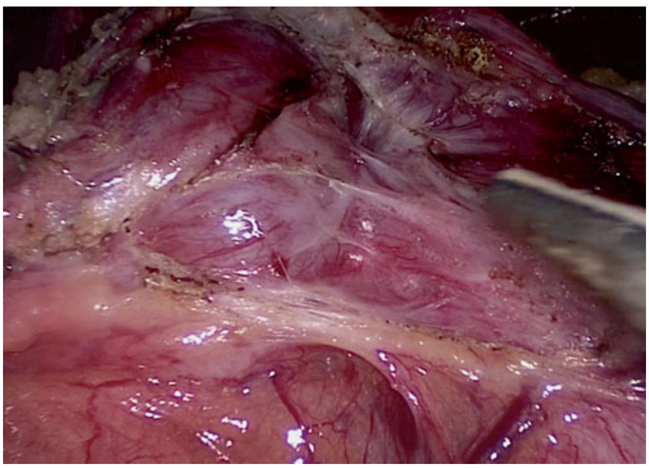

Fig. 13.13 Dissection of the gastric component of the tumor

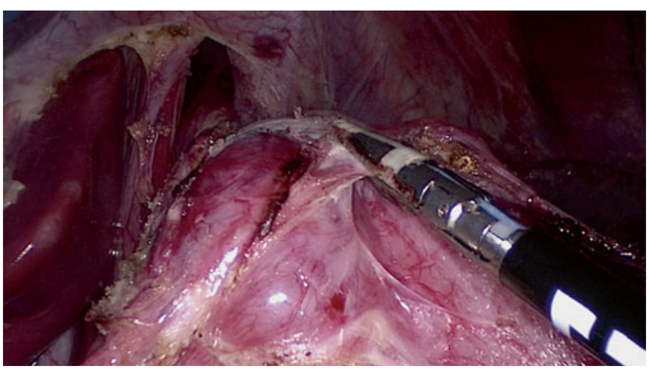

Fig. 13.14 Dissection of the gastric component of the tumor

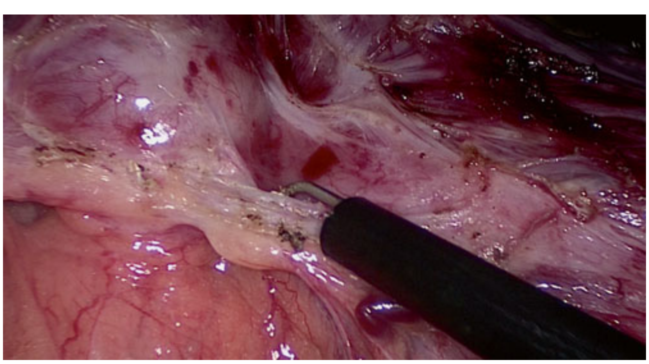

Fig. 13.15 Dissection of the gastric component of the tumor

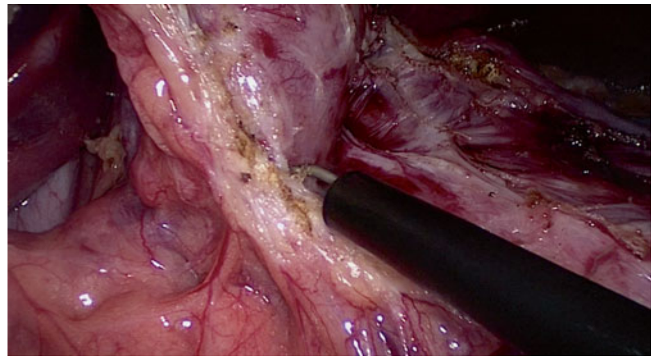

Fig. 13.16 Dissection of the gastric component of the tumor

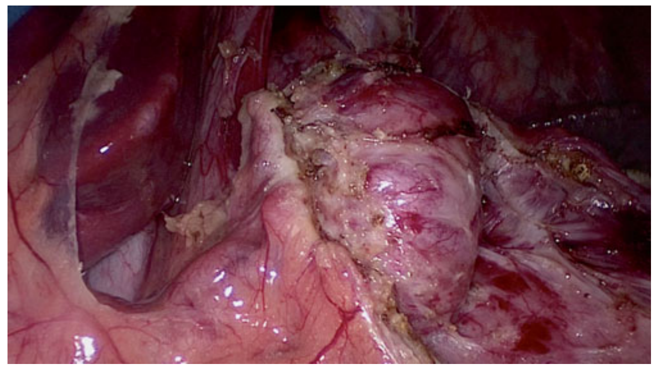

Fig. 13.17 Dissection of the gastric component of the tumor

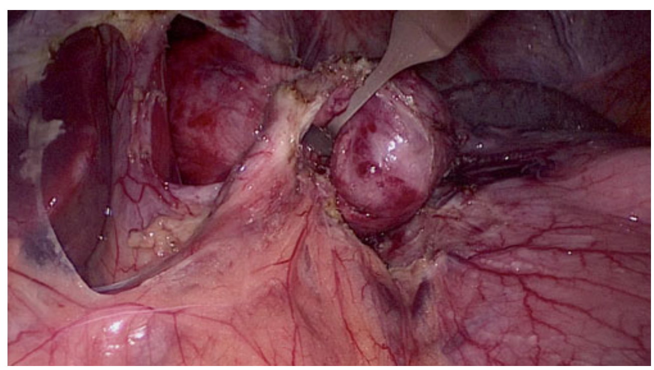

Fig. 13.18 Dissection of the gastric component of the tumor

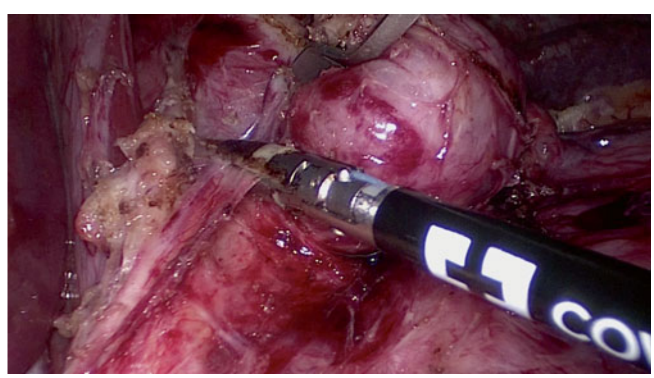

Fig. 13.19 Dissection of the gastric component of the tumor

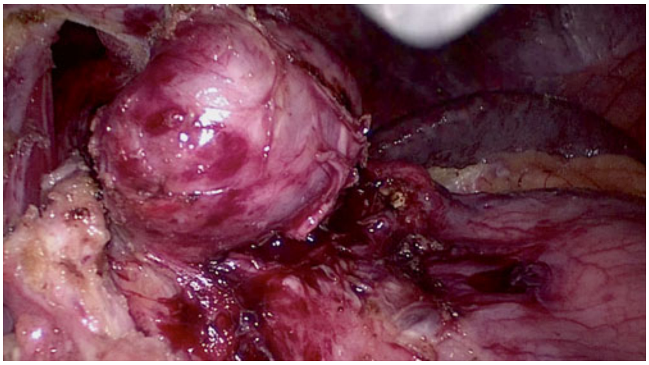

Fig. 13.20 Dissection of the gastric component of the tumor

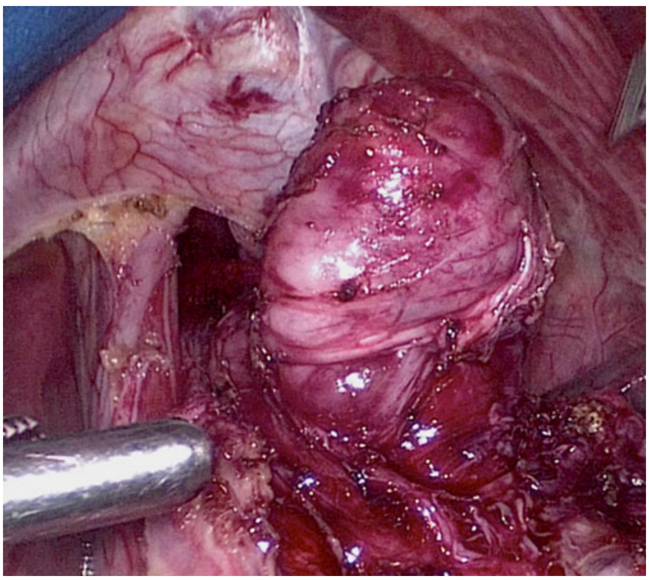

Fig. 13.21 Dissection of the esophageal component of the tumor

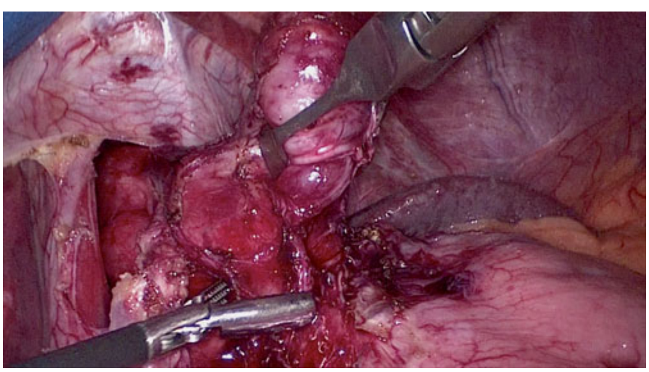

Fig. 13.22 Dissection of the esophageal component of the tumor

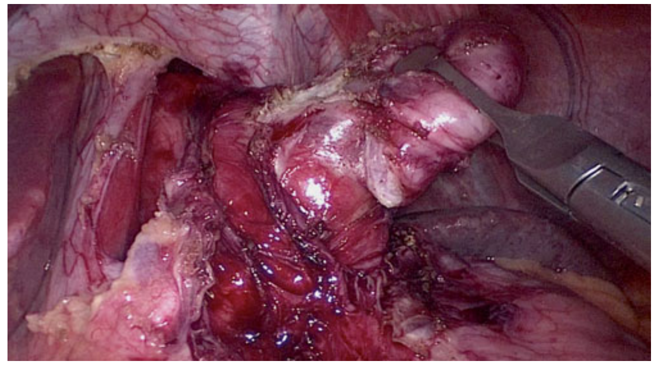

Fig. 13.23 Dissection of the esophageal component of the tumor

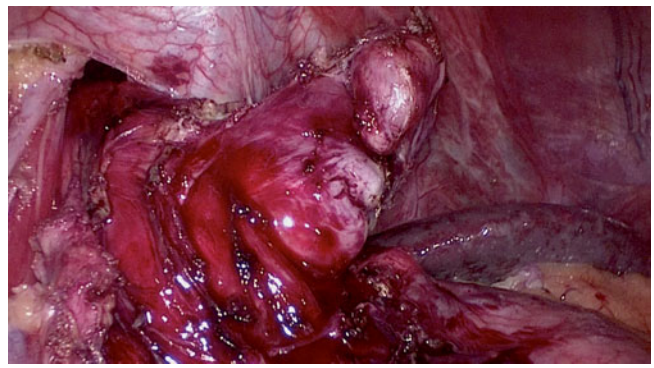

Fig. 13.24 Dissection of the esophageal component of the tumor

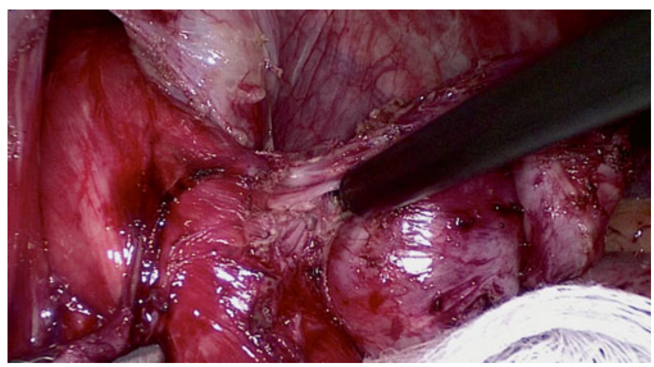

Fig. 13.25 Dissection of the esophageal component of the tumor

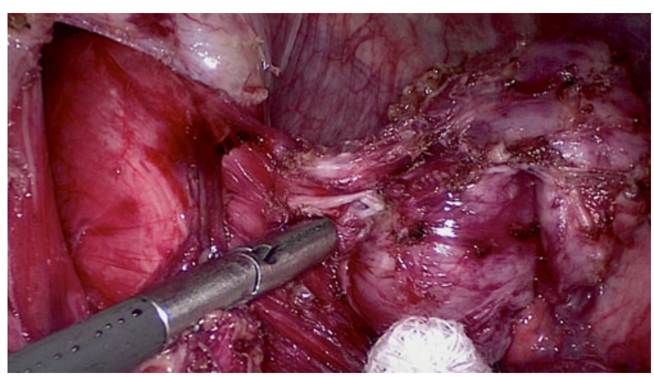

Fig. 13.26 Dissection of the esophageal component of the tumor

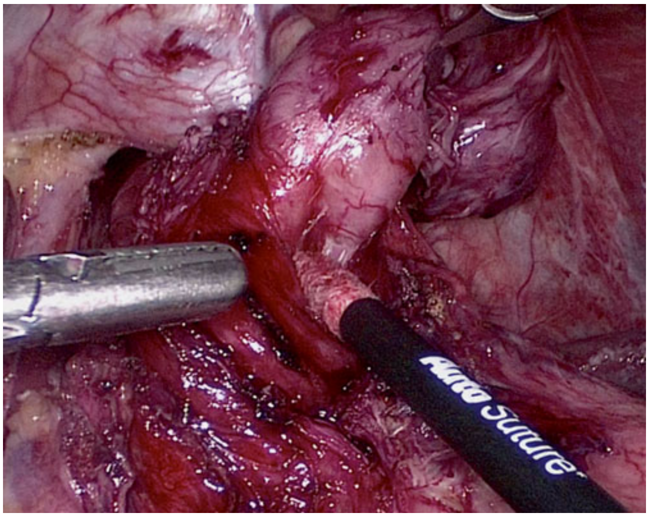

Fig. 13.27 Dissection of the esophageal component of the tumor

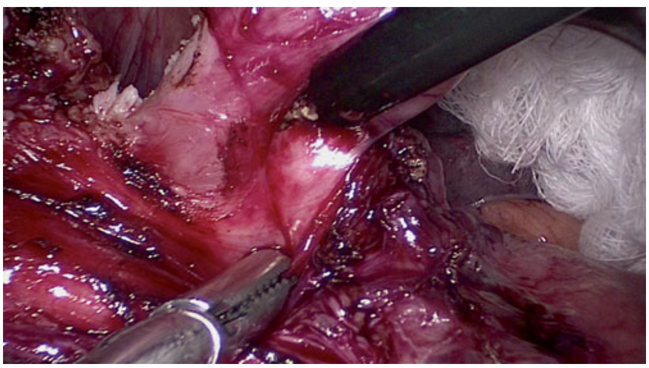

Fig. 13.28 Dissection of the esophageal component of the tumor

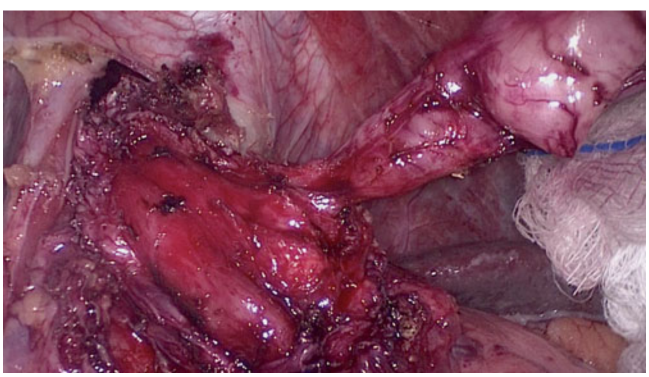

Fig. 13.29 Dissection of the esophageal component of the tumor

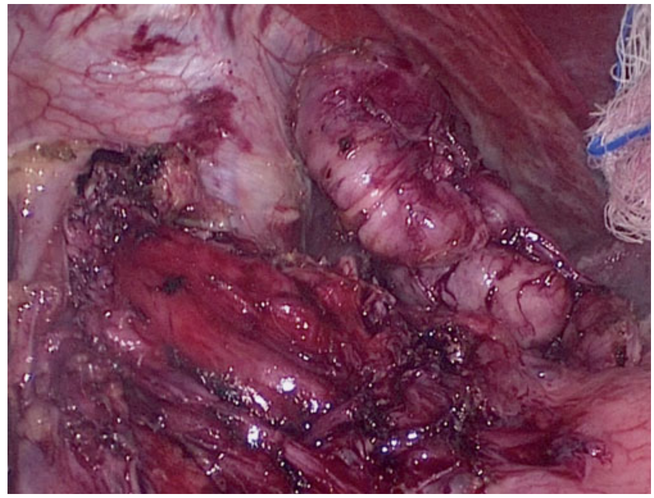

Fig. 13.30 Dissection of the esophageal component of the tumor. The submucosa is exposed completely

Fig. 13.31 Inspection of the esophageal submucosa

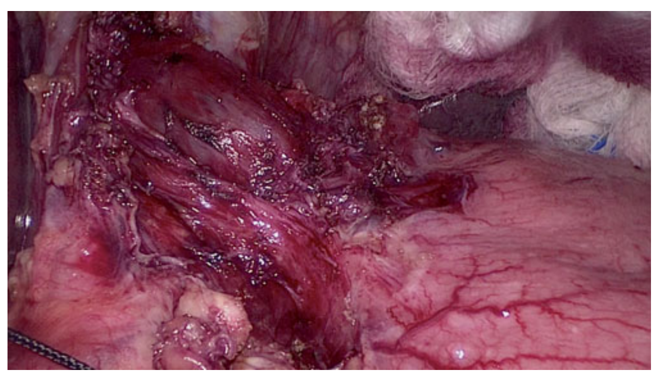

Fig. 13.32 Inspection of the esophageal mucosa

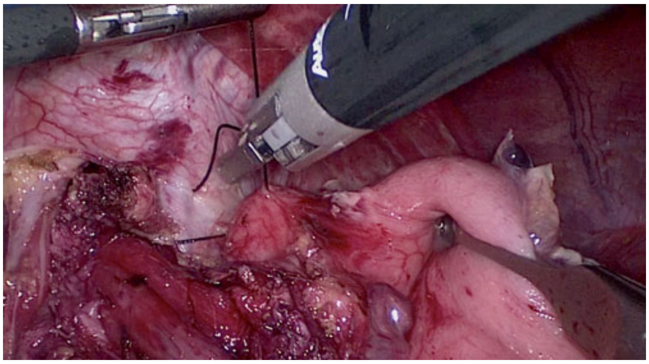

Fig. 13.33 Creation of an anterior partial fundoplication (Dor fundoplication). Left row of sutures

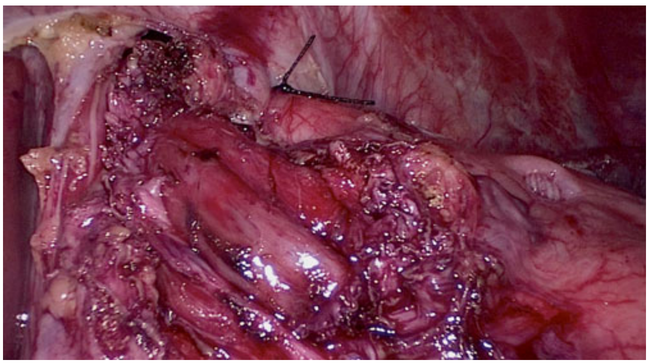

Fig. 13.34 Creation of an anterior partial fundoplication (Dor fundoplication). Left row of sutures

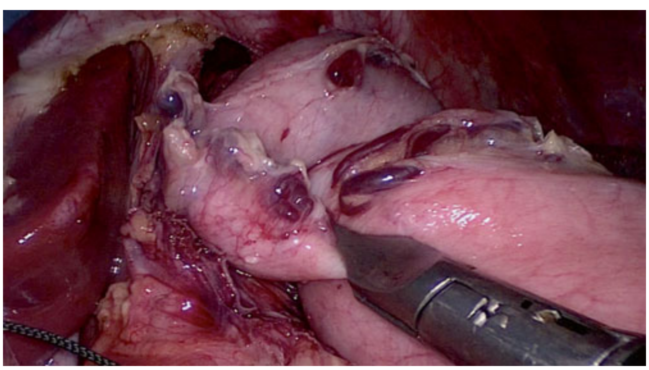

Fig. 13.35 Creation of an anterior partial fundoplication (Dor fundoplication). The fundus of the stomach is folded over the submucosa

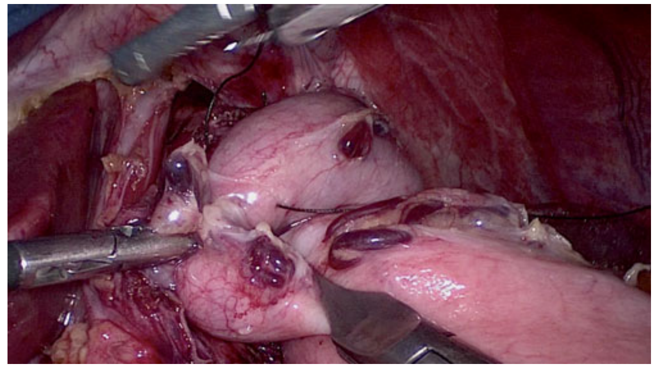

Fig. 13.36 Creation of an anterior partial fundoplication (Dor fundoplication). Right row of sutures

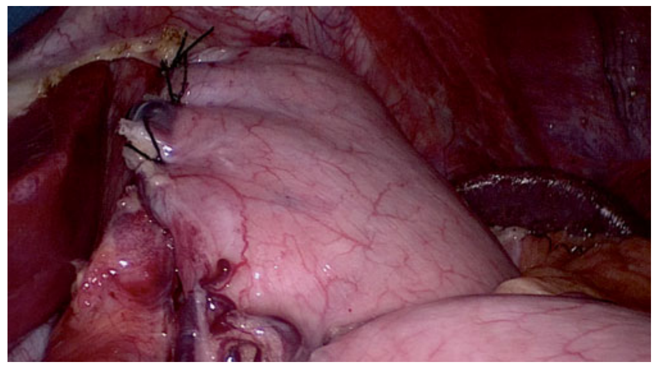

Fig. 13.37 Creation of an anterior partial fundoplication (Dor fundoplication). Right row of sutures

13.3 Postoperative Course

The patient was extubated in the operating room and admitted to a surgical unit. She had liquids for breakfast on the first postoperative day. She tolerated a soft diet for lunch and dinner, and she was discharged home the morning of postoperative day 2. Pathology showed a leiomyoma.

The patient has been doing well for 2 years since the operation, with no evidence of recurrence of the tumor, heartburn, or dysphagia.

Acknowledgement Images taken with SPIES system. Courtesy of Storz.

Selected Reading

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Roux-en-Y Gastric Bypass for GERD and Morbid Obesity

14

P. Marco Fisichella, Mauricio Ramirez, and Vivek Prachand

14.1 Clinical History

The patient is a 33-year-old morbidly obese man with a BMI of 45. Comorbidities include gastroesophageal reflux disease (GERD) with daily heartburn and regurgitation, hypertension, asthma, sleep apnea, and degenerative osteoarthritis. A workup showed the following findings:

- Endoscopy: Los Angeles grade A esophagitis
- Esophageal manometry: normal peristalsis and normal resting pressure and relaxation of the lower esophageal sphincter
- Esophageal pH monitoring: GERD, with a DeMeester score of 34 (normal <14.7)

This patient was offered a laparoscopic Roux-en-Y gastric bypass instead of a laparoscopic Nissen fundoplication because the surgical treatment of GERD independent of the primary achievement of weight loss presents several potential disadvantages:

- Failure to act on the distinct pathophysiologic mechanism of GERD in the obese patient population
- Increase in the long-term failure rate of antireflux surgery
- Increase in the difficulty and morbidity of later bariatric surgery in those who eventually elect a gastric bypass
- Detrimental effects on the overall well-being of obese patients, whose comorbidities will not improve without a gastric bypass.

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P.M. Fisichella, M.G. Patti (eds.), *Atlas of Esophageal Surgery*, DOI 10.1007/978-3-319-13015-6_14

14.2 Operation

14.2.1 Patient Positioning

Figure 14.1 illustrates the position of the patient and the operative team. A hoover mattress is placed on the operative table. The operative table should be slid all the way down to allow for maximal reverse Trendelenburg. A cover on the ramp should be placed under the patient's head and back. Once the patient is intubated, a Foley catheter and an orogastric tube are inserted. A footboard is positioned with padding so that the feet lie flat, the legs are taped around the bed, and the arms are abducted on arm-board with padding or blankets. The full reverse Trendelenburg position is tested prior to the operation. After the patient is intubated, the ramp is pulled.

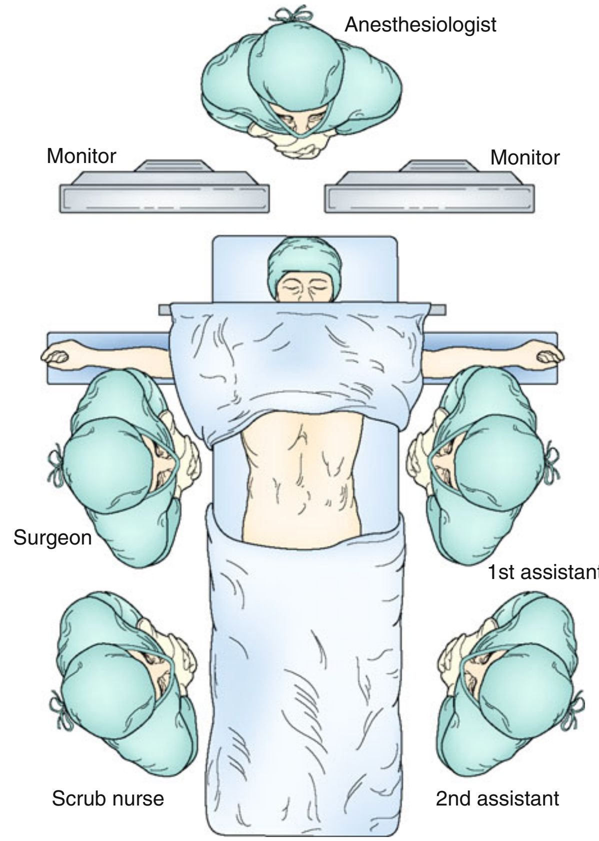

Fig. 14.1 The position of the patient and the operative team

14.2.2 Port Placement

Figure 14.2 illustrates the position of trocars, which follow a "V" configuration. While the patient is in the supine position, a 12-mm optical port is placed to the left and just superior to the umbilicus, using a 0° laparoscope. The abdomen is insufflated, and the laparoscope is changed to a 45° laparoscope. The assistant places a 15-mm port very lateral just below the right costal margin as seen laparoscopically; this port will allow the placement of the EEA™ Stapler (Covidien; Minneapolis, MN). An additional 12-mm port is placed in the mid-upper right quadrant; another 12 mm port is placed between the 12 and 15 mm ports. The Nathanson retractor is inserted in the epigastrium to retract the lateral portion of the left lobe of the liver away from the hiatus; it is then secured to the operative table.

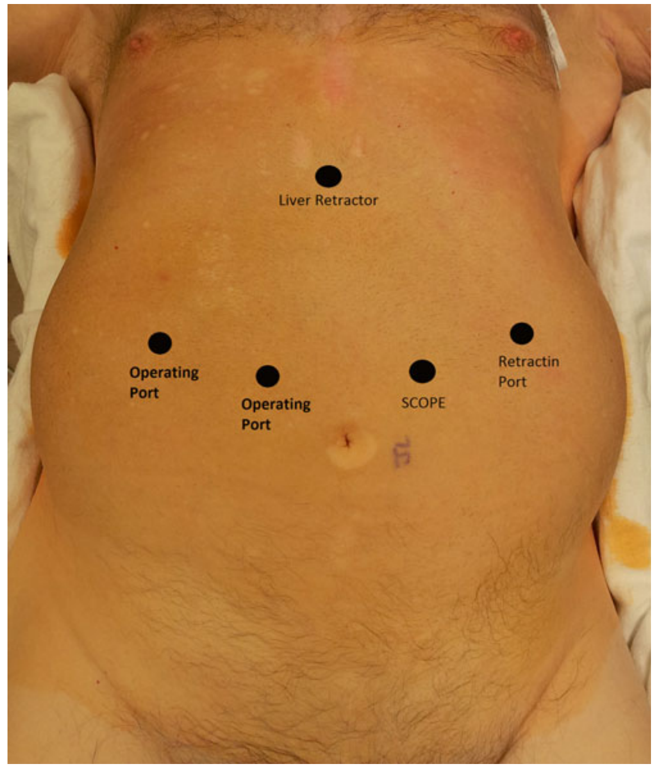

Fig. 14.2 Port placement

14.2.3 Operative Procedure

Step 1 *Create the gastric pouch*

Figures 14.3, 14.4, 14.5, 14.6, 14.7, 14.8, 14.9, and 14.10 show the steps in creating the gastric pouch. The patient is placed in fully steep reverse Trendelenburg. The gastro-esophageal fat pad is excised from the stomach until the left crus is visible. If a hernia is found, an anterior repair is performed at this time by stitching the apex of the left and right crus anteriorly with a 2-0 silk suture. At this time, the orogastric tube and the esophageal temperature probe are removed. The hepatogastric ligament is incised and access to the posterior gastric wall is gained by transecting the omentum of the lesser sac with a stapler. The dissection of the posterior wall of the stomach is continued and the pouch is created by firing one more load transversely and two more loads longitudinally towards the angle of His. At this time, the surgeon should make sure that there is not too much stomach posteriorly on the pouch.

Step 2 *Divide the small bowel*

The patient is positioned supine. The omentum is retracted towards the right upper quadrant until the transverse colon is exposed and retracted upwards so that the ligament of Treitz is identified. The assistant then grasps the small bowel at approximately 30 cm distal to the ligament of Treitz. The small bowel is divided with a stapler (Fig. 14.11) and the jejunal mesentery is divided down to its root.

Step 3 *Create the gastro-jejunostomy*

Figures 14.12, 14.13, 14.14, 14.15, 14.16, 14.17, and 14.18 show the creation of the gastro-jejunostomy. The omentum is split anteriorly and the patient is placed in fully steep reverse Trendelenburg. The jejunum is measured roughly 150 cm and the proximal stapled end is placed in the right upper quadrant. Two stay sutures are placed between the pouch and jejunum. The pouch is opened and a manual anastomosis is performed with an Endo Stitch™ (Covidien), using a 2-0 running suture, first posteriorly and then anteriorly. The patient is placed supine and an air leak test is done using intraoperative endoscopy.

Step 4 *Create the jejuno-jejunostomy*

Figures 14.19, 14.20, and 14.21 show the creation of the jejuno-jejunostomy. Both the biliopancreatic (BP) limb and the Roux limb are approximated and secured with a 10-inch 2-0 Ethibond® suture (Ethicon, Somerville, NJ) 1 cm beyond the suture line of the BP limb, and with a 15-inch 2-0 Ethibond® suture next to the suture line of the BP limb. An enterotomy is created between the two stay sutures, and an enterostomy is created with the stapler. The enterotomy is closed with a running suture using the previously placed stitch. The mesentery is closed with the previously placed Ethibond® stay suture in a running, interlocking fashion.

Step 5 *Place drain, remove trocars, and close incisions*

A 15 Fr Jackson-Pratt drain is placed near the gastro-jejunal anastomosis. All trocars are removed and the 15-mm port figure-of-eight suture is tied. The fascia of the other ports is not closed. The wound incisions are closed primarily.

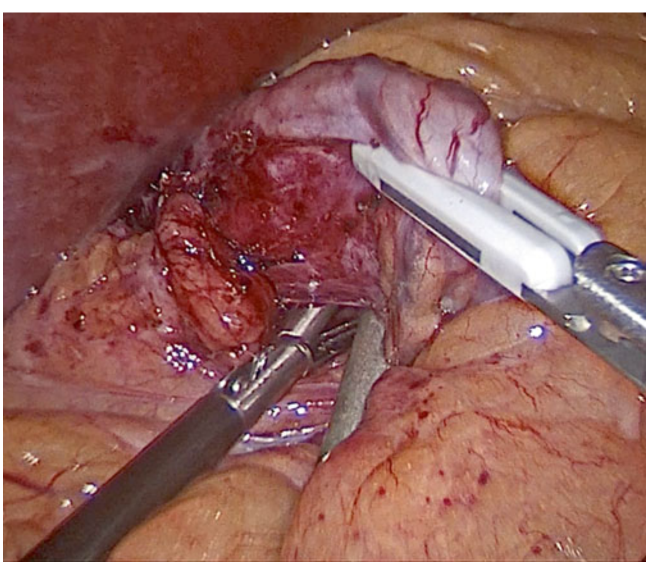

Fig. 14.3 Creation of the gastric pouch. The retrogastric window is created

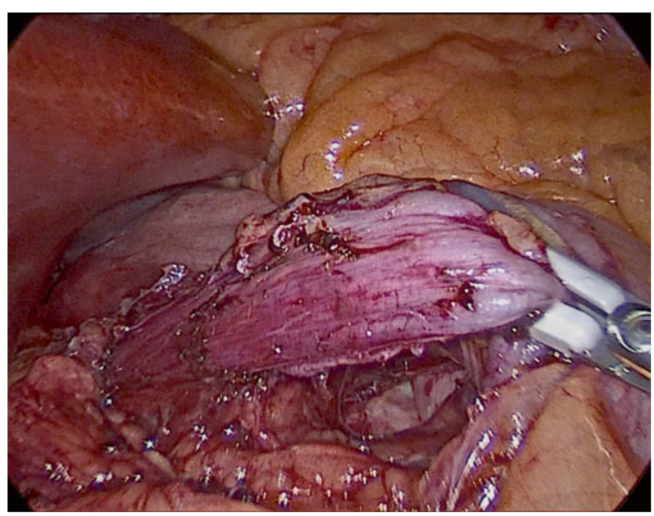

Fig. 14.4 Creation of the gastric pouch. The retrogastric window is created

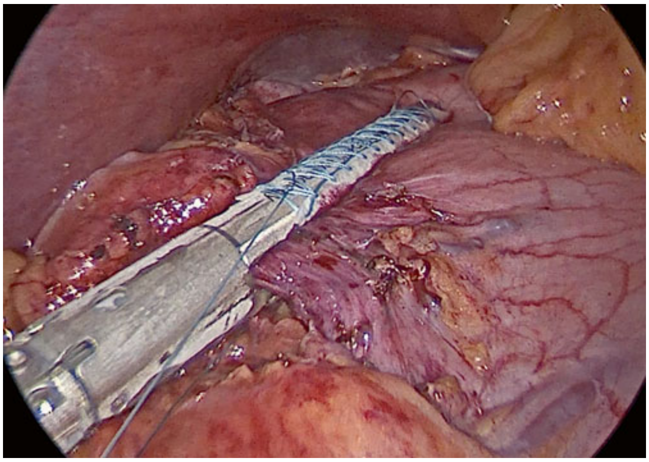

Fig. 14.5 Creation of the gastric pouch. Transverse transection of the stomach

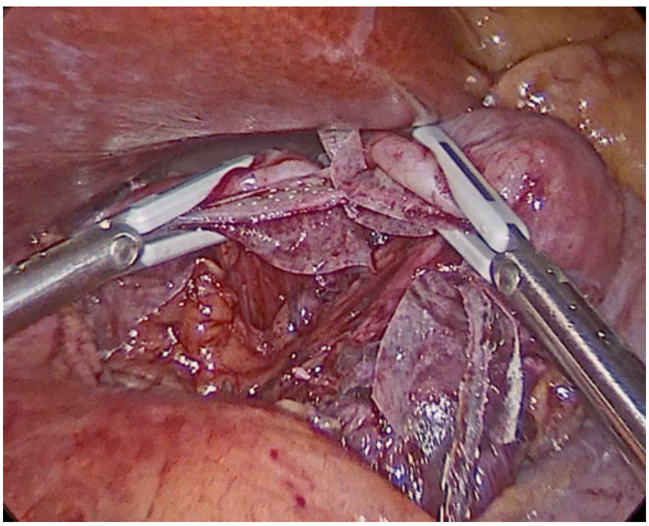

Fig. 14.6 Creation of the gastric pouch

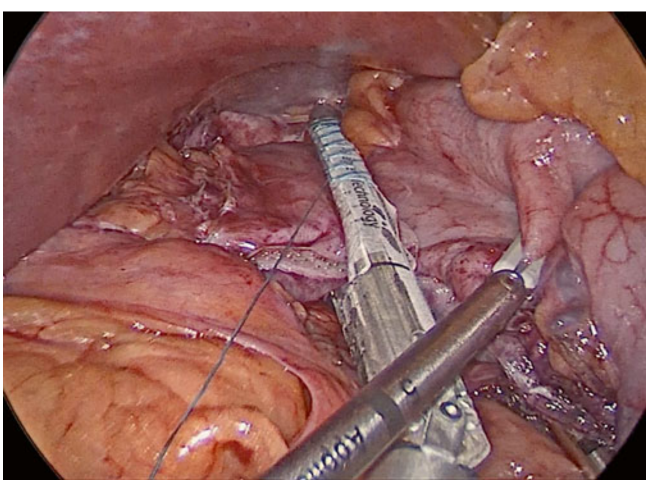

Fig. 14.7 Creation of the gastric pouch. Vertical transection of the stomach

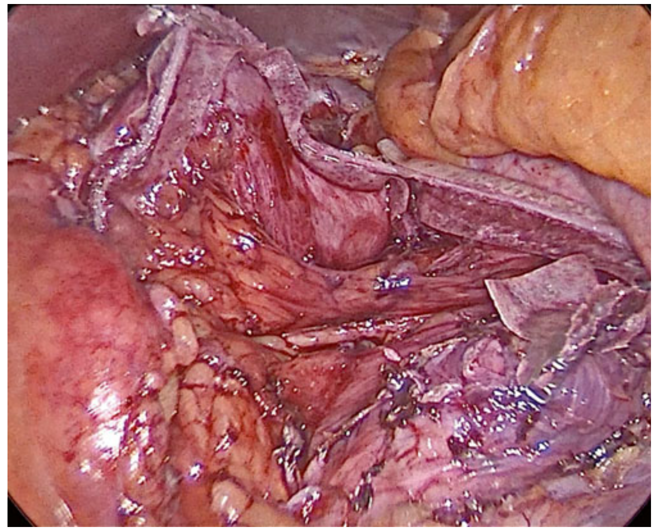

Fig. 14.8 Creation of the gastric pouch

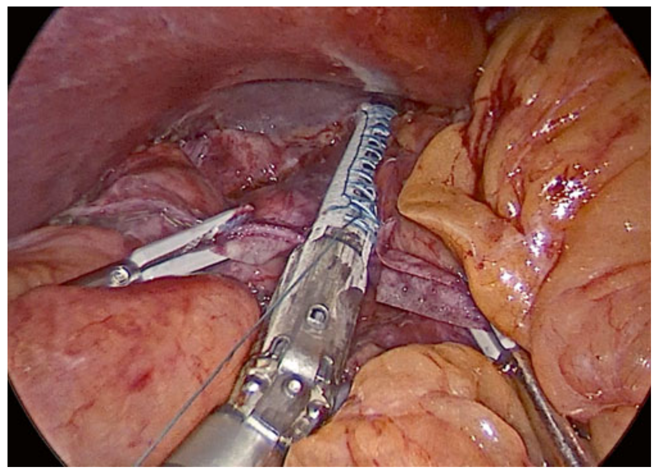

Fig. 14.9 Creation of the gastric pouch. Vertical transection of the stomach

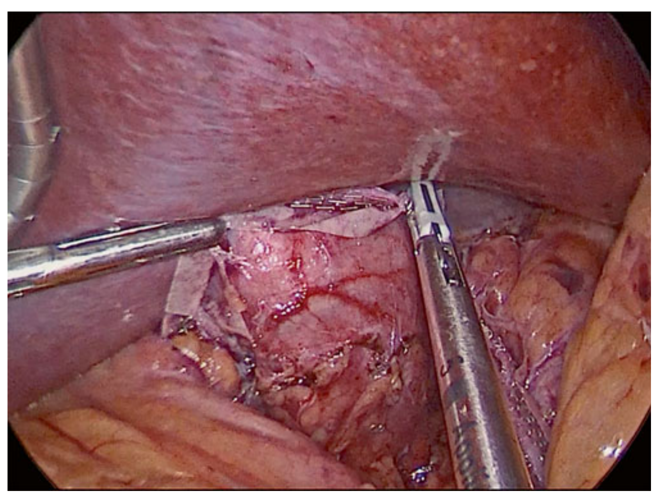

Fig. 14.10 Creation of the gastric pouch

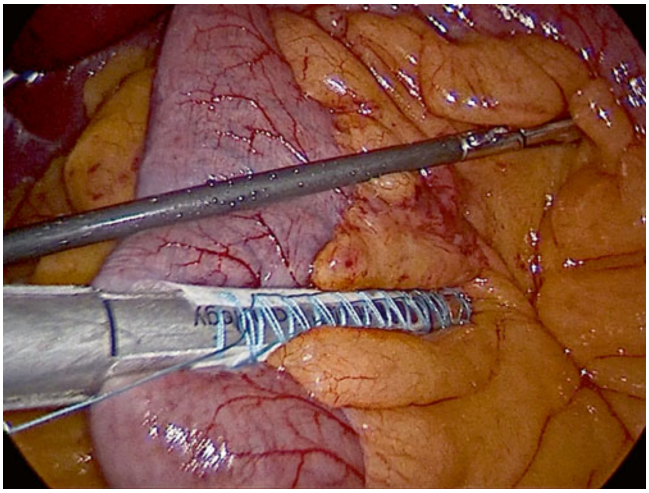

Fig. 14.11 Division of the small bowel

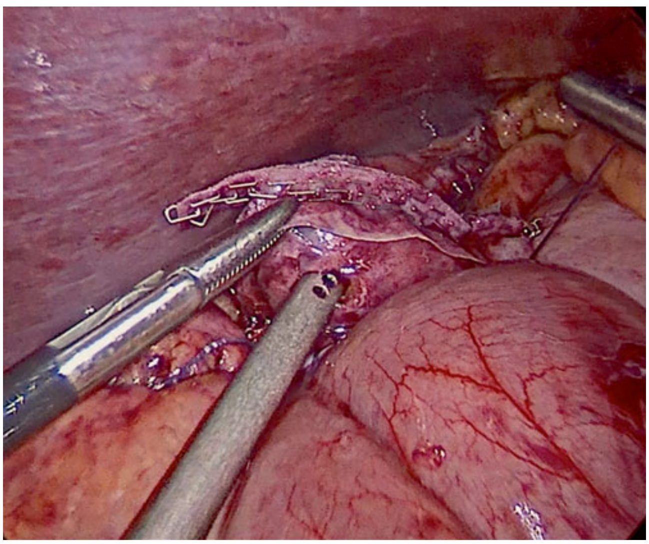

Fig. 14.12 Creation of the gastro-jejunostomy

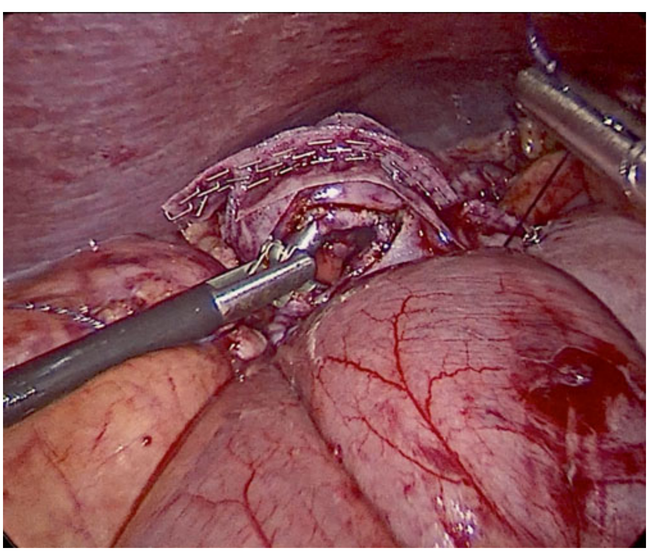

Fig. 14.13 Creation of the gastro-jejunostomy

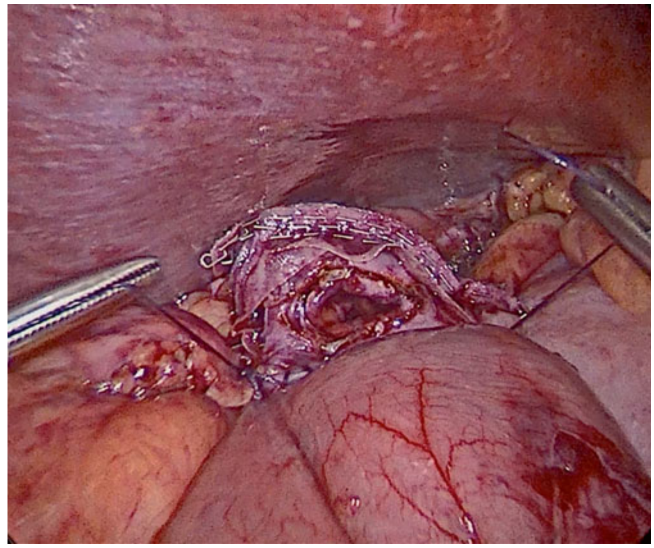

Fig. 14.14 Creation of the gastro-jejunostomy

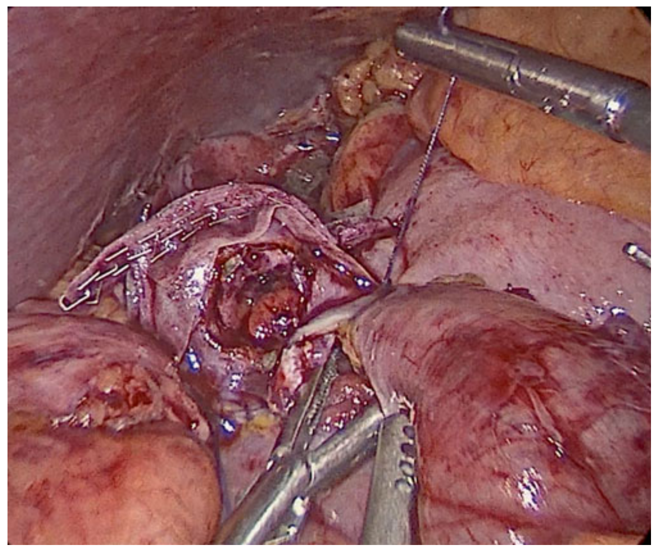

Fig. 14.15 Creation of the gastro-jejunostomy

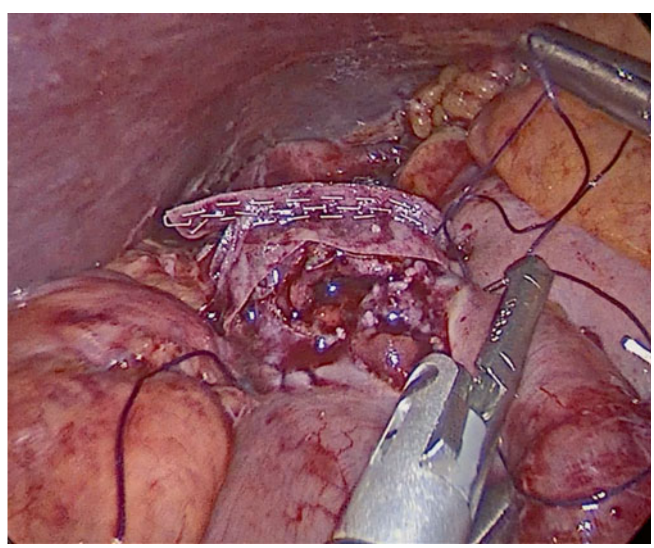

Fig. 14.16 Creation of the gastro-jejunostomy

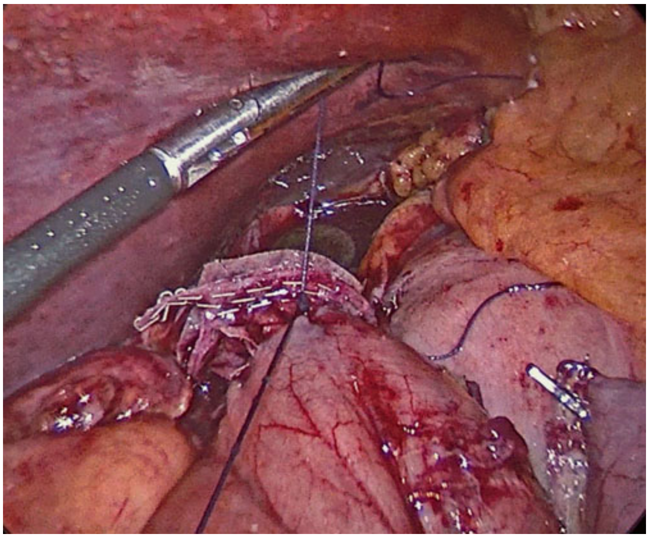

Fig. 14.17 Creation of the gastro-jejunostomy

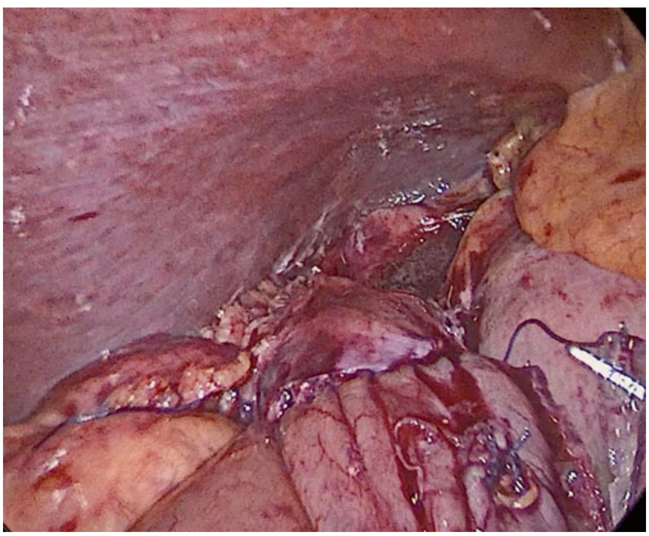

Fig. 14.18 Creation of the gastro-jejunostomy

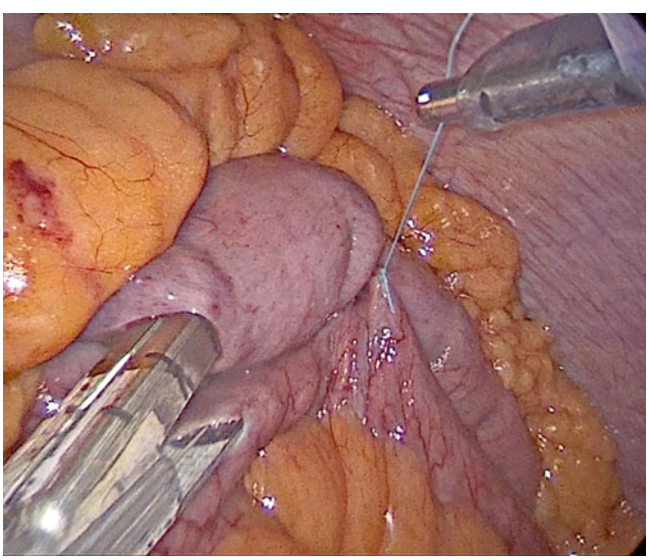

Fig. 14.19 Creation of the jejuno-jejunostomy

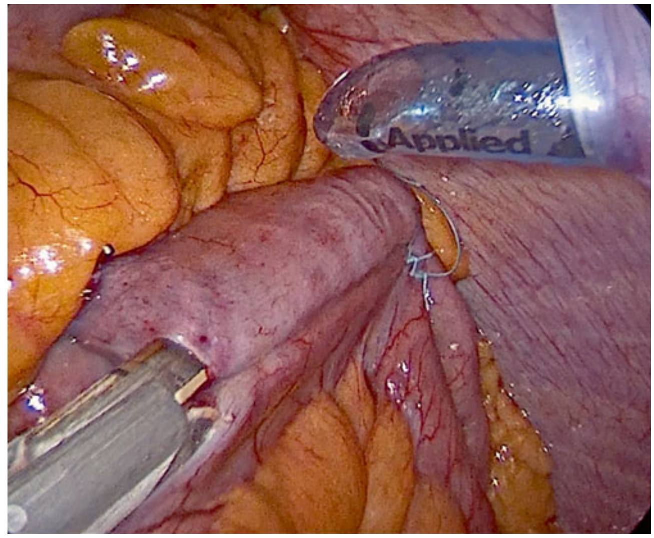

Fig. 14.20 Creation of the jejuno-jejunostomy

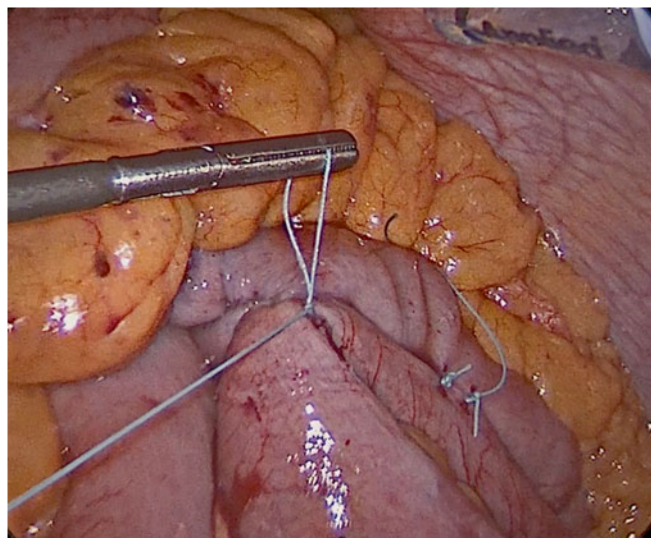

Fig. 14.21 Creation of the jejuno-jejunostomy

14.3 Postoperative Care

The postoperative care of bariatric patients is usually guided by a clinical protocol that is unique to each institution. In general, however, pain management is achieved with short-acting opioid analgesics rather than nonsteroidal anti-inflammatory drugs. Heparin is given subcutaneously to prevent thromboembolic episodes. Antiemetics and proton pump inhibitors are prescribed. The Foley is removed on postoperative day 1, and a barium swallow is performed on day 1, after which a liquid diet is started.

This patient was seen in follow-up 2 weeks after the operation; the GERD had resolved and her asthma had improved.

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15 Transhiatal Esophagectomy

Jukes P. Namm and Mitchell C. Posner

There are no compelling data to support a disease-free or overall survival benefit for any one of the various surgical techniques over another for esophageal carcinoma. Each technique has advantages. Transhiatal esophagectomy has been shown to be safe, with fewer pulmonary complications than the transthoracic approach and a more benign clinical course in the event of an anastomotic leak from a cervical esophagogastrostomy, thereby resulting in reduced perioperative mortality.

15.1 Surgical Technique

15.1.1 Patient Positioning

The patient is positioned supine with the head extended and rotated to the right. The left arm is tucked, leaving the right arm for venous or arterial access. If a central venous catheter is required, it is placed in the right internal jugular vein. The patient's skin is prepped from the left ear superiorly to the pubis inferiorly and laterally to both midaxillary lines.

15.1.2 Abdominal and Lower Mediastinal Phase

Access to the abdomen is obtained through an upper midline incision (xiphoid to umbilicus). Costal margins are retracted with a table-fixed retractor. Division of the ligamentum teres and the falciform and triangular ligaments enables retraction of the left lateral segment of the liver. First, the adequacy of the gastric conduit is assessed—always handling the stomach gently and avoiding unnecessary traction. Next, the gastrocolic omentum is divided a safe distance from right gastroepiploic vessels, to avoid injury to the main blood supply of the conduit. The left gastroepiploic and short gastric vessels are ligated, followed by division of the gastrohepatic omentum after ensuring that a replaced left hepatic artery is not present. The dissection is then carried inferiorly along the lesser curve, with the right gastric artery preserved if at all possible. For adequate mobilization of the pylorus to the

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esophageal hiatus, the hepatic flexure is taken down, and an extensive Kocher maneuver is performed to expose the border of the superior mesenteric vessels. A pyloromyotomy or pyloroplasty is performed to help prevent delayed gastric emptying. The common hepatic, celiac, proximal splenic, and left gastric nodal basins are dissected en bloc with the specimen. While retracting the stomach anteriorly and superiorly, the left gastric artery and coronary vein are ligated; in patients with a replaced left hepatic artery, the left gastric artery should be ligated distal to its takeoff. Dissection of all the remaining nodal tissue around the crus of the diaphragm and aorta is then completed. After the diaphragmatic hiatus is opened, it is widened by ligating the inferior phrenic vein and dividing the crus anteriorly. The gastroesophageal junction is then encircled with umbilical tape to aid with traction during the mediastinal dissection. Dissection of the distal esophagus is carried out under direct vision to the level of the carina laterally between the pleura, anteriorly from the pericardium, and posteriorly from the aorta, using electrocautery and hemoclips. Hemostasis in the mediastinum is best achieved with surgical packing.

15.1.3 Cervical Phase

The neck is entered via an incision along the anterior border of the left sternocleidomastoid muscle, beginning just above the suprasternal notch. The platysma is incised and the sternocleidomastoid muscle is retracted laterally, followed by division of the central tendon of the omohyoid muscle and middle thyroid vein. A blunt, self-retaining retractor is used to retract the sternocleidomastoid muscle laterally and the trachea and thyroid medially, with care to avoid injury to the recurrent laryngeal nerve located in the tracheoesophageal groove (Fig. 15.1). A Penrose drain is used to encircle the cervical esophagus, which is bluntly dissected under direct vision to the level of the innominate artery (Fig. 15.2).

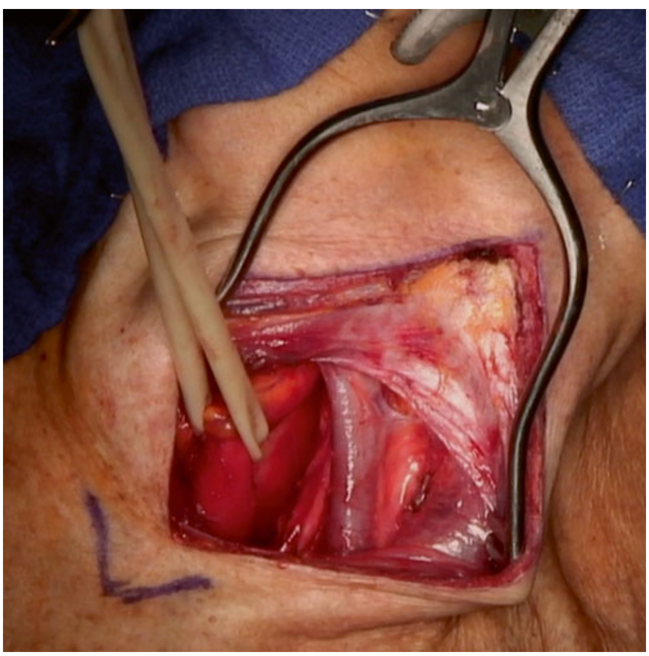

Fig. 15.1 Left cervical exposure with retraction of the sternocleidomastoid muscle, carotid artery, and internal jugular vein laterally and the trachea and thyroid medially

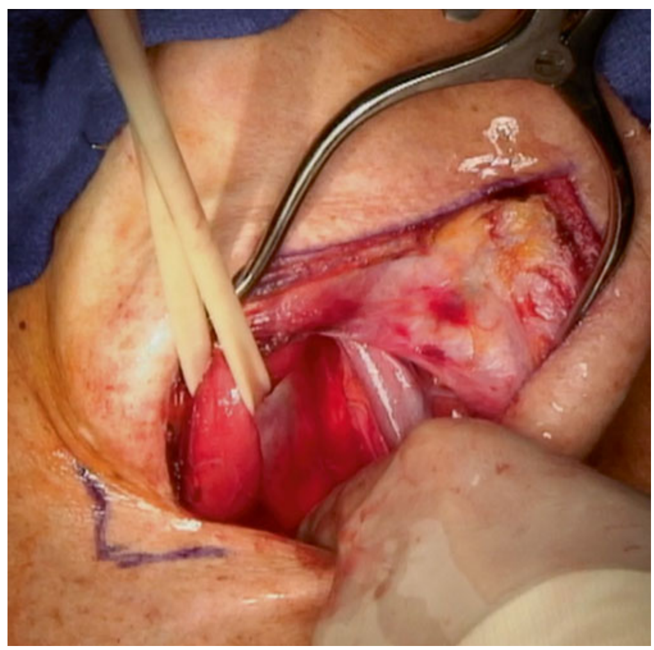

Fig. 15.2 Vessel loop encircling the cervical esophagus to aid in retraction during blunt dissection

15.1.4 Mid and Upper Mediastinal Phase

With downward retraction on the umbilical tape around the gastroesophageal junction, the posterior attachments of esophagus are dissected bluntly with a hand through the diaphragmatic hiatus to the level of the cervical dissection. Next, the anterior attachments are dissected manually, while staying directly on the anterior surface of the esophagus. Care must be taken to avoid injury to the membranous portion of the trachea and to avoid excessive pressure on the heart during dissection, which can cause hypotension. (This hypotension can be readily corrected with volume resuscitation.) Using a sweetheart retractor, the inferior lateral attachments are ligated and divided between large hemoclips. The cervical and upper mediastinal esophagus is brought out through the cervical incision, and after withdrawal of the nasogastric tube, the esophagus is divided with a GIA™ stapler (Covidien, Minneapolis, MN), securing a long Penrose drain marked to maintain its orientation during passage through the mediastinum (Fig. 15.3). With the stomach and mid/distal esophagus brought out through the abdominal incision, the gastric tube is carefully fashioned to a diameter of 4–5 cm with multiple firings of the GIA™ stapler, preserving the greater curvature and its blood supply (Fig. 15.4). The lesser curvature and a portion of the fundus and cardia are removed with the esophagus, nodal basins, and tumor (Fig. 15.5). The Penrose drain that traverses the mediastinum from the cervical to the abdominal incision is now sutured to the posterior aspect of the gastric conduit to maintain orientation during transposition to the neck.

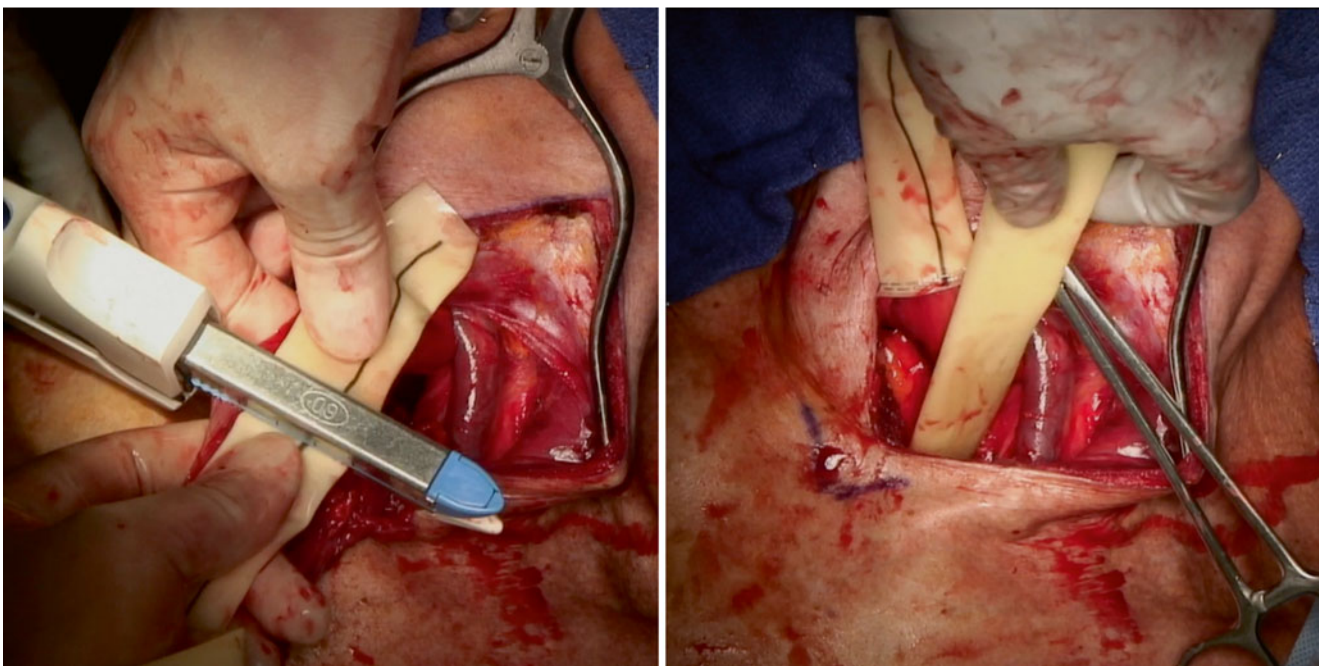

Fig. 15.3 The cervical esophagus is divided with a GIA™ stapler (Covidien, Minneapolis, MN), incorporating a marked Penrose drain to maintain orientation

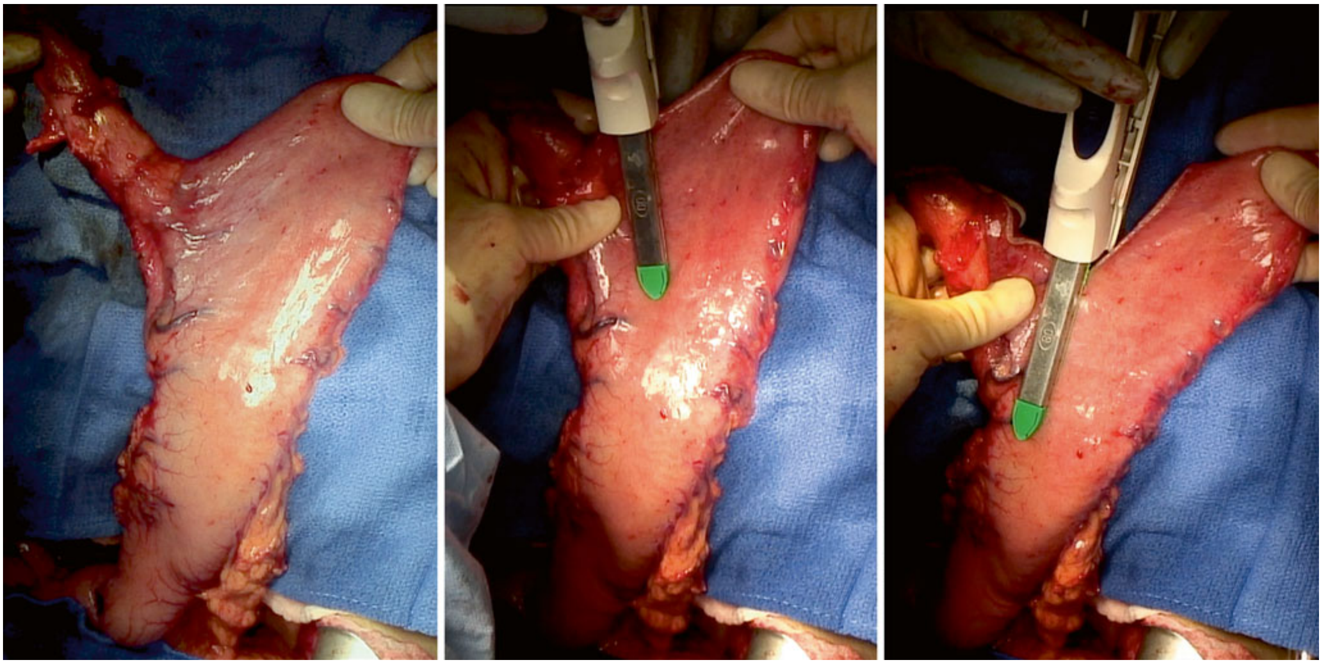

Fig. 15.4 The gastric tube is fashioned to a diameter of 4–5 cm with multiple firings of the GIA™ stapler, preserving the greater curvature and its blood supply

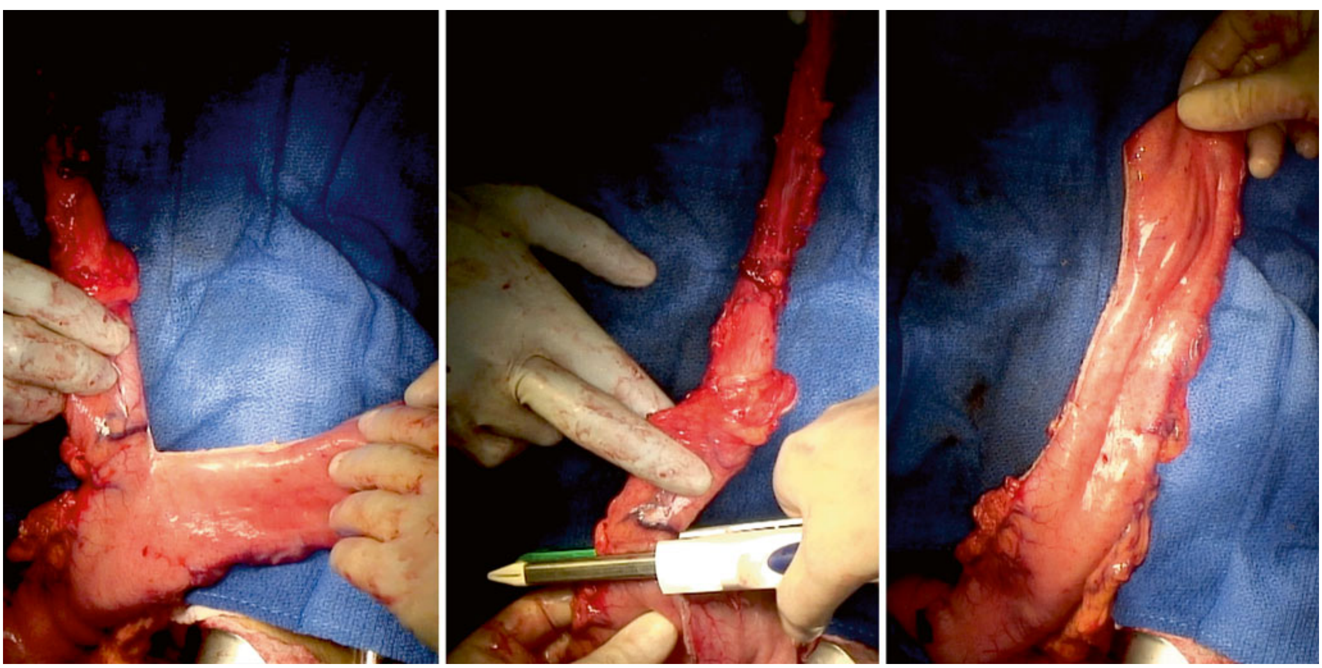

Fig. 15.5 The lesser curvature and a portion of the fundus and cardia are removed with the esophagus, nodal basins, and tumor

15.1.5 Gastric Transposition and Anastomosis

An automatic purse-string applier is used to place a nylon purse-string suture around the proximal cut end of the cervical esophagus. The anvil of a 25-mm EEA™ circular stapling device (Covidien, Minneapolis, MN) is passed into the cervical esophagus and the purse-string suture is secured (Fig. 15.6). The gastric conduit is gently pushed through the diaphragmatic hiatus while simultaneously gently pulling on the Penrose drain from the cervical incision until 6–8 cm of the stomach is mobilized into the cervical field (Fig. 15.7). Avoid excessive pulling of the gastric conduit during transposition, as the result may be trauma and ischemia that could compromise the anastomosis. Through an anterior gastrotomy, a 25-mm EEA™ circular stapling device is used to anastomose the cervical esophagus to the proximal posterior gastric wall (Figs. 15.8 and 15.9). After the nasogastric tube is replaced to the level of the gastric antrum, excess gastric tissue proximal to the anastomosis (including the anterior gastrotomy site) is excised with a TA™ 60-mm stapler (Covidien) (Fig. 15.10). The anastomosis is interrogated for an air leak and reinforced with silk sutures if necessary. The gastric tube is secured to surrounding tissue with care to avoid placing sutures in the prevertebral fascia, which could predispose to abscess formation. The platysma is reapproximated and the skin is closed with staples. Through the abdominal incision, the antrum of the stomach is secured to the hiatus and a needle catheter feeding jejunostomy tube is placed. Drains are unnecessary.

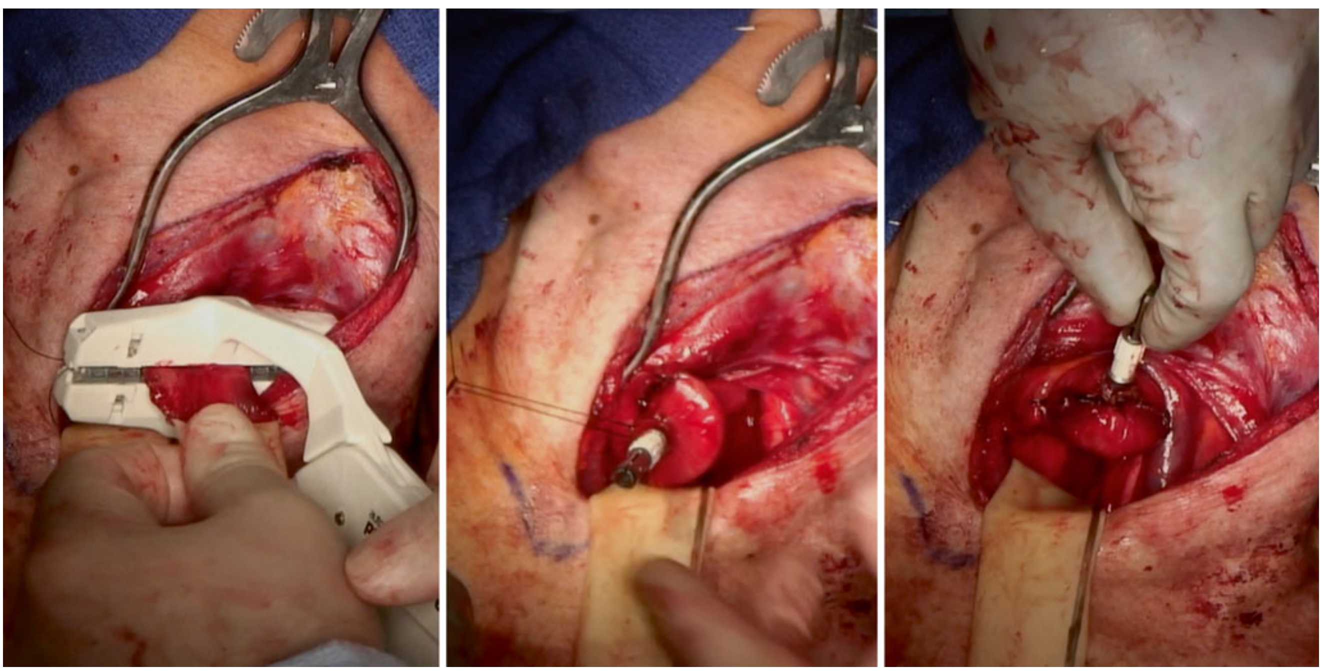

Fig. 15.6 Placement of a purse-string to anchor the anvil of the EEA™ stapling device (Covidien) to the proximal cervical esophagus

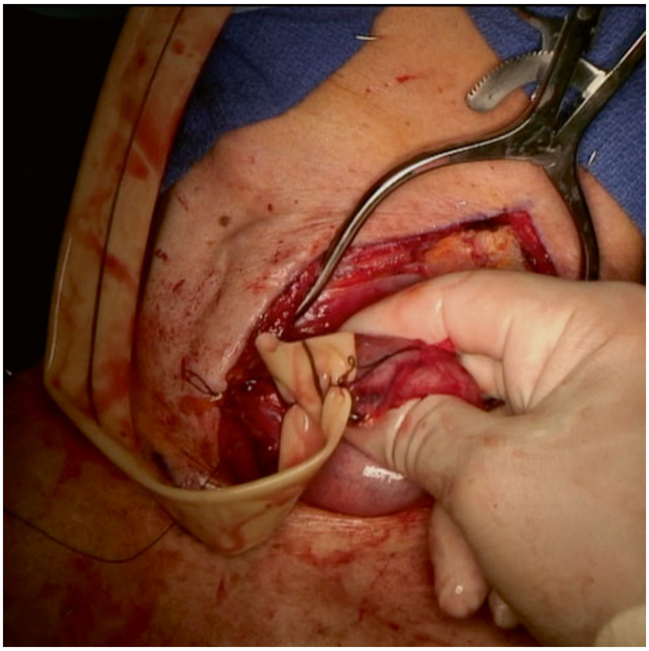

Fig. 15.7 Mobilization of the gastric conduit into the cervical field, with the marked Penrose drain to maintain orientation

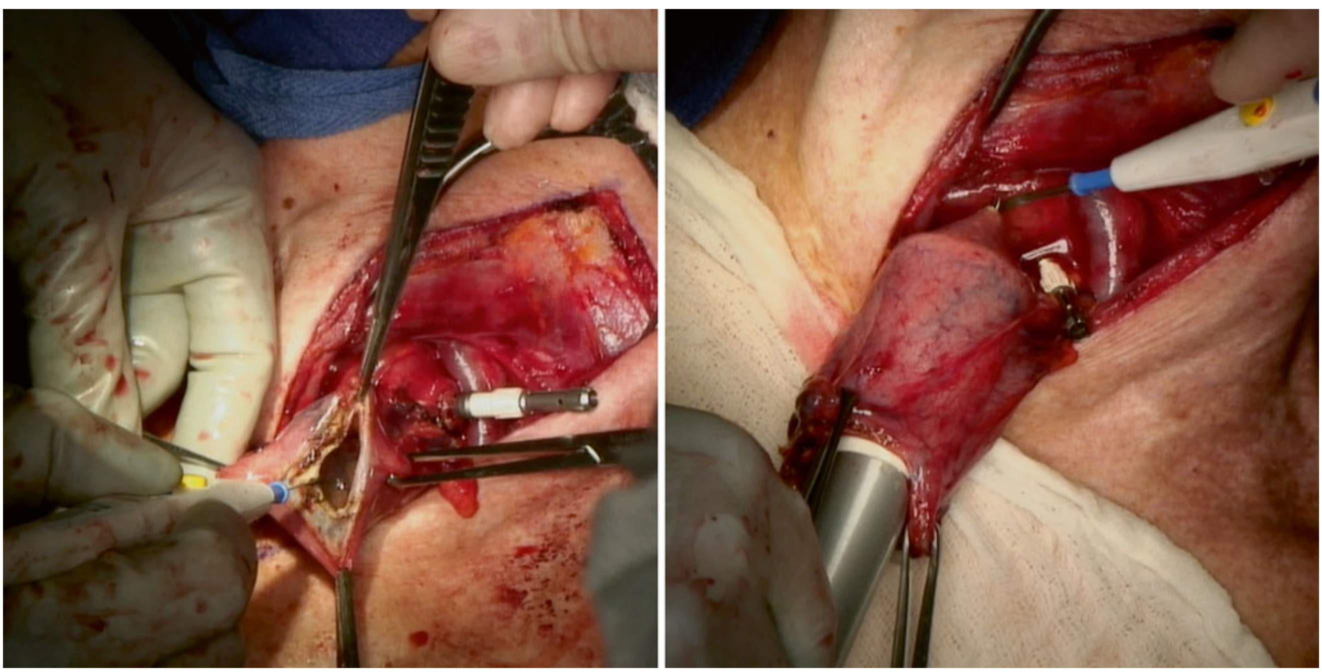

Fig. 15.8 Creation of the anterior gastrotomy and anastomosis to the cervical esophagus using an EEA™ stapling device

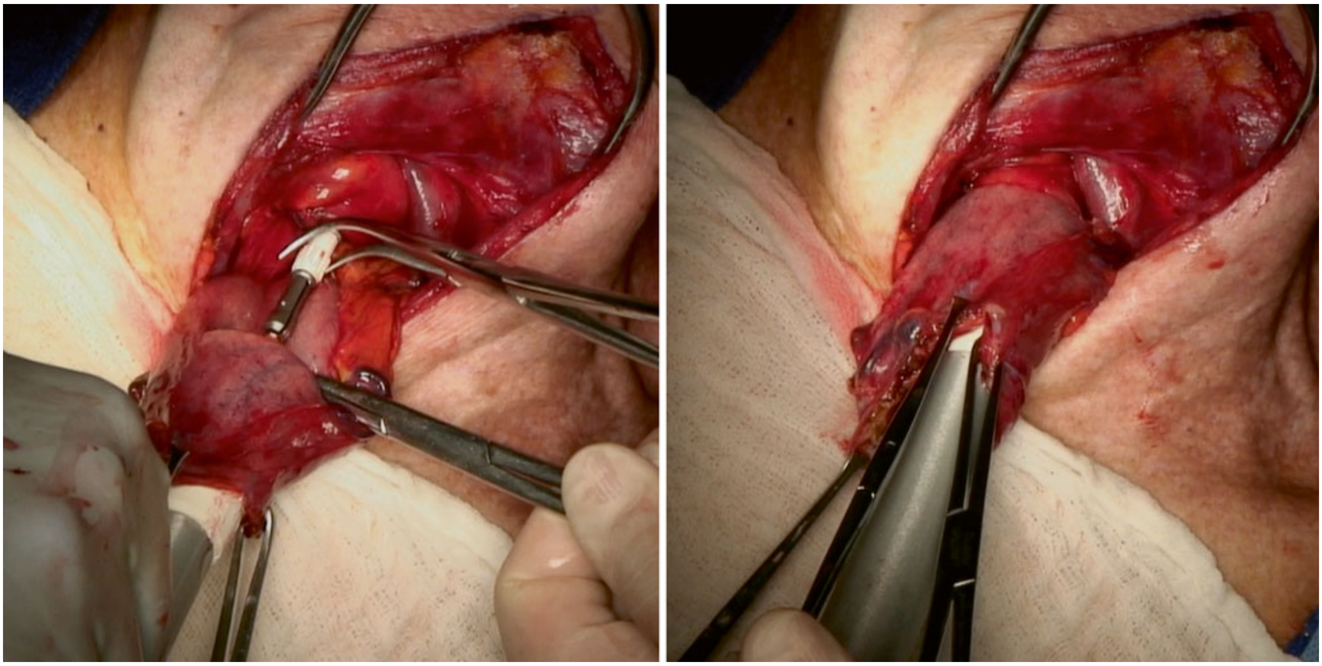

Fig. 15.9 Creation of the anterior gastrotomy and anastomosis to the cervical esophagus using an EEA™ stapling device

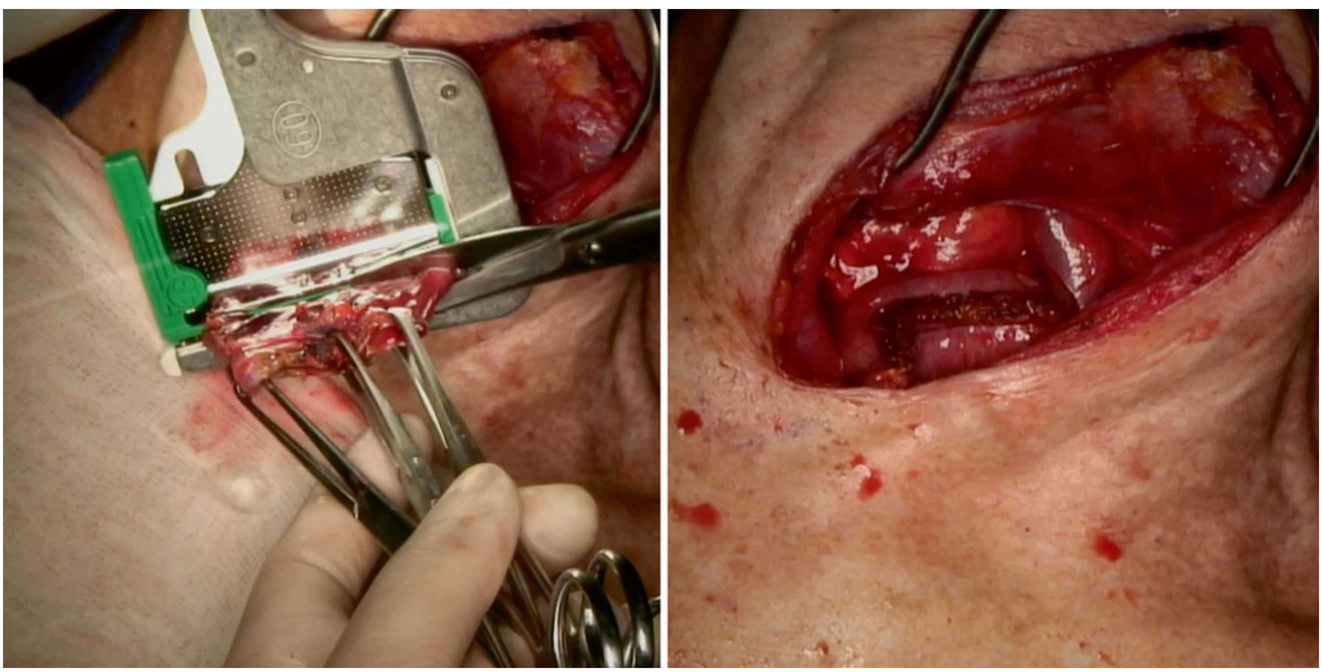

Fig. 15.10 Gastric tissue proximal to the anastomosis, including the gastrotomy site, is excised with a TA™ 60-mm stapling device (Covidien)

15.2 Contraindications

The only absolute contraindications for the transhiatal approach are tracheobronchial adherence or invasion by tumor of the upper or middle third of the esophagus, or severe adhesions of the esophagus to vital structures. Therefore, thoracotomy is rarely necessary for additional exposure to ensure a safe esophageal resection.

15.3 Postoperative Management

15.3.1 Pain Management

A thoracic epidural catheter aids in a more effective cough, allows vigorous physiotherapy, and facilitates early mobilization.

15.3.2 Recurrent Laryngeal Nerve Injury

Most injuries result in temporary hoarseness, but prevention is paramount, as dysphagia and aspiration can result in serious postoperative morbidity.

15.3.3 Anastomotic Leak

Leaks can be managed conservatively by opening the cervical incision and local wound care. Early endoscopy with dilation of the anastomosis may help decrease fistula output and promote fistula closure.

15.3.4 Gastric Tube Necrosis

This uncommon complication requires proximal diversion and delayed reconstruction with a colonic interposition or a jejunal free flap.

15.3.5 Anastomotic Stricture

Strictures are more common after anastomotic leaks and can be managed with dilations.

15.3.6 Chylothorax

Injury to the thoracic duct may occur in patients with locally advanced tumors. These injuries should be managed with early thoracoscopy and ligation.

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Ivor Lewis Esophagectomy

16

Henner M. Schmidt and Donald E. Low

In August 1944, the Welsh surgeon Ivor Lewis (1895–1982) described a two-staged esophagectomy, including a laparotomy followed by a right-sided thoracotomy, and an immediate intrathoracic gastroesophageal anastomosis. Because this approach advocated immediate rather than delayed reconstruction and also involved two standardized incisions, the Ivor Lewis procedure gained immediate popularity and is now the most commonly utilized approach for esophageal resection worldwide. The evolution of surgical technology has led to the description of hybrid, total, minimally invasive, and robotic approaches.

Selecting an operative approach for esophageal resection must be preceded by a complete preoperative evaluation that includes accurate tumor staging, an assessment of the patient's comorbidities and past medical history (with particular attention to prior history of surgery), and a patient-specific physiologic assessment. Pulmonary function testing should be performed routinely, in preparation for single-lung ventilation. In patients with documented coronary artery disease, congestive heart failure, or atrial or ventricular dysrhythmia, selected objective cardiac testing is recommended.

Surgical treatment for esophageal cancer is indicated in patients with loco-regional disease and may be accompanied by neoadjuvant therapy, if appropriate. Patients with distant metastases or lymph node metastases not included in the surgical resection field should undergo definitive chemotherapy, radiation, or palliation.

With the variety of different surgical approaches currently available for esophagectomy, the choice of resectional approach should take into account individual patient and tumor characteristics. No single approach to esophageal resection is appropriate for all patients. The Ivor Lewis esophagectomy has advantages in cancers of the mid and distal esophagus, as it provides optimal visualization during dissection of the esophagogastric junction and thoracic esophagus, and it allows a complete two-field thoracoabdominal lymphadenectomy. With mid-level tumors abutting the tracheobronchial tree, the aorta, or the spine, a three-stage approach with initial right thoracotomy should be considered. We believe that the Ivor Lewis procedure also should be the approach of choice in patients with documented significant cardiac comorbidity, as the right thoracic approach minimizes intraoperative cardiac manipulation. Our unit's experience over the past 4 years shows that 43 % of patients (60 of 137) underwent Ivor Lewis resections, and even though 70 % of these patients had significant cardiac comorbidities, operative mortality in the group having Ivor Lewis resections was 1 %.

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16.1 Case Description

The patient is a 61-year-old woman with a long history of gastroesophageal reflux disease, which led to a combined hiatal hernia repair and cholecystectomy. After several years of relief, her heartburn symptoms recurred, and she has been back on antacid medication for many years.

She has a history of smoking and carries a diagnosis of COPD. Her past medical history is also significant for deep venous thrombosis at the ages of 22 and 35 and for atrial fibrillation, which led to the placement of a pacemaker. After a recent emergency coronary bypass operation for her second myocardial infarction, she experienced progressive dysphagia for solids.

A diagnostic work-up produced the following findings:

- Conventional chest x-ray: history of sternotomy for coronary bypass surgery as well as previous placement of cardiac pacemaker (Fig. 16.1a)
- Endoscopy: 3 cm–long ulcerated mass at the gastroesophageal junction (Fig. 16.1b). Targeted biopsies confirmed a moderately differentiated invasive adenocarcinoma
- Endoscopic ultrasound: transmural extension of the tumor into the adventitia without invasion into adjacent organs; paraesophageal nodes suspicious for malignancy (Fig. 16.1b). (These nodes were not assessed by fine needle biopsy, as the needle would have had to traverse the tumor.) Endoscopic staging classified her stage as cT3 N1 because of transmural extension in the area of the ulcerated mass (cT3) and multiple enlarged paraesophageal lymph nodes (cN1).
- CT scans: esophageal thickening in the distal esophagus and esophagogastric junction without evidence of metastatic disease (Fig. 16.2a). PET/CT scans showed focal hypermetabolic activity in the distal esophagus. Mildly prominent lymph nodes in the posterior mediastinum and supraceliac region showed no definitive uptake.

Her case was presented and discussed at the multidisciplinary Thoracic Tumor Board. The treatment decision for her clinical T3 N0-1 MX tumor included neoadjuvant radiochemotherapy followed by surgery. She received carboplatin and paclitaxel (Taxol) along with 5040 cGy of radiation, which she tolerated well. Restaging with CT and endoscopy demonstrated a good macroscopic response, and review in the Tumor Board agreed that proceeding to surgical resection was appropriate.

This patient was taking a beta blocker, which was continued. On the day of surgery, a thoracic epidural was placed. Following induction of general anesthesia, the patient was intubated with a double-lumen endotracheal tube. A Foley catheter and arterial line were placed. No central venous catheter is routinely used. Bilateral compression stockings and a lower-body heating blanket are both utilized.

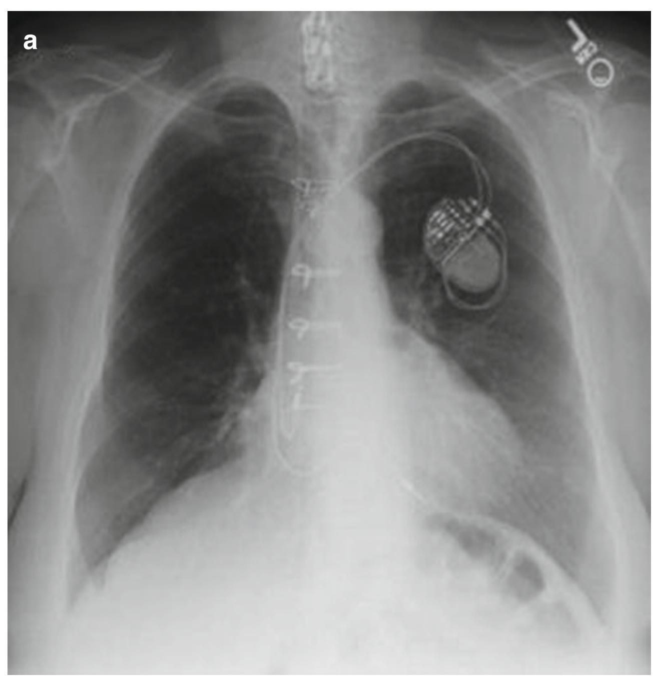

Fig. 16.1 (**a**) Conventional chest x-ray demonstrating a history of sternotomy for coronary bypass surgery, as well as previous placement of a cardiac pacemaker. (**b**) Endoscopy (*upper left*) showing ulcerated mass in the distal esophagus, and endoscopic ultrasound showing transmural extension of the tumor into the adventitia in the area of the ulcerated mass (cT3) (*two-headed arrow*) and multiple enlarged paraesophageal lymph nodes (cN1) (*arrow*)

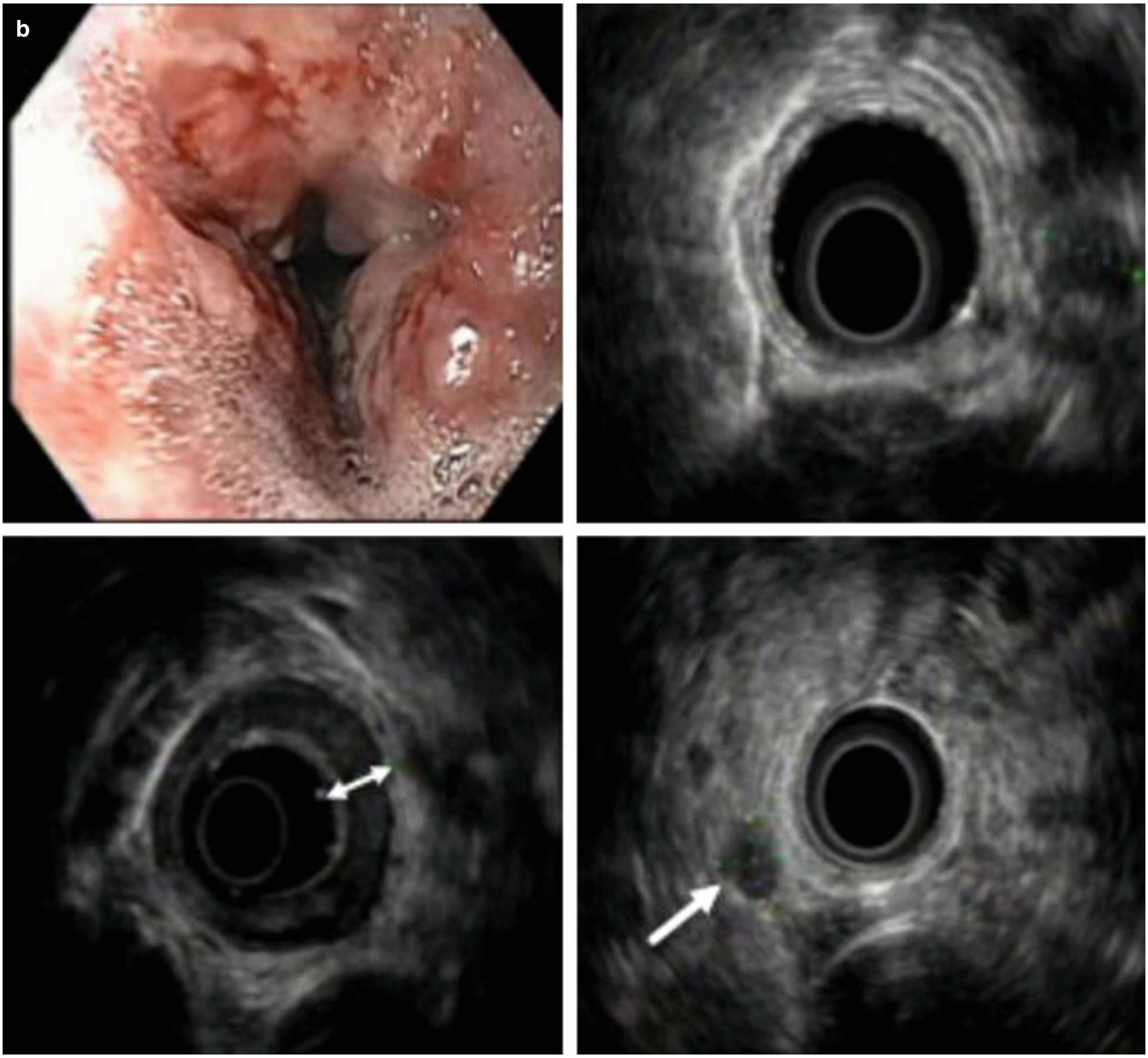

Fig. 16.1 (continued)

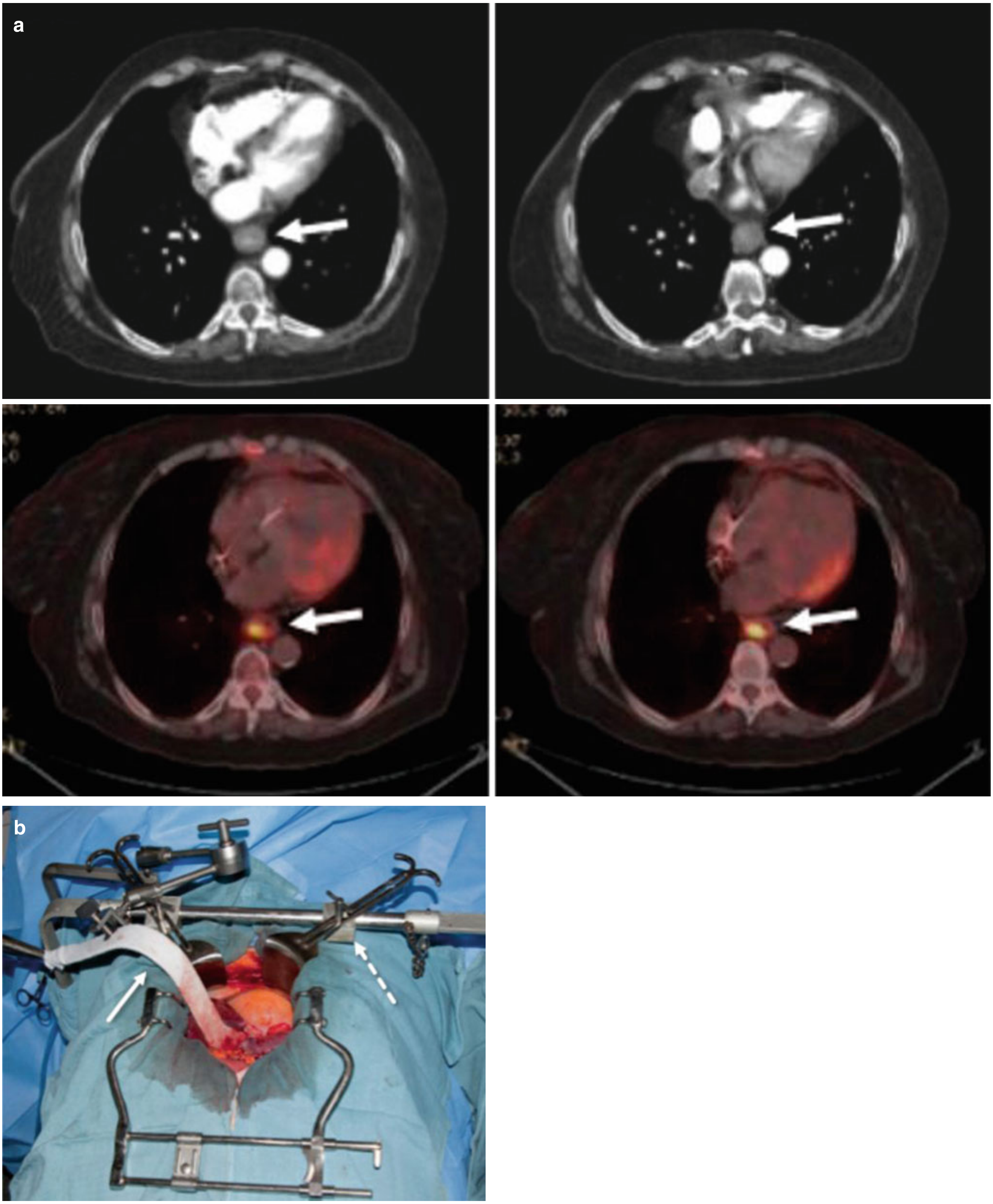

Fig. 16.2 (**a**) CT scans at initial staging (*top*) showing the distal esophageal tumor (*arrows*); PET/CT scans (*bottom*) with increased standardized uptake value (SUV 14) (*arrows*). (**b**) Limited midline incision from the xiphoid to 3–4 cm above the umbilicus. Mobilize liver by taking down the triangular ligament, and retract the liver to the patient's right with a fixed retractor (*solid arrow*). Ideally, a fixed retraction system (*dashed arrow*) lifts the costal margin to verticalize the diaphragm and provide an unobstructed view of the proximal stomach and esophagogastric (EG) junction

16.2 Procedure

Make a limited midline incision from the xiphoid to 3–4 cm above the umbilicus (Fig. 16.2b). Mobilize the liver by taking down the triangular ligament, and retract the liver to the patient's right with a fixed retractor. Ideally, the fixed retraction system will provide an unobstructed view of the proximal stomach and esophagogastric (EG) junction.

Figure 16.3a shows the completed dissection of the EG junction, encircled by a Penrose drain. Transhiatal dissection mobilizes the esophagus, mediastinal fat, and level 8 lymph nodes. Dissection should be completed over 8–10 cm. Any attachment or invasion of crura or diaphragm should be resected en bloc. Following Kocherization of the duodenum, assess for pyloric stenosis (Fig. 16.3b). Whether a pyloric procedure is done remains controversial. We do not do a pyloroplasty unless pyloric stenosis is noted at preoperative esophagogastroduodenoscopy (EGD) or intraoperatively. Ideally, the duodenum should be mobilized sufficiently to place the pylorus 3–4 cm below the hiatus.

Figure 16.4a shows the dissection of the greater curvature, ensuring preservation of the right gastroepiploic arcade. Omental attachments are taken down, starting at the watershed area between the left and right gastroepiploic arcades. The right gastroepiploic arcade is preserved (Fig. 16.4b). When the greater curve is completely mobilized (Fig. 16.4c), ideally the omentum is preserved along the upper body and cardia of the stomach to cover the anastomosis (see Fig. 16.16c). The mobilized stomach shown in Fig. 16.4d demonstrates posterior access to the left gastric pedicle. Lymph node dissection includes supraceliac, suprapancreatic, and paragastric nodes. Figure 16.5a shows dissection of the left gastric vein. The left gastric artery is ligated immediately above the celiac axis (Fig. 16.5b).

The lesser curvature is dissected 7–10 cm distal to the EG junction (Fig. 16.6a), at a location guided by pretreatment endoscopy and endoscopic ultrasound to provide a minimum of 5–7 cm of distal resection margin. The conduit is then fashioned with sequential firing of a linear stapler (Fig. 16.6b–d). It is important to keep the stapled margin oriented and parallel to the greater curve.

The extent of gastric resection can vary. It should be based on findings at endoscopy and endoscopic ultrasound. The resection in Fig. 16.7a provides a margin of 10–12 cm from the EG junction. The width of the conduit remains controversial; we aim to fashion a gastric conduit 3–4 cm in width (Fig. 16.7b), preserving the right gastroepiploic arcade and the proximal right gastric arcade.

To decrease the risk of bleeding, we recommend oversewing the staple line with interrupted 3.0 silk sutures (Fig. 16.8a). The last imbricating stitches at the tip of the conduit are left long, with the needle attached (Fig. 16.8b). These sutures are used to attach the tip of the conduit to the gastric portion of the specimen (Fig. 16.8c) so it can be drawn up into the chest following esophageal mobilization.

A 14 Fr feeding jejunostomy is placed 60–80 cm from the ligament of Treitz (Fig. 16.9a). The tube is imbricated into the antimesenteric jejunum over a 2-cm distance and suspended to the peritoneal surface circumferentially. To avoid torsion, it is then tacked proximally and distally to the peritoneal surface over 3–4 cm.

The second stage of the procedure is initiated with a limited thoracotomy, typically performed at the fourth or fifth interspace (Fig. 16.9b). The visceral pleura is incised and the azygous vein is ligated (Fig. 16.10a). The esophagus is mobilized just distal to the azygous vein (Fig. 16.10b). Esophageal mobilization proceeds distally, mobilizing all paraesophageal nodes en bloc. Subcarinal nodes can be mobilized en bloc or separately.

Dissection is continued distally following mobilization of the inferior pulmonary ligament (Fig. 16.11a). This dissection can include resection and ligation of the thoracic duct if desired. The mobilized esophagus and the gastric component of the specimen with the gastric conduit are brought up into the chest prior to initiating anastomosis (Fig. 16.11b).

The esophagus is mobilized up to the thoracic inlet (Fig. 16.12a). Level 4 (paratracheal) and Level 10 (tracheobronchial) lymph nodes can be mobilized in mid-level tumors.

The gastric conduit is placed in the apex of the chest beside the proximal esophagus and above the ligated azygous vein (Fig. 16.12b). The conduit should lie in this location without tension. Sutures are placed between the conduit and the esophagus to create a common wall (Fig. 16.13a). We recommend placing two or three of these sutures on each side. The proximal esophagus is transected with a linear stapler at or above the ligated azygous vein (Fig. 16.13b). Figure 16.13c shows the transected esophagus lying adjacent to the proximal gastric conduit. The staple line is cut away prior to anastomosis (see Fig. 16.14a).

The proximal resection margin is checked by pathology for Barrett's and cancer. A gastrostomy in the conduit is then created immediately adjacent to the end of the esophageal stump (Fig. 16.14a). Full-thickness sutures are placed between the adjacent free walls of the esophagus and gastrostomy to create a common wall prior to the anastomosis (Fig. 16.14b).

To create the anastomosis, a 30-mm linear stapler is placed with one limb in the esophagus and the other in the apex of the conduit (Fig. 16.15a). Firing the stapler creates most of the anastomosis in the common walls of the esophagus and gastric conduit (Fig. 16.15b). After the nasogastric tube is advanced down into the conduit, the esophagogastric anastomosis is completed (Fig. 16.16a) with full-thickness absorbable sutures and a second layer of imbricating 3.0 silk sutures. The conduit should be positioned vertically in the chest without redundancy above the diaphragm (Fig. 16.16b).

The anastomosis optimally is covered with adjacent omental fat and pleura (Fig. 16.16c, d).

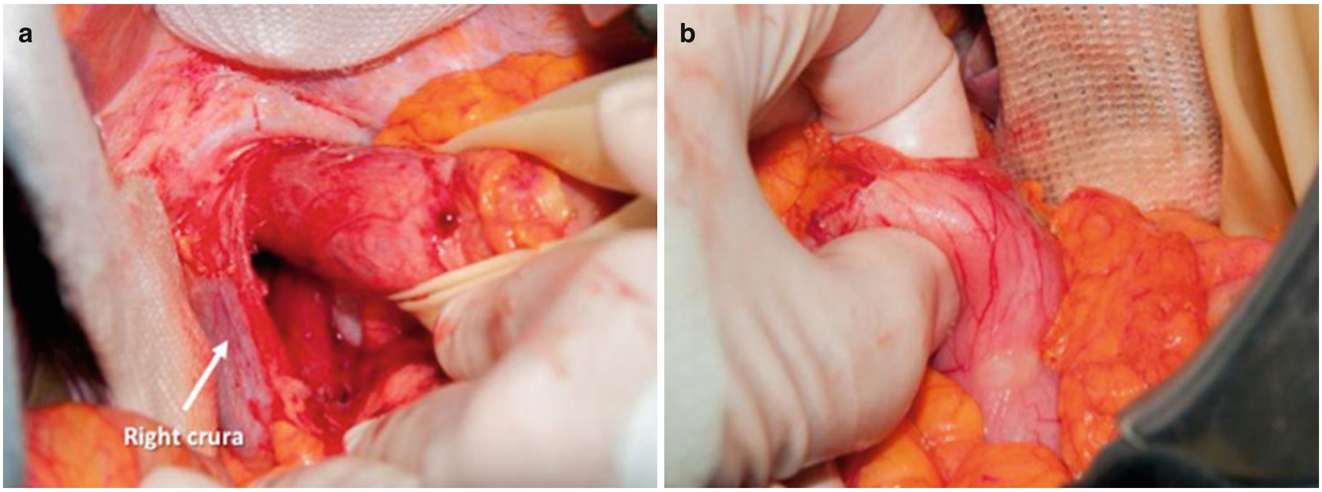

Fig. 16.3 (**a**) Completed dissection of the EG junction, encircled by a Penrose drain. (**b**) Assessing for pyloric stenosis following Kocherization of the duodenum

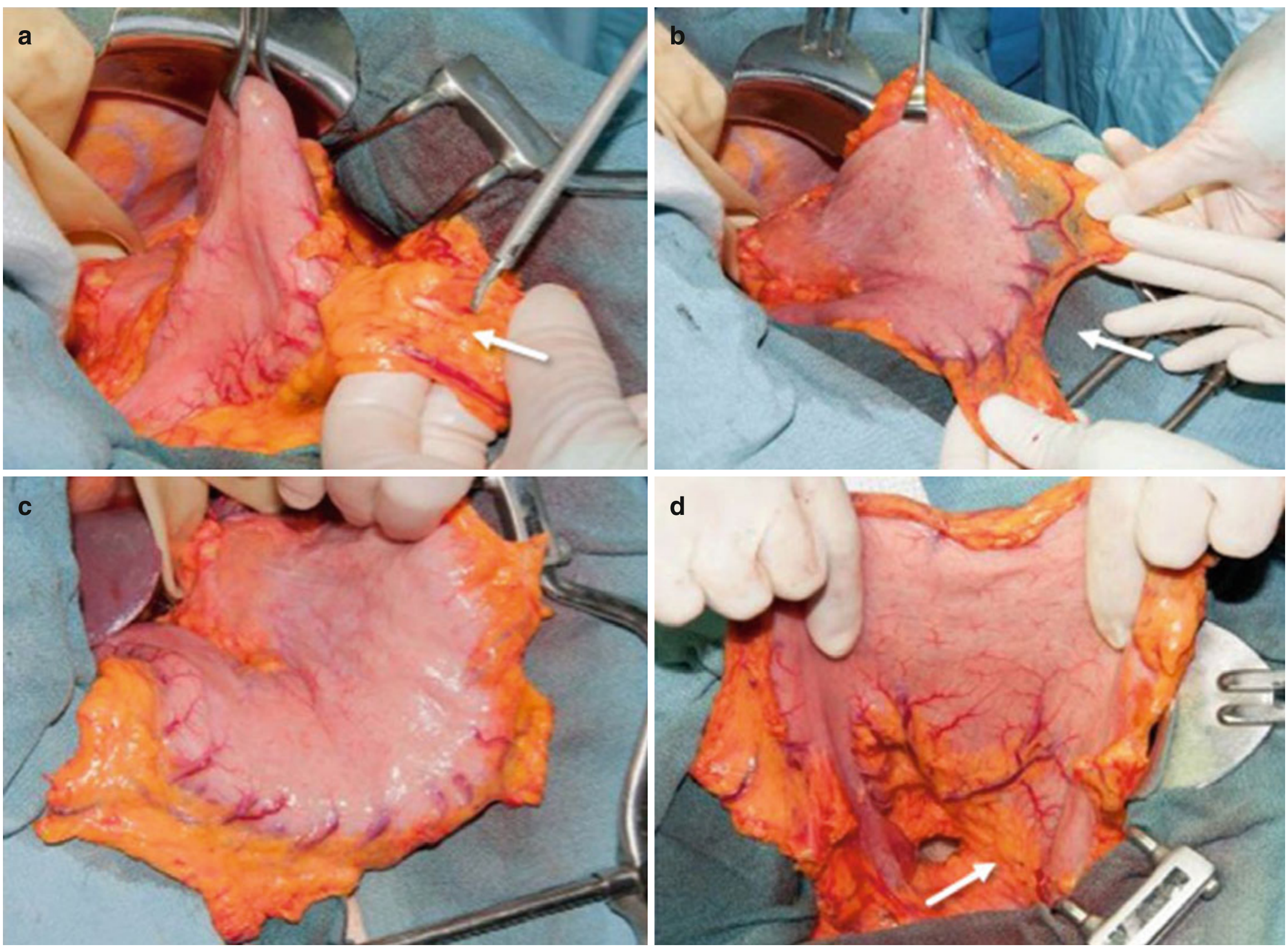

Fig. 16.4 (**a**) Dissection of greater curvature, ensuring preservation of the right gastroepiploic arcade. Starting at the watershed area (*arrow*) between the left and right gastroepiploic arcades, omental attachments are taken down. (**b**) Right gastroepiploic arcade is preserved (*arrow*). (**c**) Greater curve completely mobilized. (**d**) Mobilized stomach demonstrating posterior access to left gastric pedicle (*arrow*). Lymph node dissection includes supraceliac, suprapancreatic, and paragastric nodes

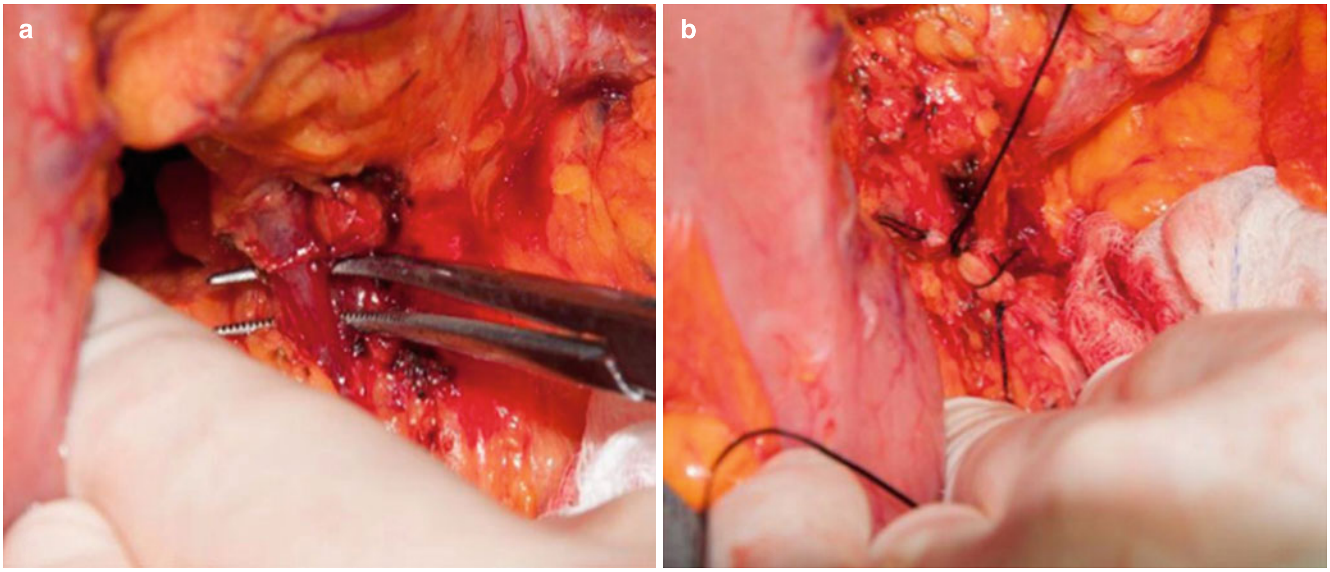

Fig. 16.5 (**a**) The entire suprapancreatic and supraceliac lymph node fields are dissected. This image shows dissection of the left gastric vein. (**b**) The left gastric artery is ligated immediately above the celiac axis

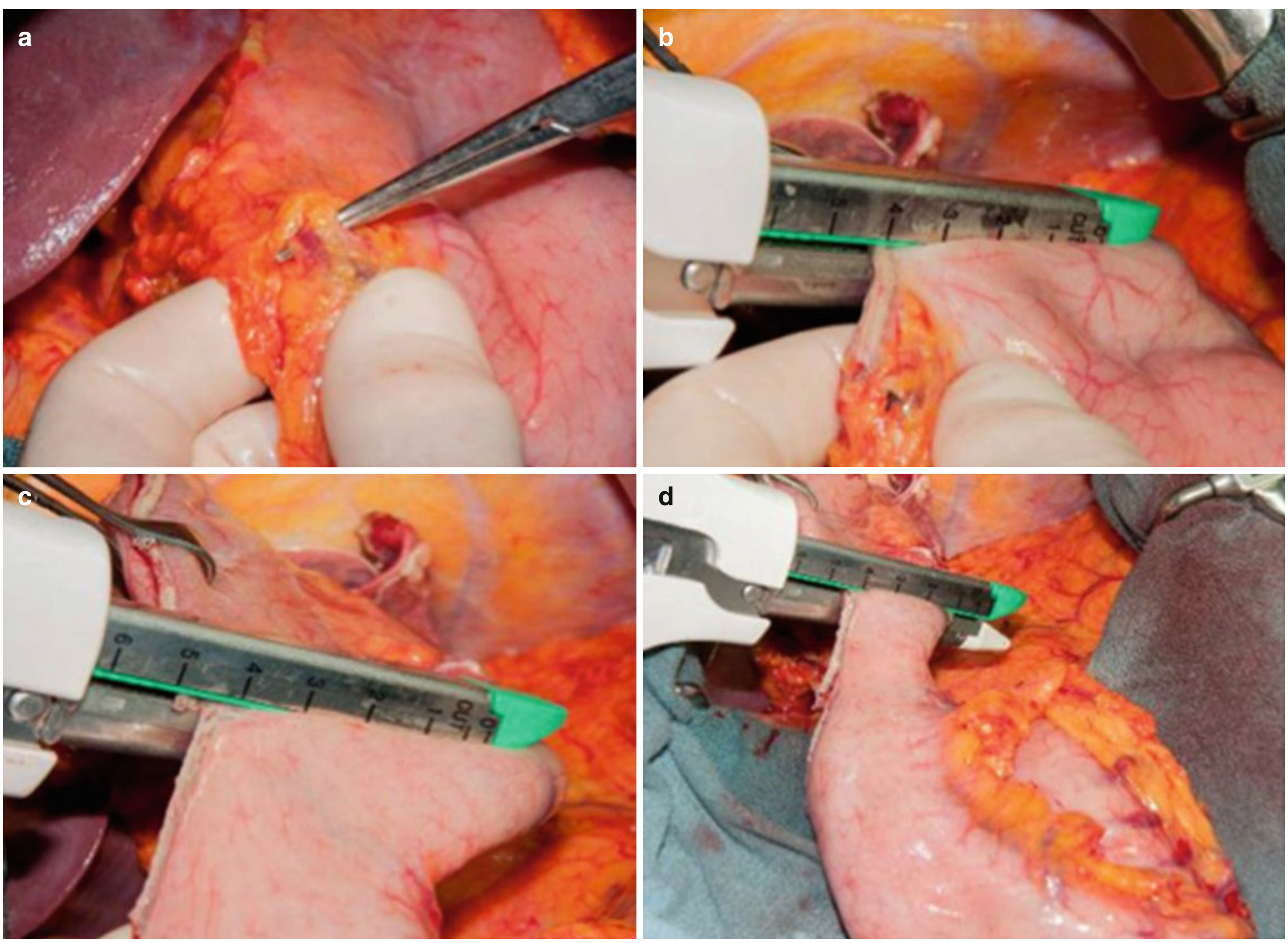

Fig. 16.6 (**a**) The lesser curvature is dissected 7–10 cm distal to the EG junction, providing a minimum of 5–7 cm of distal resection margin. (**b**–**d**) The conduit is then fashioned with sequential firing of a linear stapler

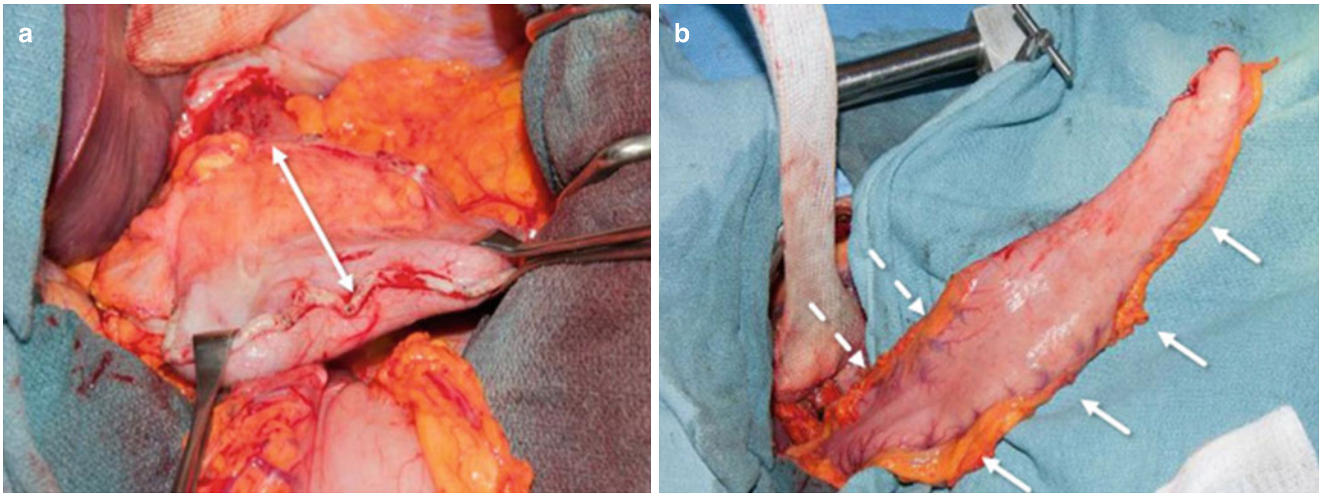

Fig. 16.7 (**a**) This gastric resection provided a 10- to 12-cm resection margin from the esophagogastric junction (*arrow*). (**b**) We aim to fashion a gastric conduit 3–4 cm wide, with preservation of the right gastroepiploic arcade (*arrows*) and proximal right gastric arcade (*dashed arrows*)

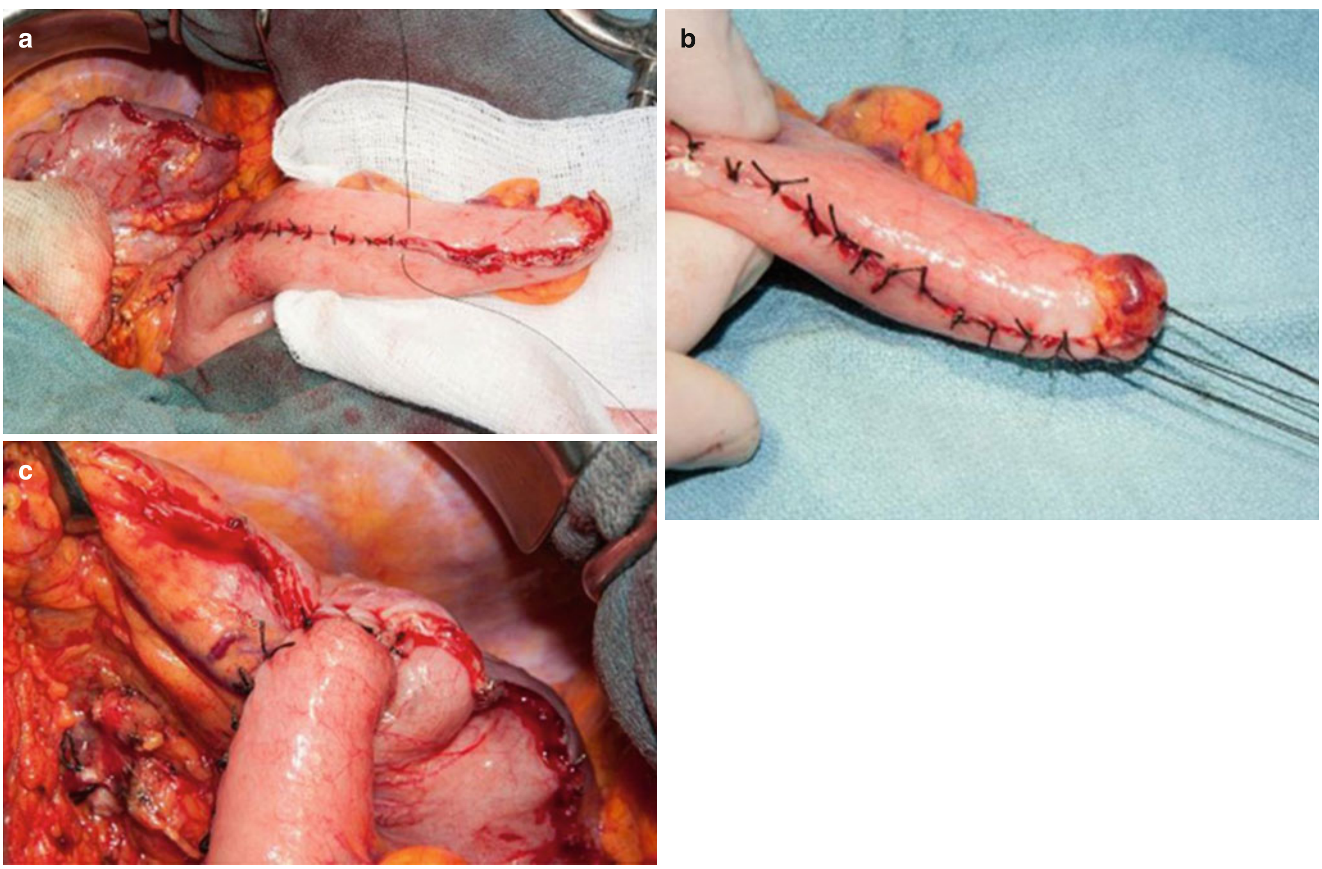

Fig. 16.8 (**a**) The staple line is oversewn with interrupted 3.0 silk sutures. (**b**) The last imbricating stitches at the tip of the conduit are left long, with the needle attached. (**c**) These sutures are used to attach the tip of conduit to the gastric portion of the specimen

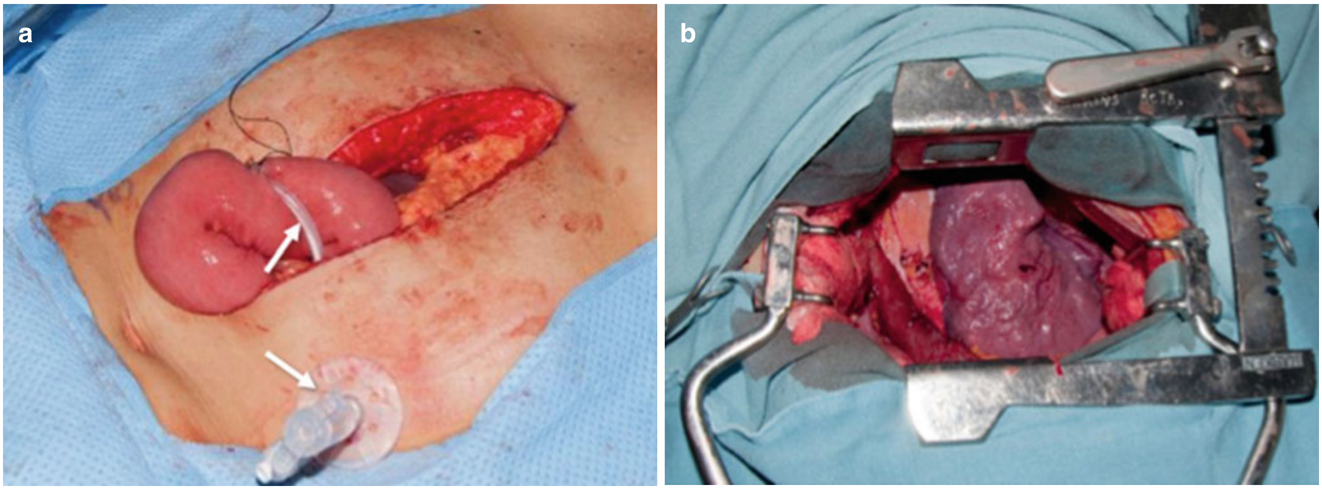

Fig. 16.9 (**a**) A 14 Fr feeding jejunostomy (*arrow*) is placed 60–80 cm from the ligament of Treitz. The tube is imbricated into the antimesenteric jejunum over a 2 cm distance and suspended to the peritoneal surface circumferentially with 3.0 silk sutures. To avoid torsion, it is then tacked proximally and distally to the peritoneal surface over 3–4 cm. (**b**) The second stage of the procedure is initiated with a limited thoracotomy, typically performed at the fourth or fifth interspace

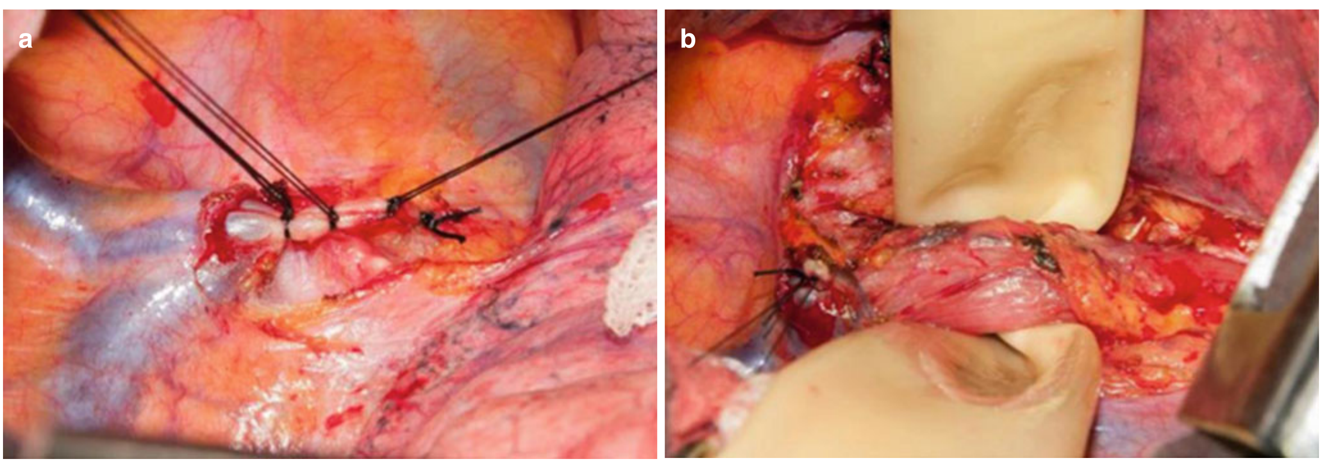

Fig. 16.10 (**a**) Incision of visceral pleura and ligation of azygous vein. (**b**) Mobilized esophagus just distal to the azygous vein

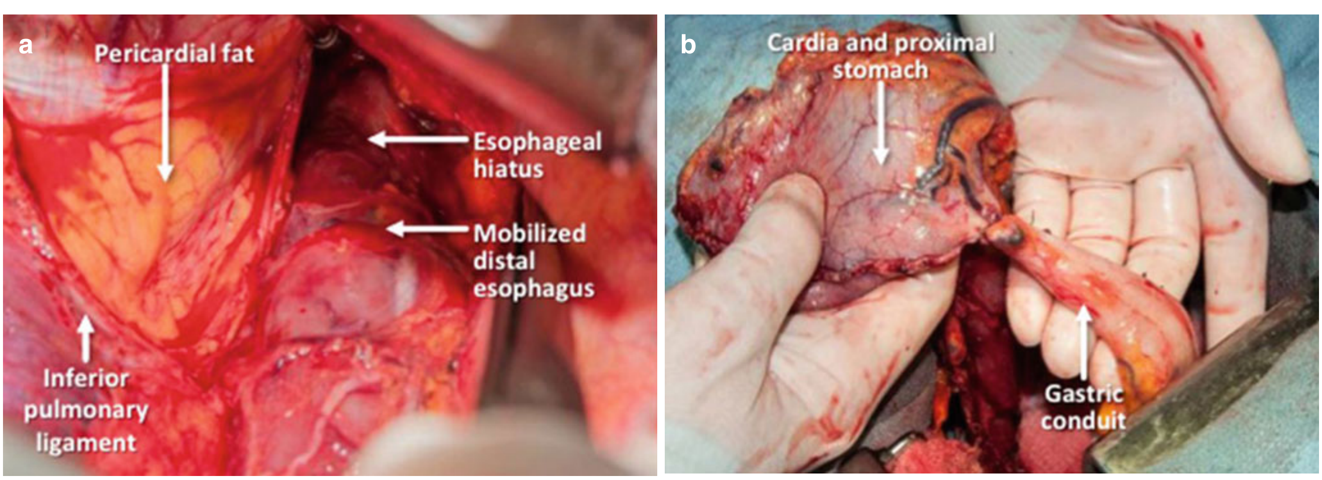

Fig. 16.11 (**a**) Dissection is continued distally following mobilization of the inferior pulmonary ligament. (**b**) The mobilized esophagus and the gastric component of the specimen with the gastric conduit are brought up into the chest prior to initiating anastomosis

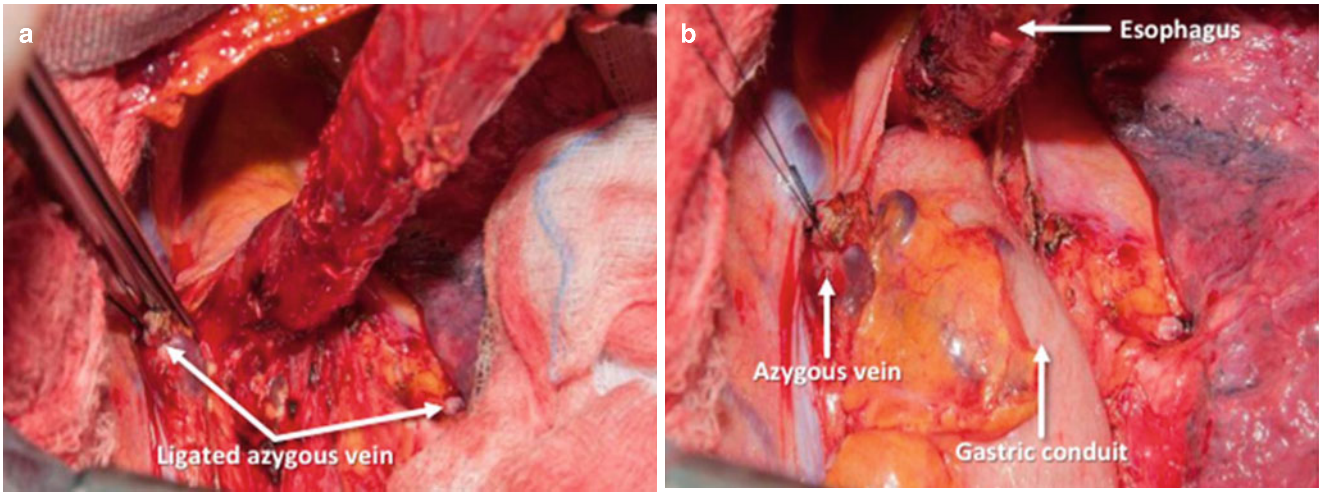

Fig. 16.12 (**a**) Esophagus mobilized up to the thoracic inlet. (**b**) Gastric conduit placed in the apex of the chest beside the proximal esophagus and above the ligated azygous vein. The conduit should lie in this location without tension

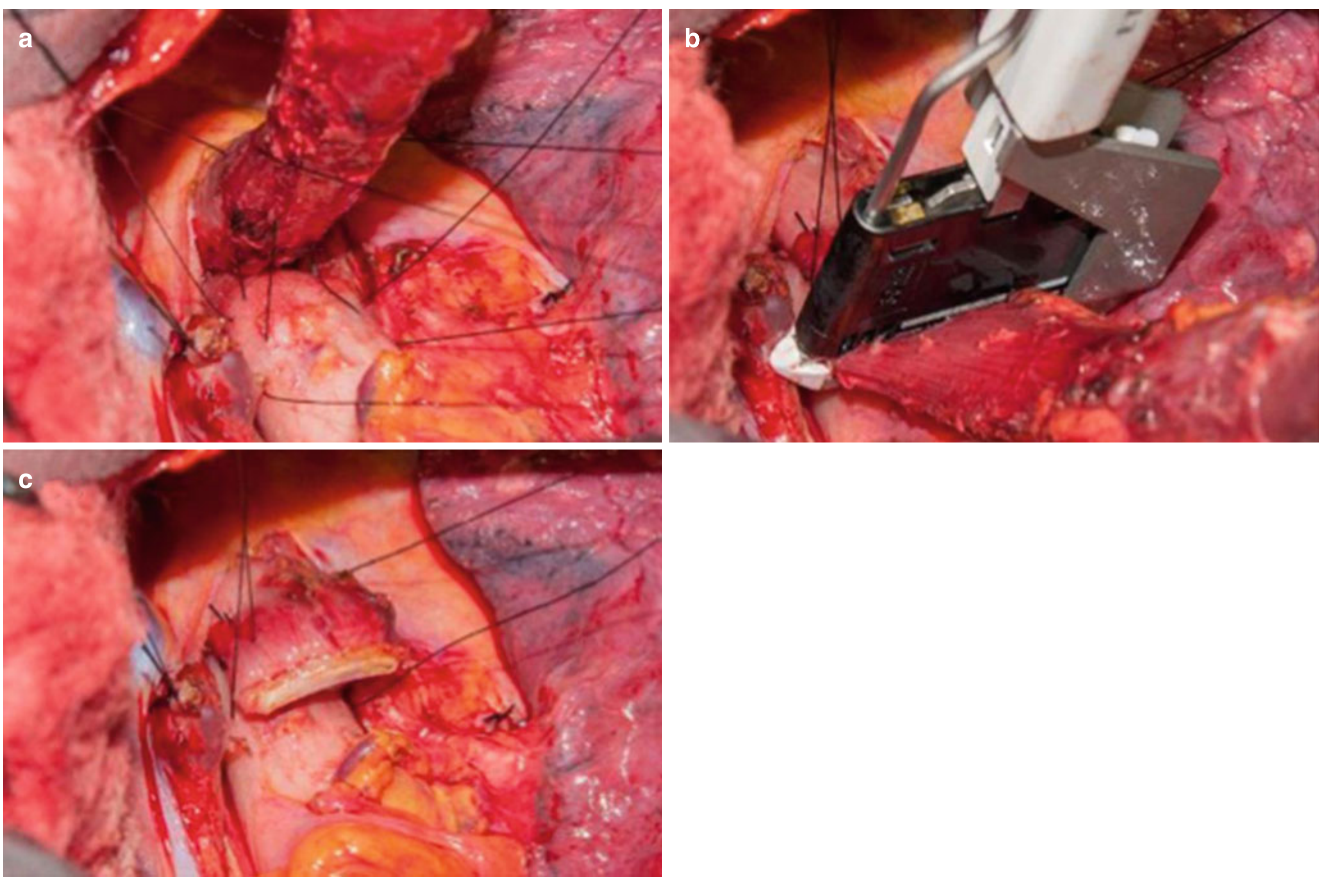

Fig. 16.13 (**a**) Sutures are placed between the conduit and esophagus to create a common wall. (We recommend two or three sutures on each side.) (**b**) Transection of the proximal esophagus with a linear stapler at or above the ligated azygous vein. (**c**) Transected esophagus lying adjacent to the proximal gastric conduit. The staple line is cut away prior to anastomosis

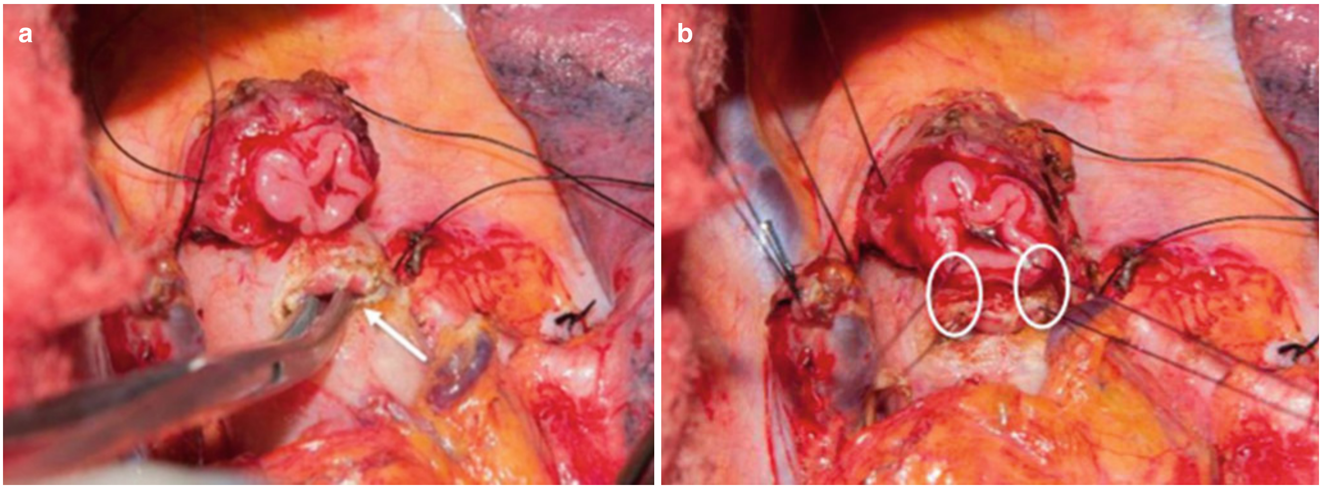

Fig. 16.14 (**a**) Following pathologic checking of proximal resection margin for Barrett's and cancer, a gastrostomy (*arrow*) in the conduit is created immediately adjacent to the end of the esophageal stump. (**b**) Full-thickness sutures are placed between the adjacent free walls of the esophagus and gastrostomy to create a common wall prior to the anastomosis (*circles*)

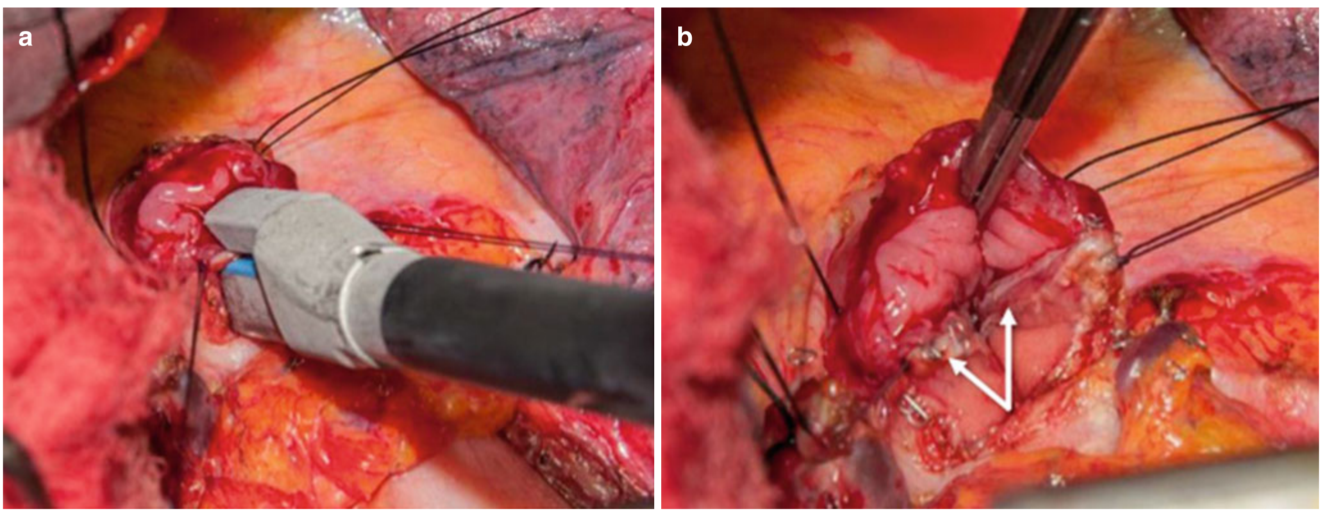

Fig. 16.15 (**a**) 30-mm linear stapler placed with one limb in the esophagus and other limb in the apex of the conduit. (**b**) Firing the stapler creates the majority of the anastomosis in the common walls of the esophagus and gastric conduit (*arrows*)

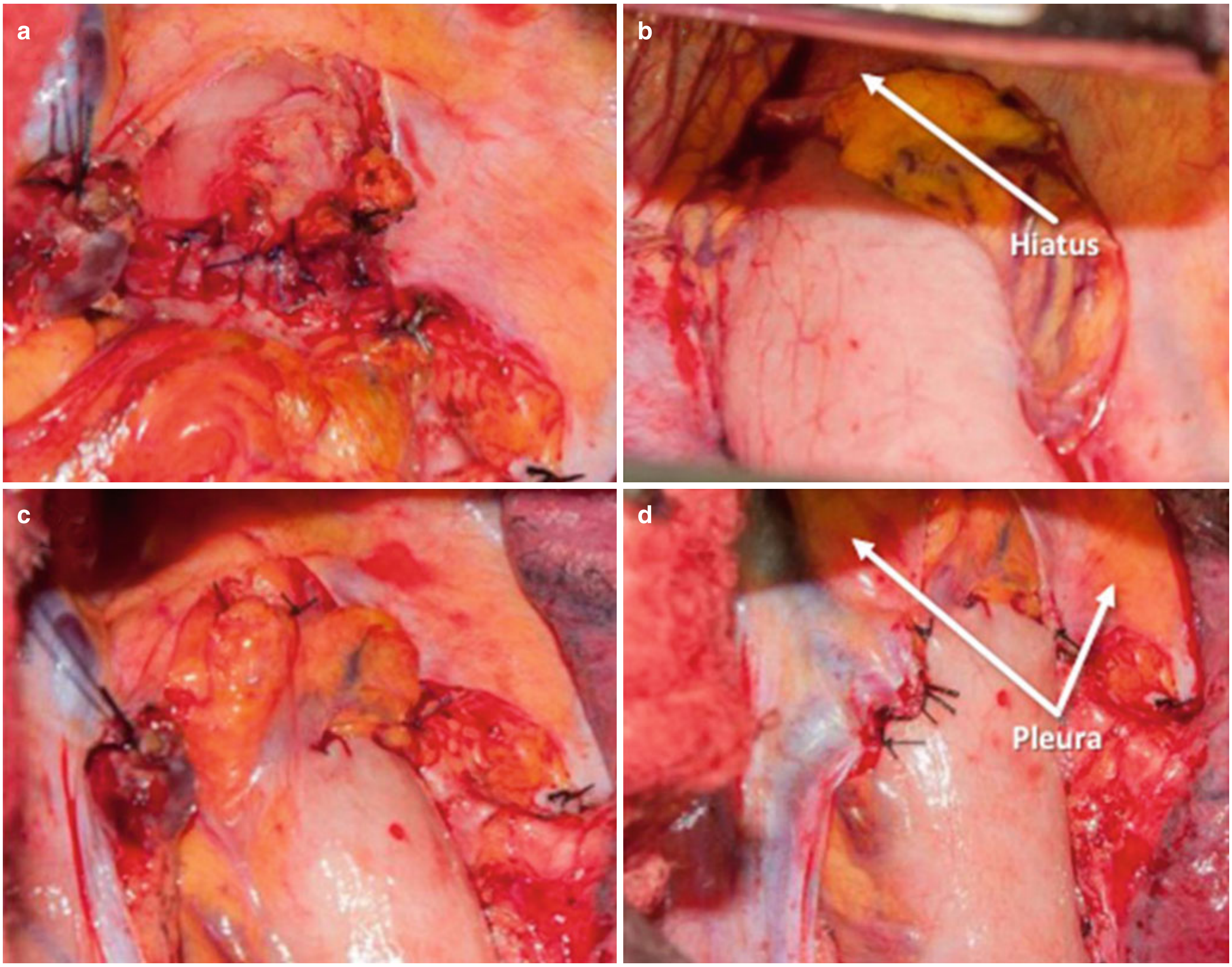

Fig. 16.16 (**a**) The esophagogastric anastomosis is completed with full-thickness absorbable sutures and a second layer of imbricating 3.0 silk sutures. (**b**) Conduit should be positioned vertically in the chest without redundancy above the diaphragm. (**c**, **d**) Anastomosis optimally covered with adjacent omental fat and pleura

16.3 Postoperative Course

Estimated operative blood loss was 150 mL. Intraoperative fluid administration was 3 L of crystalloid; no transfusions were required. The patient was extubated in the operating room and taken to the postoperative stepdown unit. The patient was managed according to a standardized care pathway defining specific goals for each day of her recovery (Markar et al. 2014). She was mobilized into the chair on the same night as surgery, and hemodynamic management (IV fluids, pressors, and epidural adjustments) were aimed at maintenance of a mean arterial pressure greater than 70 mmHg. On postoperative day 1, the patient was transferred to the regular ward, her jejunostomy tube feeds were initiated, and her mobilization plan progressed to include 3–4 walks in the hall. On day 3, she underwent an upper GI contrast study, which showed no evidence of an anastomotic leak and rapid emptying of the stomach into the duodenum (Fig. 16.17). Her nasogastric tube was then removed.

The patient was transitioned off her epidural on day 4, and oral intake was initiated on the same day. The patient was able to independently mobilize on day 5 and was tolerating full jejunostomy feeds. She was sent home on day 6 following resection. Patient followed up in Clinic 3 weeks and 3 and 6 months postoperatively.

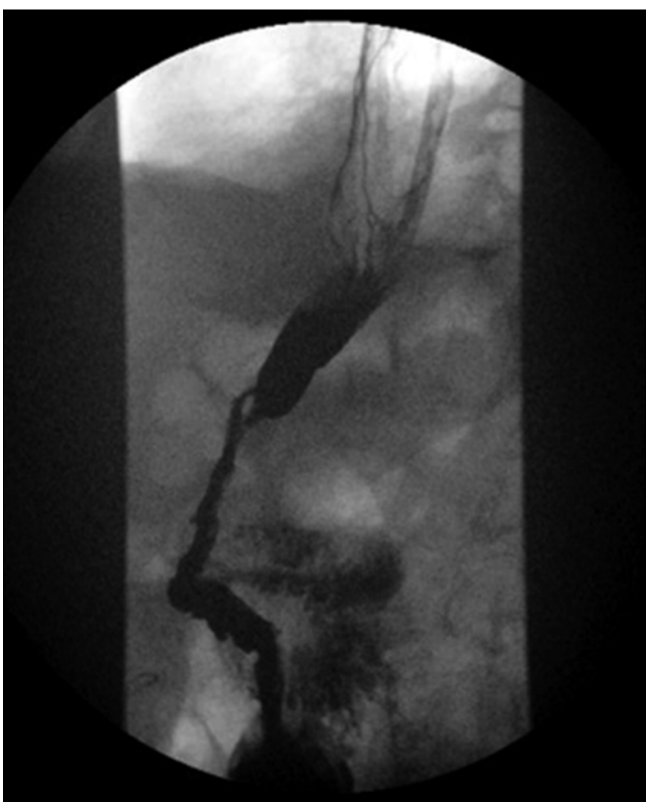

Fig. 16.17 Upper GI contrast study at postoperative day 3. Anastomosis is assessed, but more importantly, gastric emptying is assessed. This study shows immediate gastric emptying in a patient who did not have pyloroplasty

16.4 Pearls and Pitfalls

- The laparotomy and thoracotomy are standard incisions and therefore are easy to teach.
- The Ivor Lewis approach allows for esophageal dissection and complete two-field thoracoabdominal lymphadenectomy, all under direct visualization.
- Depending on the preoperative or operative findings regarding the extent of required gastric resection, the anastomosis can be placed at a variety of levels within the chest, depending on the length of the gastric conduit. It should be recognized, however, that the best results are obtained by placing the anastomosis above the azygous vein and by ensuring that the conduit has a straight pathway through the hiatus without any redundancy above the diaphragm.
- Stapling the conduit further down the lesser curvature and stapling smaller lengths along the greater curvature will provide a longer conduit.
- Patients with significant cardiac comorbidities such as congestive heart failure, ischemic heart disease, or atrial dysrhythmia will benefit from the Ivor Lewis approach because there is minimal need for cardiac manipulation or intraoperative hypotension, which is more common in other types of resections.
- By performing an intrathoracic anastomosis, the risk of vocal cord injury is less than with cervical anastomoses. Intrathoracic anastomotic leaks have historically been associated with higher levels of mortality compared with cervical anastomosis, however.
- Extra omentum, left at the mid and proximal conduit, can be used to cover the intrathoracic anastomosis; doing so may decrease the incidence and severity of leaks.
- The linear stapled esophagogastric anastomosis is a good option in an esophagus with a small luminal diameter, as it may decrease anastomotic stricture formation.
- Surgeons should focus on ensuring that the conduit is well oriented and in a vertical position in the thorax, without supradiaphragmatic redundancy. This position will provide good gastric emptying regardless of whether a pyloric drainage procedure is performed.
- Placing the posterior chest tube in the costovertebral groove in proximity to (but not adjacent to) the anastomosis will be sufficient to provide good drainage and monitor the anastomosis.
- In patients undergoing an open Ivor Lewis esophagectomy, a thoracic epidural should be placed for pain control. This will also facilitate early mobilization, which will potentially decrease pulmonary complications that are more commonly associated with thoracotomies.

Suggested Reading

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Minimally Invasive Esophagectomy

17

Monisha Sudarshan and Lorenzo Ferri

This chapter illustrates the preoperative work-up, the operative indications, and the technique of minimally invasive esophagectomy for esophageal cancer and selected cases of Barrett's esophagus with extensive high-grade dysplasia.

17.1 Preoperative Work-Up

17.1.1 History and Physical Exam

A complete history and physical exam is performed, with particular attention to severity and type of dysphagia (solids *vs* liquids), nutritional status, and associated weight loss. It is important to elicit information on habits such as smoking and alcohol use, for counseling on preoperative optimization.

17.1.2 Common Operative Indications for Esophagectomy

The operative indications for esophagectomy are esophageal cancer and selected cases of Barrett's esophagus with extensive high-grade dysplasia.

17.1.3 Work-Up

The standard preoperative work-up includes several parts:

- Complete upper endoscopy with biopsy of lesion to assess histology
- CT and PET scans to evaluate the extent of lymph node involvement and distant metastasis
- Endoscopic ultrasound (EUS) to assess locoregional spread. EUS has poor sensitivity in characterizing T2 and T3 tumors.

Preoperative staging laparoscopy can be employed to assess for peritoneal metastases, especially for tumors of the gastroesophageal junction (GEJ). Most patients benefit from preoperative cardiac stress tests and a cardiology consultation to calculate and optimize risk of postoperative cardiac complications. Pulmonary function testing is performed, especially in the presence of chronic lung disease.

17.1.4 Preoperative Considerations

- *Epidural catheter:* Insertion of an epidural catheter is crucial in obtaining optimal pain control. We routinely insert dual catheters (thoracic and abdominal epidurals), but one must be cautious of postoperative hypotension.
- *Single-lung ventilation:* Excellent single-lung ventilation is vital to maintain good exposure during thoracoscopy. Because of the short right mainstem bronchus, we prefer a double-lumen tube rather than a bronchial blocker for lung isolation.
- *EGD:* An on-table esophagogastroduodenoscopy (EGD) is routinely performed to verify the lesion and confirm its location prior to beginning the procedure. Particular attention is devoted to the extent of involvement in the lesser and greater curvatures, which may alter the conduit.
- *Enhanced Recovery Pathway:* Establishing and following an enhanced recovery pathway (ERP) provides standardized and evidence-based postoperative management for the esophagectomy patient. ERPs have been proven to be cost-effective, with decreased complications and shortened postoperative length of stay. Elements of the pathway include extubation immediately after the operation, avoidance of routine ICU care, early removal of the nasogastric (NG) tube (at 48 h), early oral feeding, and diligent chest physiotherapy with frequent ambulation.

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P.M. Fisichella, M.G. Patti (eds.), *Atlas of Esophageal Surgery*, DOI 10.1007/978-3-319-13015-6_17

17.2 Operation: Three-Hole Minimally Invasive Esophagectomy

Indications for this procedure are mid to proximal esophageal lesions, extensive Barrett's esophagus, or benign conditions such as end-stage achalasia.

After completion of intraoperative endoscopy, the patient is positioned in the left lateral decubitus position (Fig. 17.1). The left leg (lower leg) is flexed gently at the knee and the upper leg remains in extension, with adequate padding between the legs. The arms are well padded and supported on arm boards. A vacuumed beanbag is used to secure the patient, in addition to the use of tape or Velcro.

We employ a four-port or five-port thoracoscopy, minimizing the use of 10-mm trocars to decrease the risk of intercostal nerve bundle injury (Fig. 17.2). In lieu of 10-mm port sites, we use small wound protectors. Our trocar placements are the following:

1. Fifth intercostal space, anterior axillary line: 1-cm incision with a wound protector, used for a 30° camera and retracting instruments
2. Third intercostal space, anterior axillary line: 2.5-cm incision with a wound protector, utilized for the Osugi retractor and suctioning device
3. Fourth and seventh intercostal spaces, posterior axillary line: two 5-mm operating ports

After the patient is placed in reverse Trendelenburg with slight rotation anteriorly, mobilization of the thoracic esophagus is performed from the thoracic inlet to the diaphragm, and infracarinal mediastinal lymph node dissection is completed (Fig. 17.3). Retraction of the lung and airway is facilitated with an Osugi retractor. The pleura is initially divided anteriorly and posteriorly along the length of the esophagus with hook cautery, using an atraumatic grasper to provide tension on the esophagus. Further dissection is completed with a harmonic scalpel, and a Penrose drain is used to encircle the esophagus to provide countertraction. Dissection with energy devices near the trachea is performed with great care, as inadvertent injury may result in airway fistulization. The azygous vein is circumferentially dissected and divided with an Endo GIA™ stapler (Covidien, Minneapolis, MN) at the level of the carina. ENDOLOOP® ligatures (Ethicon, Somerville, NJ) are placed on each end of the divided azygous vein and retracted through the chest wall with a suture passer to increase exposure of the mid and upper mediastinum.

Once the esophagus is fully mobilized from the thoracic inlet to the diaphragm, with all nodal tissue swept into the specimen, it is divided at a level proximal to the tumor, usually cephalad to the azygous vein, consequently also dividing the vagi below the bifurcation of the recurrent laryngeal nerves with a single firing of the Endo GIA™ stapler (Fig. 17.4). The proximal and distal margins are secured to a common umbilical tape to facilitate retrieval via the neck and laparoscopy. The chest is copiously irrigated and a large-capacity closed suction

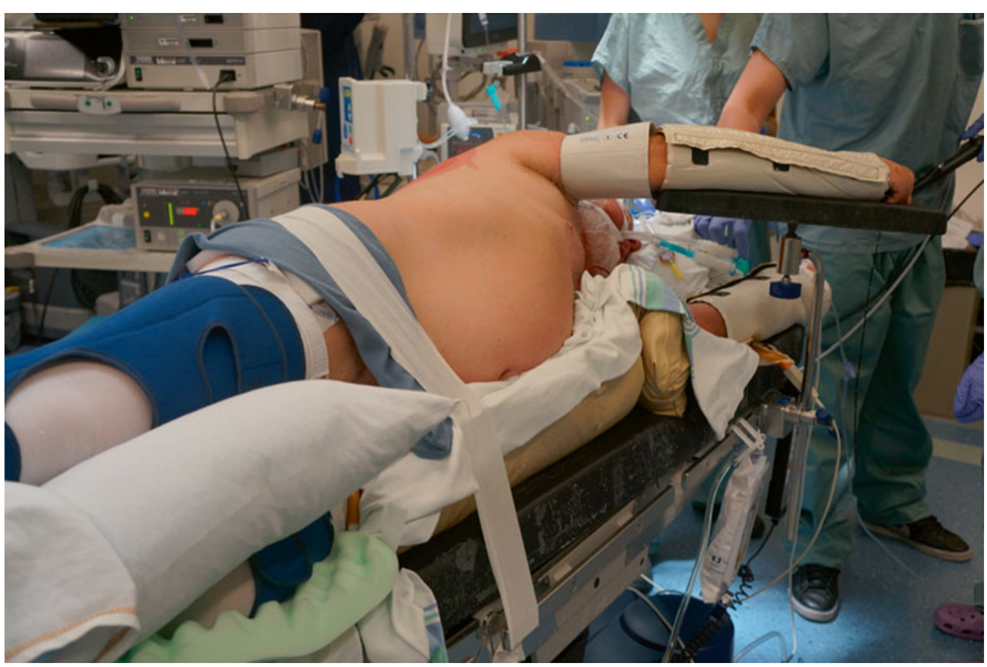

Fig. 17.1 Left lateral decubitus positioning for thoracoscopy

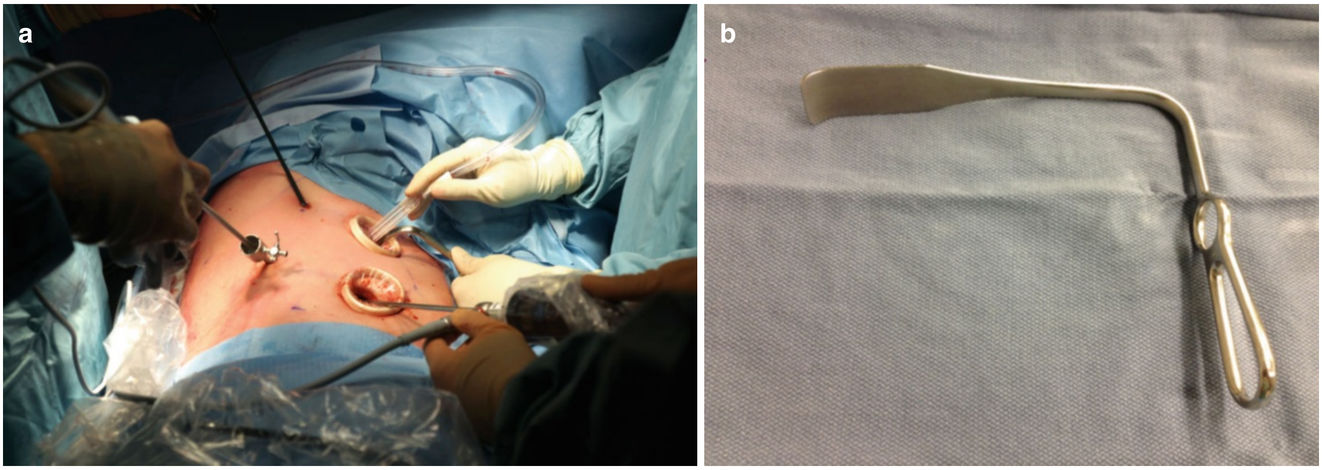

Fig. 17.2 (**a**) Trocar sites for thoracoscopy. (**b**) Use of an Osugi retractor facilitates lung retraction through wound manager

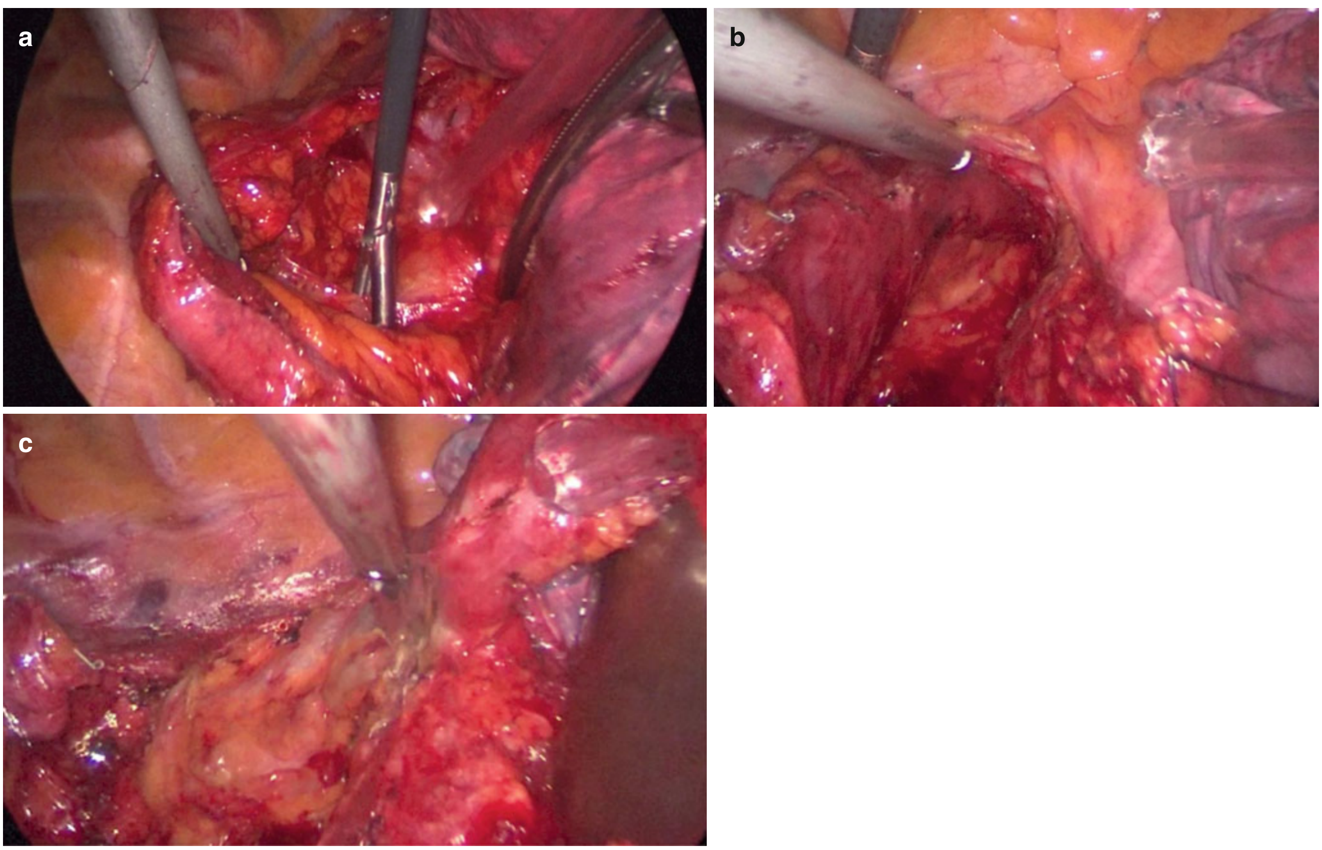

Fig. 17.3 (**a**) Esophageal mobilization. (**b**, **c**) Subcarinal dissection

drain (Jackson-Pratt) is inserted in lieu of a chest tube (Fig. 17.5). The trocar sites are closed in layers, and the double-lumen endotracheal tube is exchanged for a single-lumen tube to enhance mobility of the airway during the cervical portion of the operation.

The patient is repositioned in the supine, split-leg position for laparoscopy. The neck is extended, with a roll placed between the scapula. A five-port laparoscopy is employed (Fig. 17.6): A 10-mm Hasson port is placed supraumbilically, a 12-mm port is placed in the left upper quadrant mid-clavicular line, a 5-mm port in the left costal margin for operating instruments, a 5-mm port in the right flank for the liver retractor, and a 5-mm operating port in the right upper quadrant at the mid-clavicular line. A 5-mm, 30° camera is employed.

The gastrohepatic omentum is opened and the right and left crura are circumferentially dissected without complete division of the phrenoesophageal membrane, in order to preserve pneumoperitoneum.

We perform a complete D2 celiac lymph node dissection by skeletonizing the splenic artery, the hepatic artery, and the splenic vein (Fig. 17.7). The left gastric pedicle is dissected, skeletonized, triplely clipped, and divided. We do not staple the left gastric pedicle, as it may provide an inadequate lymph node dissection. All lymph node–bearing tissue is included with the specimen (Fig. 17.8). We also proceed along the entire celiac axis down to the aorta to include the periceliac lymph nodes en bloc with the specimen.

The greater curve is dissected after creation of a window in the gastrocolic omentum, and the lesser sac is entered. Dissection proceeds 5 cm from the greater curvature, with extreme caution taken to preserve the gastroepiploic arcade, the dependent blood supply to the future conduit (Fig. 17.9). The retrogastric attachments are freed and dissection is carried up to the left esophageal hiatus. A Kocher maneuver is completed, with adequate mobilization of the pylorus ensured by testing its extension to the caudate lobe or right crus. After ensuring satisfactory hemostasis, the esophageal hiatus is completely mobilized and the phrenoesophageal membrane is divided.

An accessory incision 5–6 cm in length is constructed in the upper midline, with insertion of a wound protector (Fig. 17.10). A pyloromyotomy is completed to ensure optimal conduit drainage. A 4- to 5-cm gastric conduit is fashioned with sequential firings of the GIA™ stapler (generally three firings) and oversewing of the staple line (Fig. 17.11). Extracorporeal construction is a useful adjunct in the creation of an excellent conduit and greatly facilitates assessment and revision of the distal margin, should this be necessary.

A 4- to 5-cm cervical collar incision is made (Fig. 17.12a), the platysma is incised, and subplatysmal planes are generated. The omohyoid muscle and middle thyroid vein are divided for optimal exposure. Blunt dissection and lateral mobilization are completed in order to deliver the esophagus into the wound (Fig. 17.12b). Identification of the left recurrent laryngeal nerve is paramount to its preservation. The proximal margin is revised in the neck, and stay sutures of 4-0 silk are placed at four corners to facilitate the eventual anastomosis (Fig. 17.13).

The conduit is introduced into an endoscopic camera bag in preparation for guidance to the neck (Fig. 17.14). The proximal end is secured with a Foley catheter, which is also attached to the umbilical tape at the cervical esophagus. The surgeon then gently guides the conduit in the posterior mediastinal orthotopic position, using the accessory incision and delivering the conduit into the neck while always maintaining orientation to prevent conduit torsion.

The cervical anastomosis can be completed with a stapling device (side to side or end to side) or, as we prefer, through a hand-sewn anastomosis (Fig. 17.15). Our preference is to use single-layer running suture with incorporation of the muscular layer and small bites of mucosa. Prior to completion, an NG tube is placed under direct vision past the anastomosis, and a Jackson-Pratt drain is inserted in the neck near the anastomosis. We do not routinely employ a jejunostomy under most circumstances because the associated complication rate surpasses our rate of anastomotic leak. Fascia for the abdominal incisions is closed with 1 polydioxanone suture (PDS). The platysma at the collar incision is approximated with 2-0 Vicryl sutures. Skin closure is completed with 4-0 Monocryl sutures.

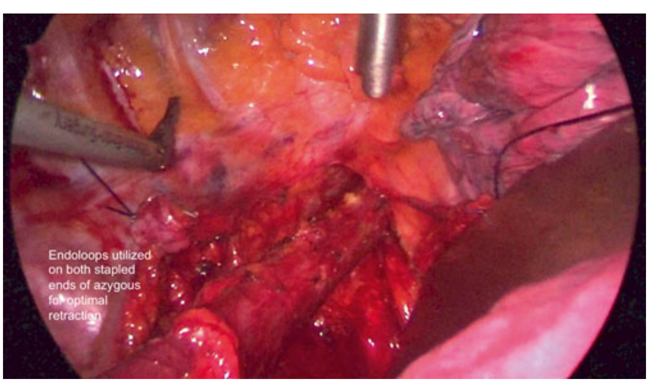

Fig. 17.4 Completion of thoracoscopy

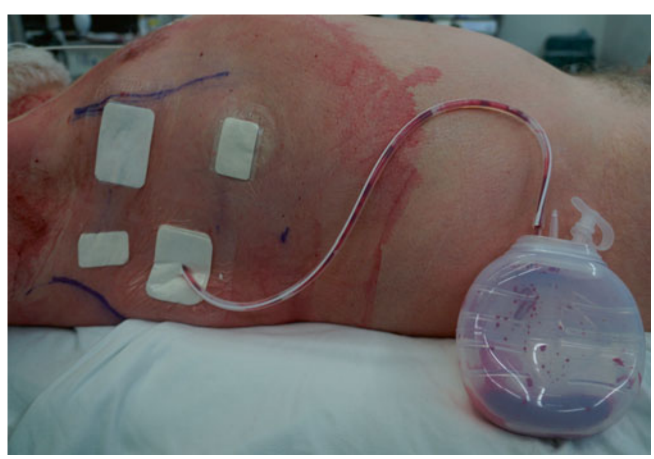

Fig. 17.5 Use of large-capacity Jackson-Pratt drains in lieu of chest tubes

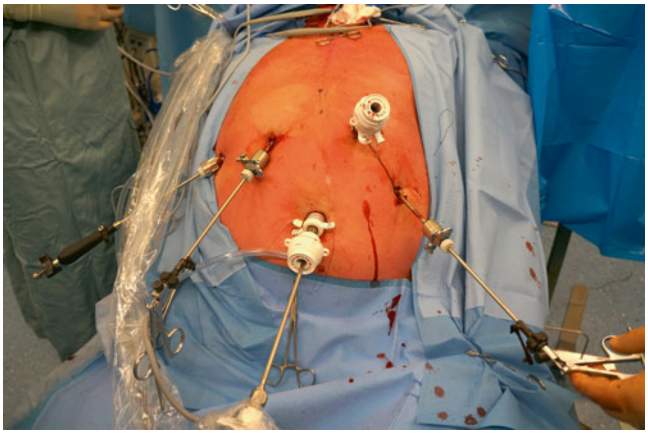

Fig. 17.6 Port placement

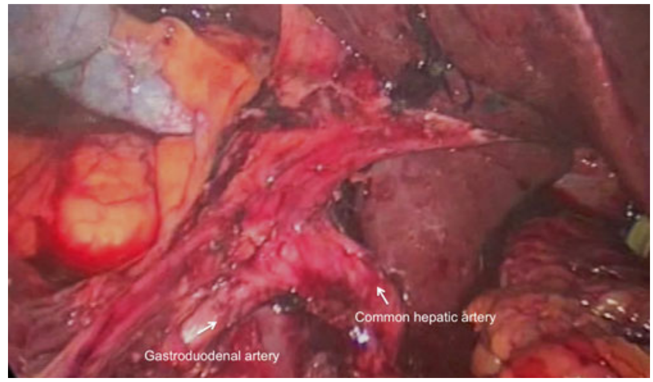

Fig. 17.8 Completed D2 dissection demonstrating skeletonized hepatic and gastroduodenal arteries

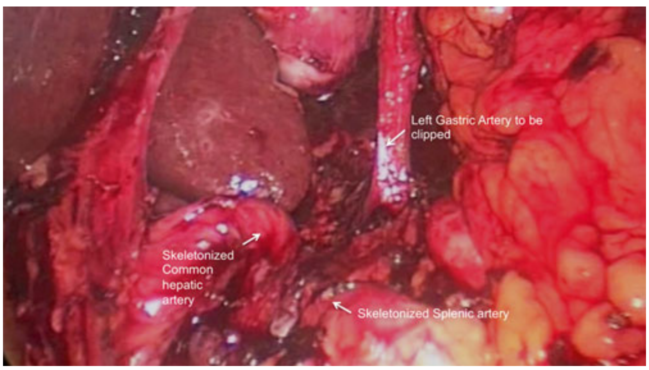

Fig. 17.7 D2 dissection and dissection of the left gastric pedicle to be divided

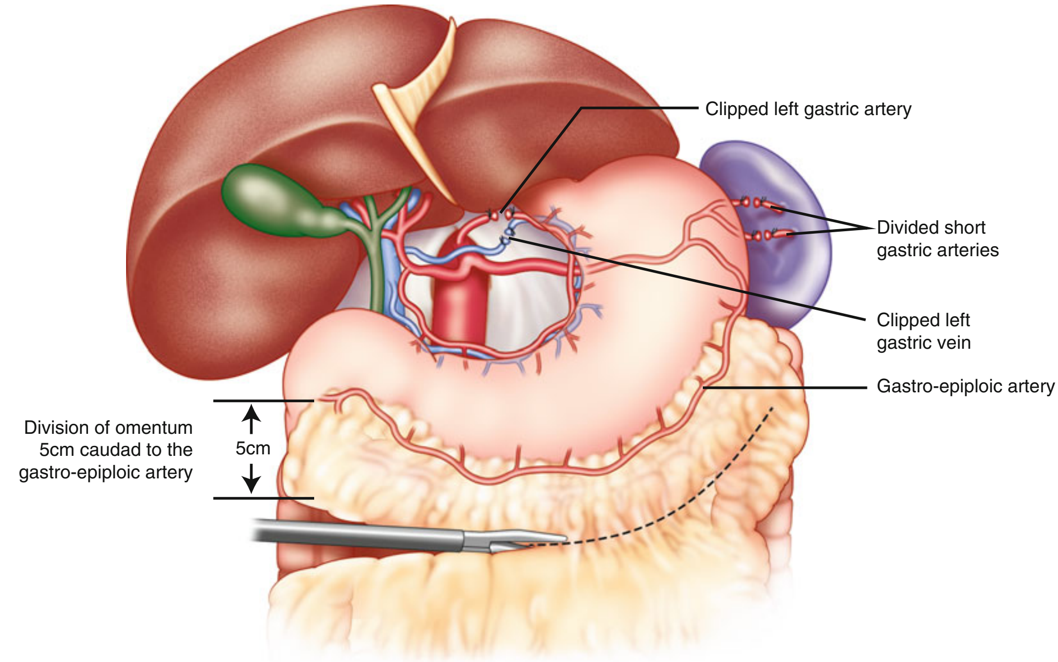

Fig. 17.9 Dissection along the greater curve of the stomach

Fig. 17.10 Accessory incision

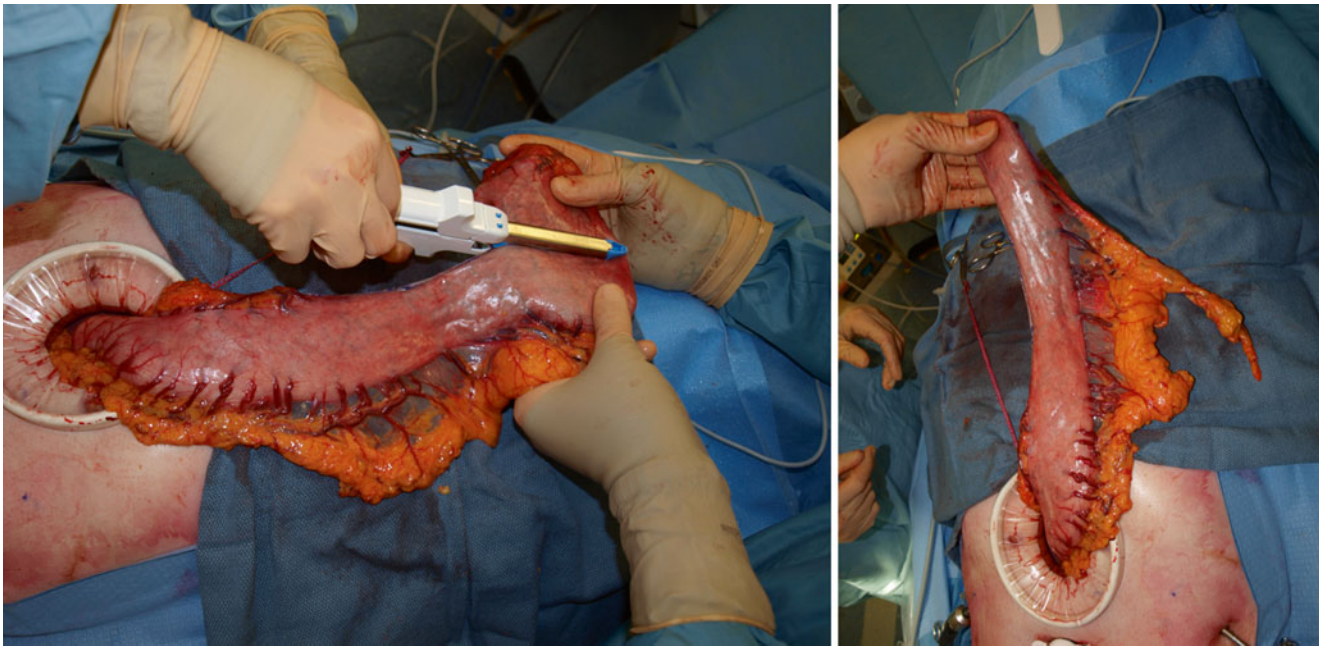

Fig. 17.11 Construction of gastric conduit

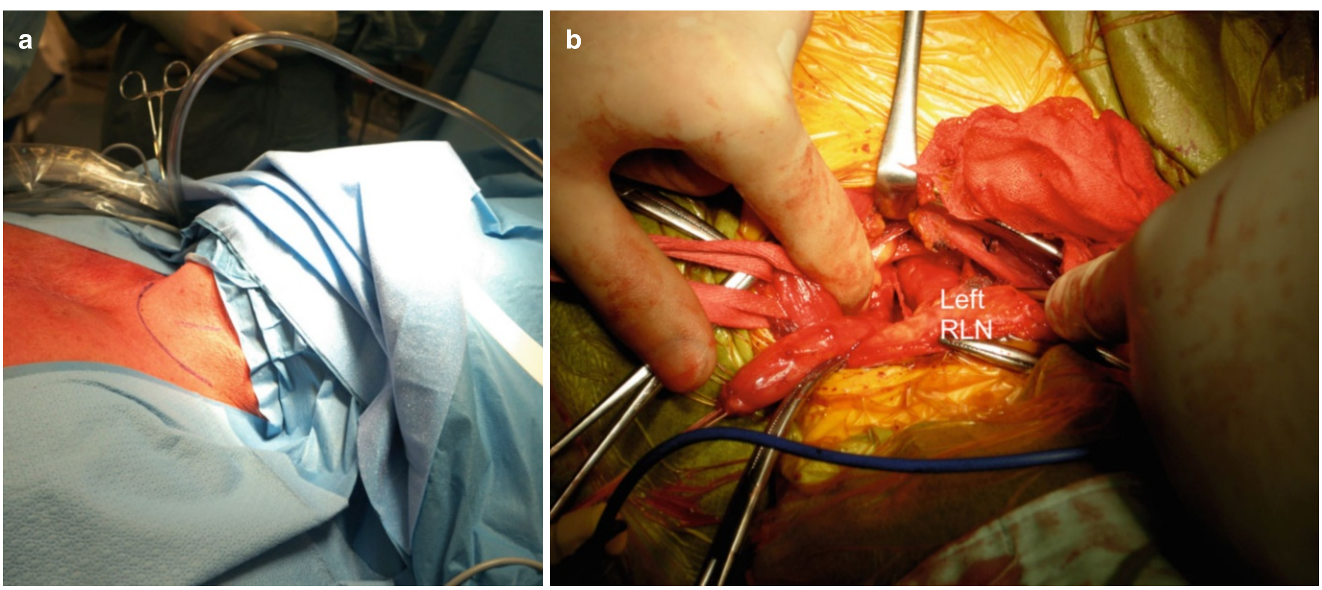

Fig. 17.12 (**a**) Cervical collar incision. (**b**) Dissection of cervical esophagus with visualization and preservation of recurrent laryngeal nerves (RLN)

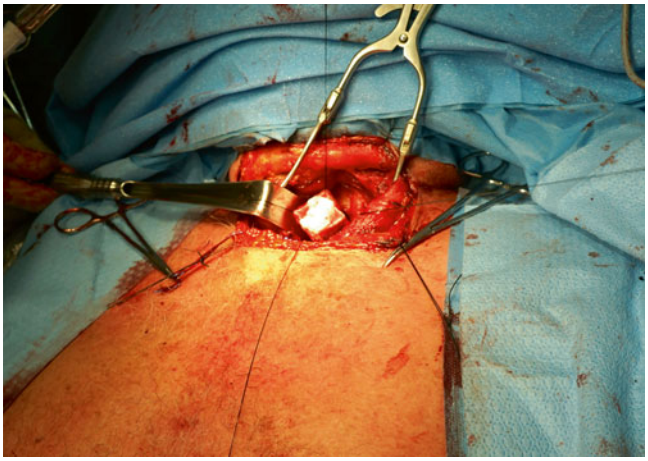

Fig. 17.13 Prepared cervical esophagus with stay sutures

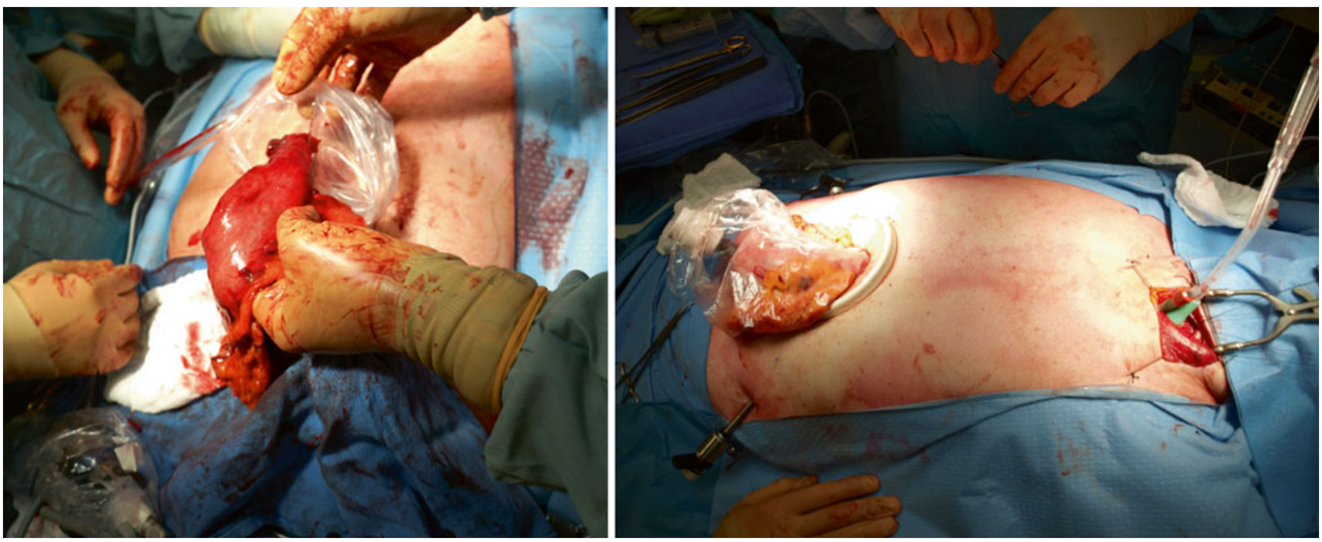

Fig. 17.14 Insertion of conduit in camera bag in preparation for guidance to neck

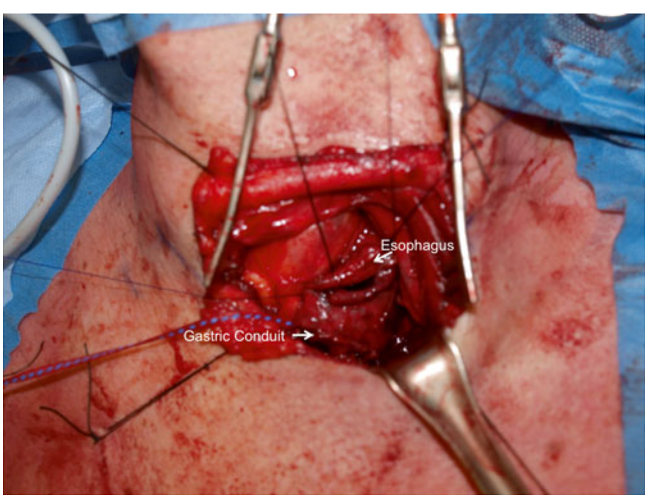

Fig. 17.15 Construction of cervical anastomosis

17.3 Operation: Minimally Invasive Ivor Lewis Esophagectomy

After completion of an on-table endoscopy, the patient is positioned supine and a five-port laparoscopy is used as discussed above (Fig. 17.6). We proceed with dissection of the crura and the greater curve with a complete D2 lymphadenectomy as illustrated in Fig. 17.8. Again, we employ a 5- to 6-cm accessory incision in order to complete a drainage procedure (pyloromyotomy or pyloroplasty) and prepare the conduit.

The 4- to 5-cm gastric conduit is constructed through sequential firings of the GIA™ stapler and oversewing of the staple line. The apex of the gastric conduit and specimen is left attached and is not completely divided, to maintain orientation and aid the division of the esophagus according to optimal conduit length. The specimen and conduit are introduced into the mediastinum and a loose hiatoplasty is completed to avoid a postoperative hernia. Fascia for the abdominal incisions is closed with 2-0 PDS. Skin closure is completed with 4-0 Monocryl.

The patient is repositioned in the left lateral decubitus position for thoracoscopy (Fig. 17.1), with port sites as shown in Figure 17.2. After placing the patient in reverse Trendelenburg with slight rotation anteriorly, mobilization of the thoracic esophagus is performed from the thoracic inlet to the diaphragm and infra-carinal mediastinal lymph node dissection is completed as described above (Fig. 17.3). Upon complete mobilization of the esophagus from the thoracic inlet to the diaphragmatic hiatus, the specimen and conduit are retrieved. The proximal esophagus is divided at the level of the azygous vein after considering the conduit length, reach, and extent of the esophageal pathology. The conduit and specimen are stapled and separated, and the specimen is retrieved for intraoperative frozen section pathology.

The esophagogastric anastomosis can be constructed with a stapling technique or can be hand-sewn. For a stapled anastomosis, an endoscopic circular stapler is employed, with the anvil introduced in the proximal esophagus via either a transthoracic or transoral route. Our preference is to construct a hand-sewn end-to-side esophagogastric anastomosis in a running continuous fashion with 3-0 PDS; this is performed through a slightly larger accessory incision (5–6 cm). The anastomosis is further reinforced with mediastinal pleura using 4-0 braided nylon sutures. The conduit is secured to the hiatus with an Endo Stitch™ (Covidien, Minneapolis, MN) in order to prevent herniation. An NG tube is guided across the anastomosis.

The chest is copiously irrigated and a 19-French Jackson-Pratt drain is placed adjacent to the anastomosis. The ribs are reapproximated with 2-0 Vicryl sutures and the muscle and subcutaneous tissue are closed in layers (Fig. 17.16).

Fig. 17.16 Postoperative wound result after minimally invasive Ivor Lewis esophagectomy

17.4 Technical Pitfalls and Complications

17.4.1 Bleeding

Serious hemorrhage during esophageal surgery is reported to occur in up to 4 % of surgeries. The extent of bleeding and repair largely depends on the vessel injured. Excellent anatomical knowledge and awareness of the trajectory of all major vessels is critical during esophageal dissection. The esophagus is in proximity to several major vessels, including the aorta, pulmonary veins, and pulmonary arteries; their inadvertent injury will result in catastrophic hemorrhage. Furthermore, if the feeding vessels to the esophagus originating from the aorta are not adequately controlled during mobilization, significant bleeding can result.

17.4.2 Splenic Injury

Splenectomy rates during esophagectomy are reported to be between 4 and 9 %. Injury is primarily due to excessive tension on the short gastrics during gastric mobilization, which results in a splenic capsular tear. If possible, splenic salvage techniques for arresting the hemorrhage are attempted prior to splenectomy. The increasing use of laparoscopy has decreased splenic injury rates, owing to decreased tension on the short gastric vessels.

17.4.3 Airway Injury

The trachea, the carina, and the right and left bronchi are all susceptible to injury during esophageal mobilization. The thin-walled membranous portion of the airway that abuts the esophagus is particularly vulnerable to cautery or blunt injury. Injuries proximal to the endotracheal tube usually will not result in an unstable physiological status, as air does not escape into the thoracic cavity. These injuries are primarily repaired with absorbable sutures in an interrupted fashion, with further buttressing with muscle or a fat pad. Injuries that are distal to the endotracheal tube may result in significant hemodynamic instability (although this is limited for double-lumen tubes). Repair options include advancing the tube past the injury, if possible, and swift repair of the opening.

17.4.4 Nerve Injury

The recurrent laryngeal nerve is vulnerable to injury during dissection at the thoracic inlet and during the cervical portion of the three-hole esophagectomy. Careful dissection and clear visualization of the nerve avoids its inadvertent injury (see Fig. 17.12)

17.4.5 Conduit Necrosis

One of the most dreaded complications is the loss of the gastric conduit due to inadvertent injury to the right gastroepiploic arcade. The rate of gastric conduit ischemia is approximately 3 %, with higher rates reported for colonic and jejunal conduits. Conduit ischemia can be addressed by gentle handling of the conduit, careful dissection (especially at the pyloro-antral region), and verification of the artery trajectory during dissection of the greater curve.

17.4.6 Other Postoperative Complications

A complete discussion of postoperative complications is beyond the scope of this chapter. Early postoperative complications include chylothorax, delayed conduit necrosis, and anastomotic leak. Respiratory complications (atelectasis, pneumonia) are among the most common and morbid for the postesophagectomy patient and are best avoided with early ambulation, incentive spirometry, and excellent chest physiotherapy. Cardiac complications such as atrial fibrillation and supraventricular tachycardia may occur in isolation in the postoperative period, but they often herald another complication such as an anastomotic leak or pneumonia, so their occurrence should prompt a thorough work-up.

Suggested Reading

Lee L, Sudarshan M, Li C, Latimer E, Fried GM, Mulder DS, et al. Cost-effectiveness of minimally invasive versus open esophagectomy for esophageal cancer. Ann Surg Oncol. 2013;20:3732–9.

Li C, Ferri LE, Mulder DS, Ncuti A, Neville A, Lee L, et al. An enhanced recovery pathway decreases duration of stay after esophagectomy. Surgery. 2012;152:606–14.

Luketich JD, Pennathur A, Awais O, Levy RM, Keeley S, Shende M, et al. Outcomes after minimally invasive esophagectomy: review of over 1000 patients. Ann Surg. 2012;256:95–103.

Raymond D. Complications of esophagectomy. Surg Clin North Am. 2012;92:1299–313.

Sudarshan M, Ferri L. A critical review of minimally invasive esophagectomy. Surg Laparosc Endosc Percutan Tech. 2012;22:310–8.

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Hybrid Transthoracic Esophagectomy

18

Bernardo Borraez and Marco G. Patti

18.1 Clinical History

The patient is a 68-year-old man with a 20-year history of heartburn and regurgitation. He was initially treated empirically with H_2 blocking agents and antacids. Ten years after onset, the patient felt that his symptoms were getting worse, so a complete work-up was done, with the following findings:

- Barium swallow: large sliding hiatal hernia
- Endoscopy: 4-cm segment of Barrett's esophagus, with metaplasia but no dysplasia
- Manometry: ineffective esophageal motility
- pH Monitoring: a severe amount of reflux in both the supine and upright positions.

The patient was advised to have a laparoscopic fundoplication and yearly endoscopic follow-up, but he did not want the operation and decide to continue proton pump inhibitors. He did not visit his gastroenterologist for follow-up for 10 years, after which endoscopy showed an 8-cm segment of Barrett's esophagus with metaplasia and low-grade and high-grade dysplasia. Biopsy of a 5-mm nodule was positive for adenocarcinoma. Endoscopic ultrasound could not distinguish between a T1a and a T1b. No pathologic nodes were identified. A chest and abdominal CT scan was normal. The patient underwent an uneventful endoscopic mucosal resection, but pathology showed involvement of the deep margin by cancer. It was decided to proceed with esophagectomy.

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P.M. Fisichella, M.G. Patti (eds.), *Atlas of Esophageal Surgery*, DOI 10.1007/978-3-319-13015-6_18

18.2 Operation: Hybrid Transthoracic Esophagectomy

This approach combines laparoscopy for preparation of the stomach and pyloroplasty, with a thoracotomy for gastric pull-up, resection of the esophagus, and esophagogastric anastomosis.

Before the beginning of the operation, an epidural catheter, a double-lumen endotracheal tube, and an arterial catheter were inserted.

18.2.1 Laparoscopic Component

Figure 18.1 shows the position of the operating team around the operating table for the laparoscopic portion of the operation. Five trocars are then placed for use in the dissection and gastric preparation for pull-up (Fig. 18.2). During this part of the operation, the camera is inserted through trocar # 1. For the pyloroplasty, the camera is switched to trocar # 3, and trocars #1 and #5b are used for the suturing.

The gastrohepatic ligament is divided, beginning the dissection above the caudate lobe of the liver where the ligament is thinner (Figs. 18.3 and 18.4). An accessory left hepatic artery originating from the left gastric artery is divided between clips (Figs. 18.5 and 18.6).

Dissection is continued proximally, and the right pillar of the crus is separated from the esophagus (Fig. 18.7). The phrenoesophageal membrane is divided using electrocautery (Fig. 18.8). Dissection is then performed in the posterior mediastinum (laterally, anteriorly and posteriorly) for about 5 cm above the diaphragm (Fig. 18.9). This step is important as it allows separation of esophagus from the aorta. Sometimes it can be difficult to find the plane between these two structures, either because of radiation changes or extramural spread of the tumor. In these cases, it is safer to proceed with this part of the dissection during the thoracotomy. Lower mediastinal lymph nodes are retrieved.

The right gastroepiploic artery is identified (Fig. 18.10) and the gastrosplenic ligament is opened using a bipolar instrument (Fig. 18.11). All the short gastric vessels are divided, and the dissection is continued all the way to the left pillar of the crus (Fig. 18.12). A window is created between the left pillar of the crus, the esophagus, and the stomach (Figs. 18.13 and 18.14). A Penrose drain is passed around the esophagus.

The coronary vein and the left gastric artery are divided. The vessels are dissected all the way to their base in order to retrieve as many left gastric nodes as possible (Figs. 18.15, 18.16, 18.17, and 18.18). An Endo GIA™ stapler (Covidien, Minneapolis, MN) with a 45-mm vascular cartridge is inserted through port 2 and is used for the transection of these vessels (Figs. 18.19, 18.20, and 18.21). Adhesions posterior to the esophagus and stomach are taken down using scissors or the hook cautery.

The gastrocolic ligament is opened using the bipolar instrument and the hook cautery (Figs. 18.22, 18.23, 18.24, and 18.25). Upon completion of this step, the blood supply of the stomach is based on the right gastric artery and the right gastroepiploic artery.

To begin the pyloroplasty, the pylorus is opened longitudinally (Figs. 18.26 and 18.27). A rolled-up sponge of absorbable material is inserted through the opening (Figs. 18.28 and 18.29) to separate the anterior from the posterior wall. The opening is then closed transversely with interrupted 2-0 silk sutures (Figs. 18.30 and 18.31). For this step of the procedure, the camera is switched to trocar #3 in order to create a 120° angle for suturing. The surgeon stands on the right side of the table and uses trocars #1 and #5b for suturing.

After a final inspection of the peritoneal cavity (especially the stomach), the trocars are removed, the trocars sites are closed, local anesthesia is injected, and sterile dressings are applied.

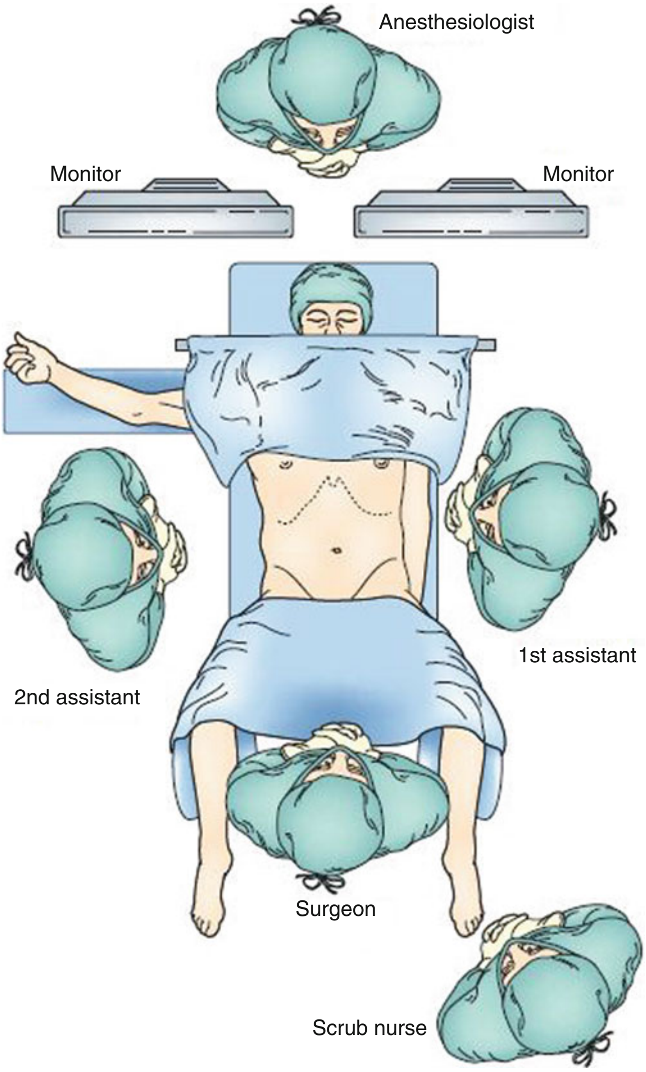

Fig. 18.1 Position of the operating team around the operating table

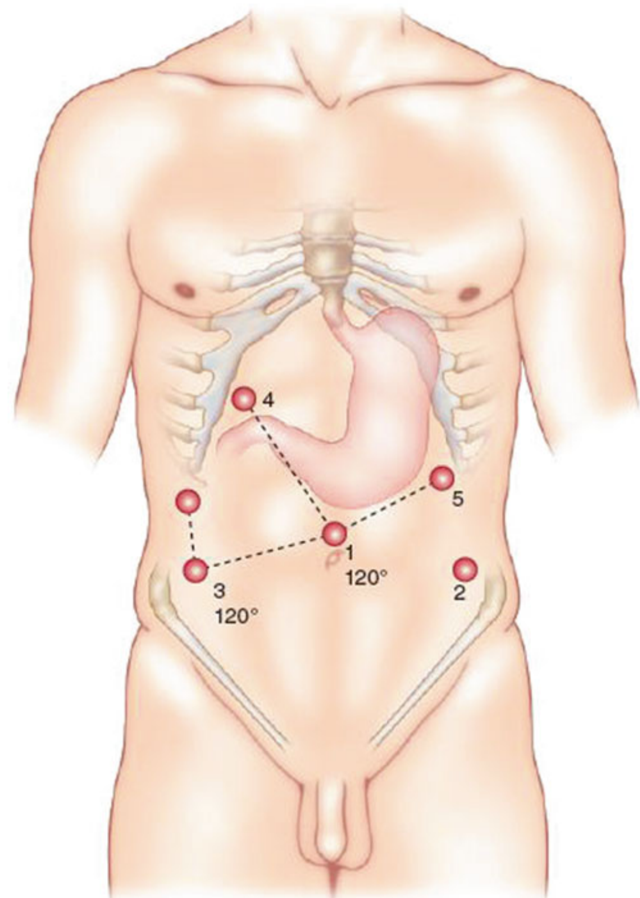

Fig. 18.2 Placement of trocars

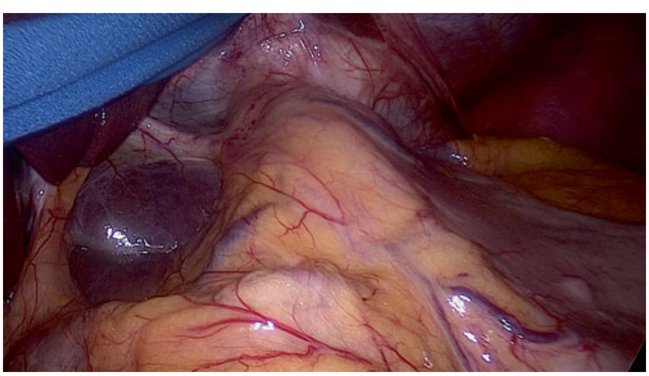

Fig. 18.3 The gastrohepatic ligament

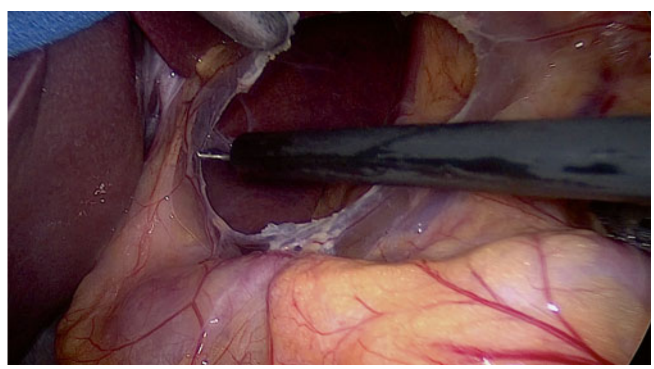

Fig. 18.4 The dissection of the gastrohepatic ligament, begun above the caudate lobe of the liver, where the ligament is thinner

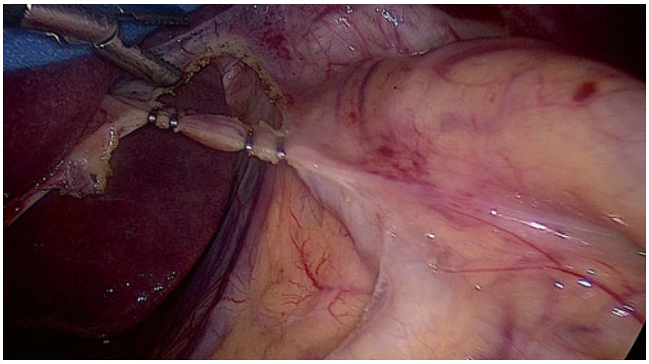

Fig. 18.5 Clips placed on an accessory left hepatic artery originating from the left gastric artery so it can be divided

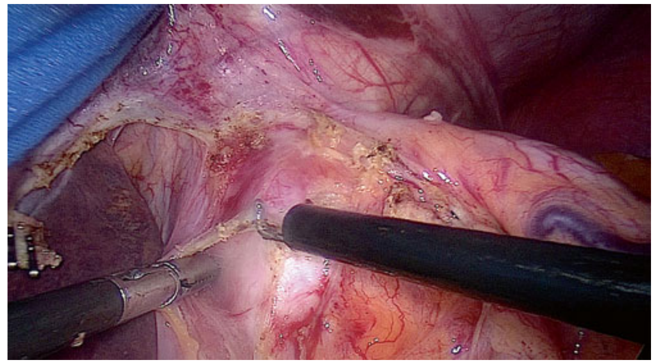

Fig. 18.8 The phrenoesophageal membrane is divided using electrocautery

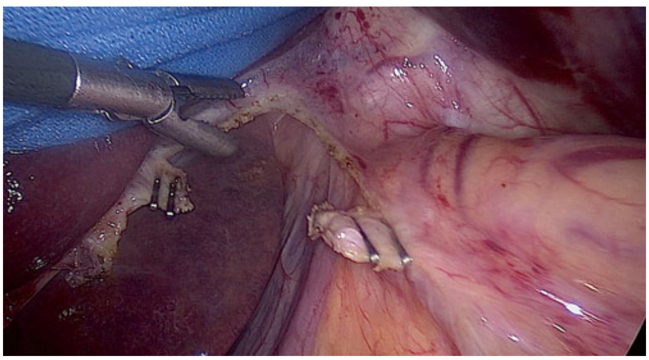

Fig. 18.6 The accessory left hepatic artery divided between clips

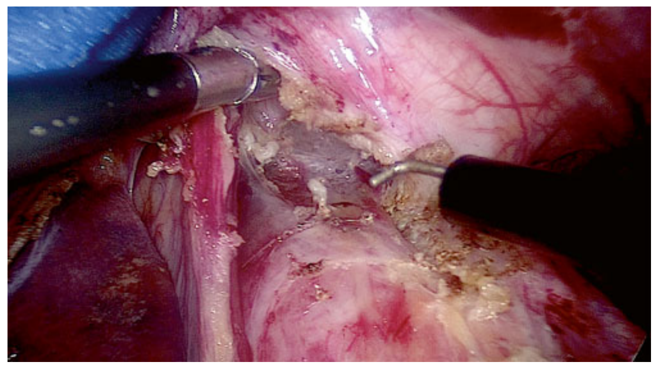

Fig. 18.9 Dissection performed in the posterior mediastinum (laterally, anteriorly, and posteriorly) for about 5 cm above the diaphragm

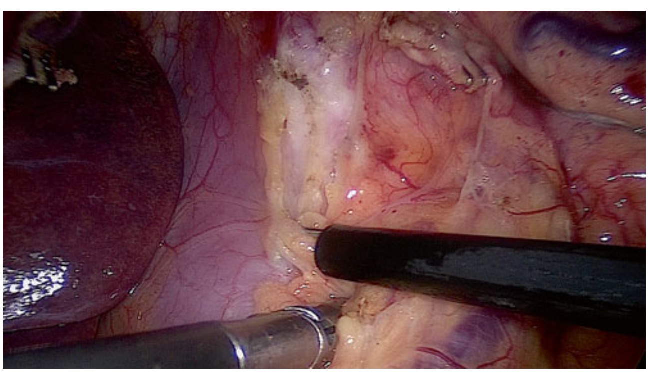

Fig. 18.7 Dissection continued proximally; the right pillar of the crus is separated from the esophagus

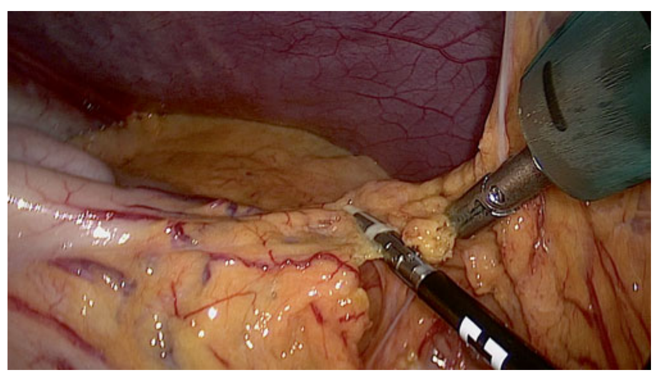

Fig. 18.10 Identification of the right gastroepiploic artery

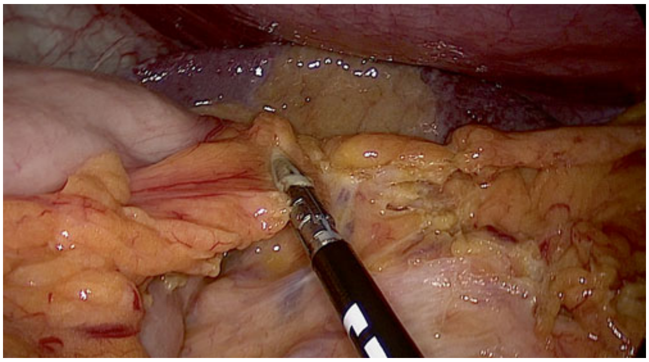

Fig. 18.11 Opening of the gastrosplenic ligament, using a bipolar instrument

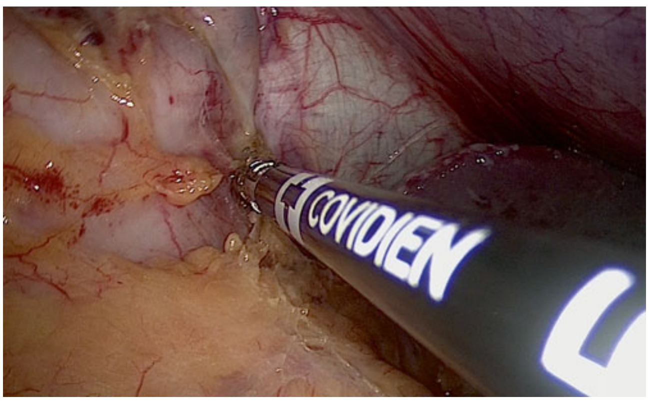

Fig. 18.12 Division of the short gastric vessels; dissection continued all the way to the left pillar of the crus

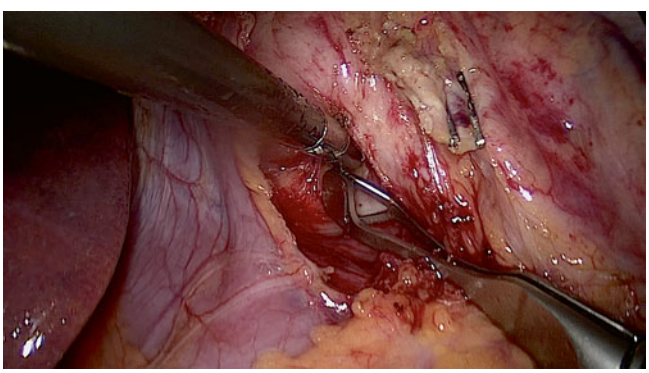

Fig. 18.13 Creation of a window between the left pillar of the crus, the esophagus, and the stomach

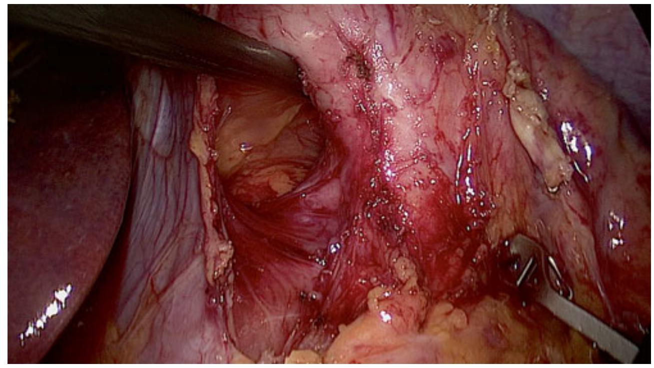

Fig. 18.14 Creation of a window between the left pillar of the crus, the esophagus, and the stomach

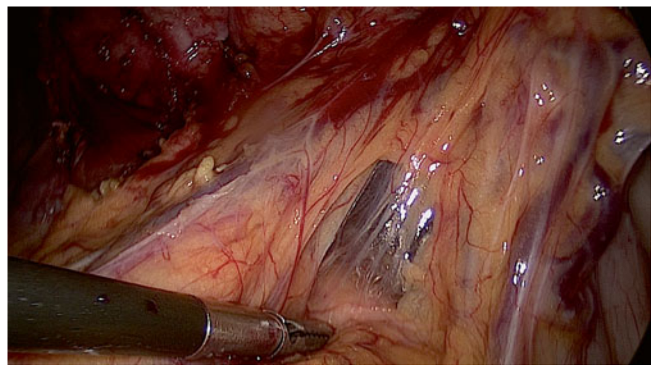

Fig. 18.15 Division of the coronary vein and the left gastric artery, which are dissected all the way to their base

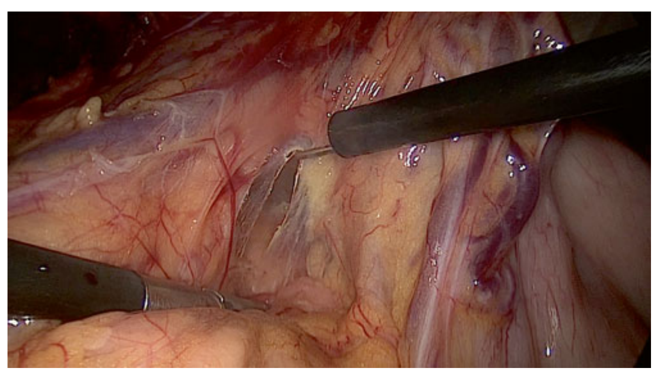

Fig. 18.16 Division of the coronary vein and the left gastric artery, which are dissected all the way to their base

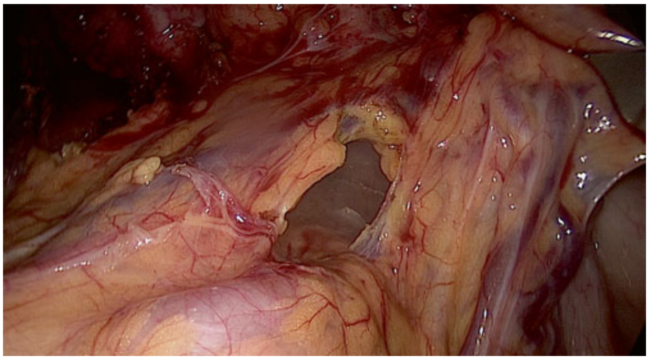

Fig. 18.17 Division of the coronary vein and the left gastric artery, which are dissected all the way to their base

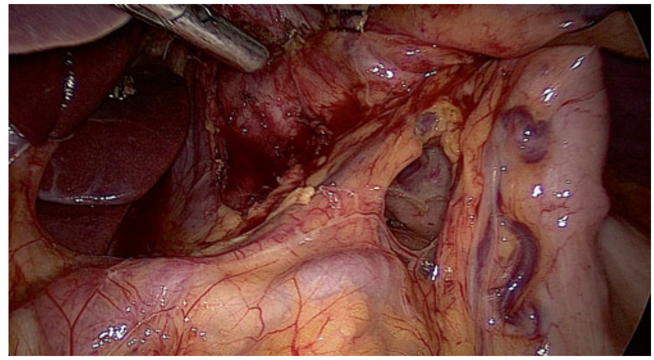

Fig. 18.18 Division of the coronary vein and the left gastric artery, which are dissected all the way to their base

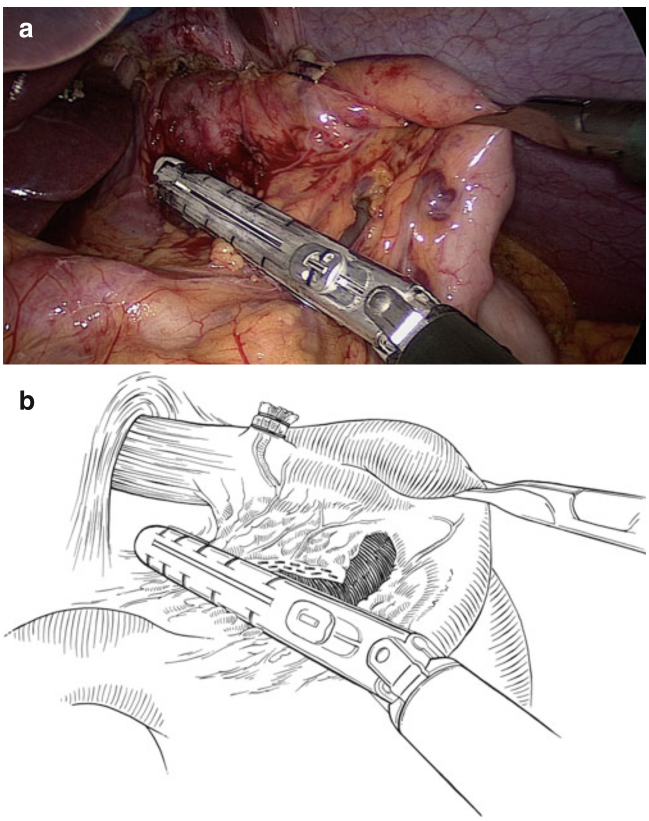

Fig. 18.19 (**a**, **b**) An Endo GIA™ stapler (Covidien, Minneapolis, MN) with a 45-mm vascular cartridge is used for the transection of the coronary vein and left gastric artery

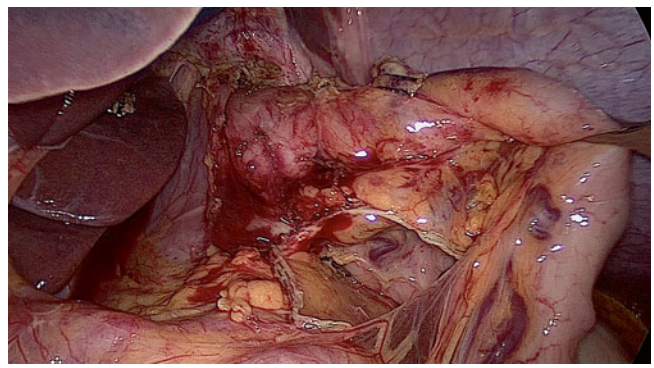

Fig. 18.20 The transected vessels after stapling

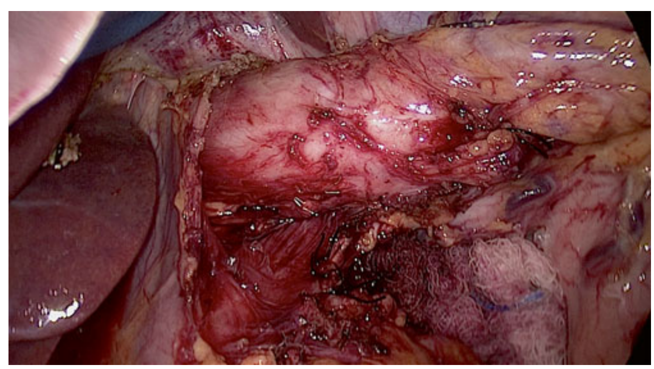

Fig. 18.21 The transected vessels after stapling

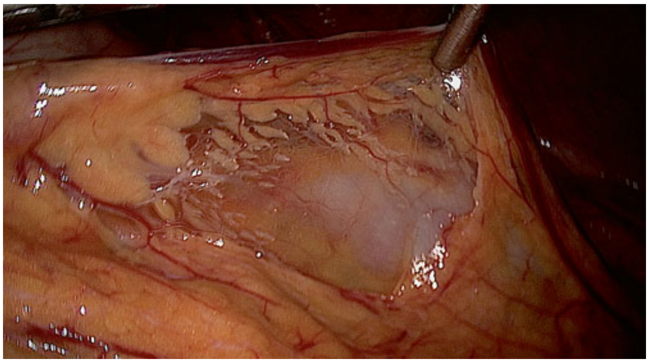

Fig. 18.22 Opening of the gastrocolic ligament

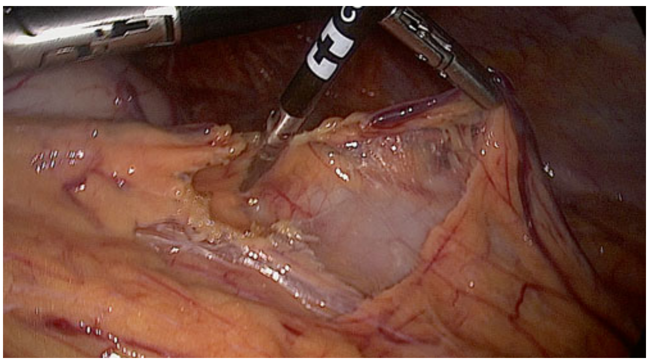

Fig. 18.23 Opening of the gastrocolic ligament

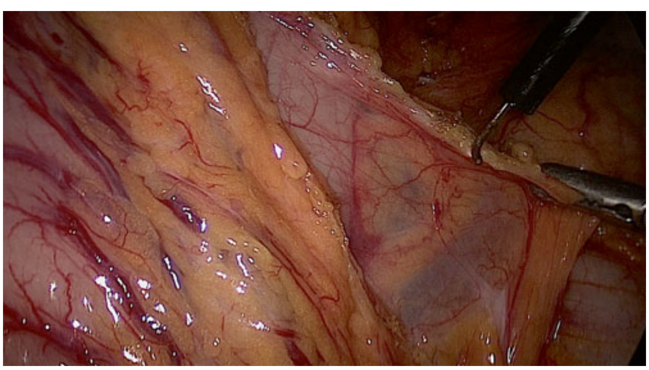

Fig. 18.24 Opening of the gastrocolic ligament

Fig. 18.25 Opening of the gastrocolic ligament

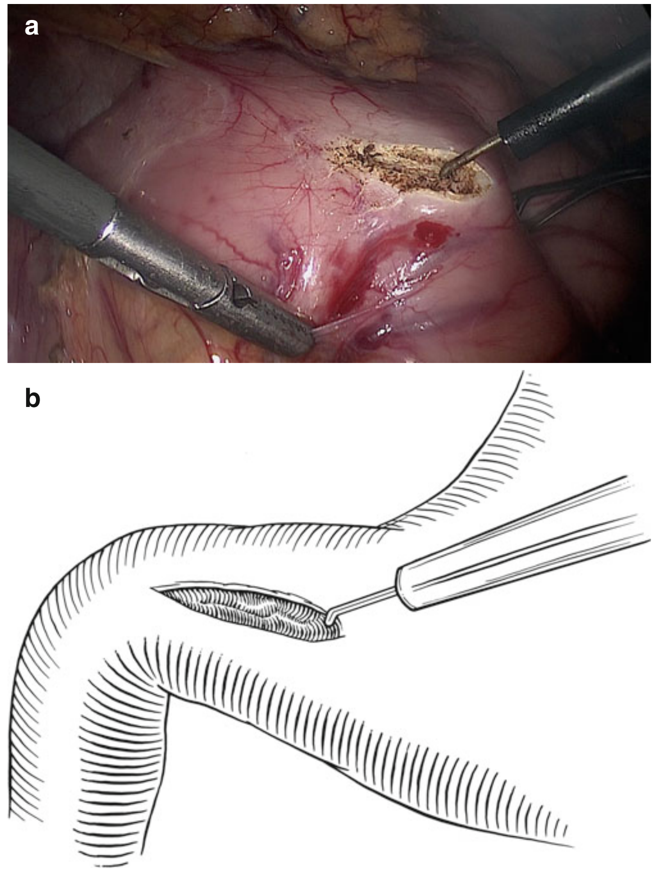

Fig. 18.26 (**a**, **b**) Longitudinal opening of the pylorus

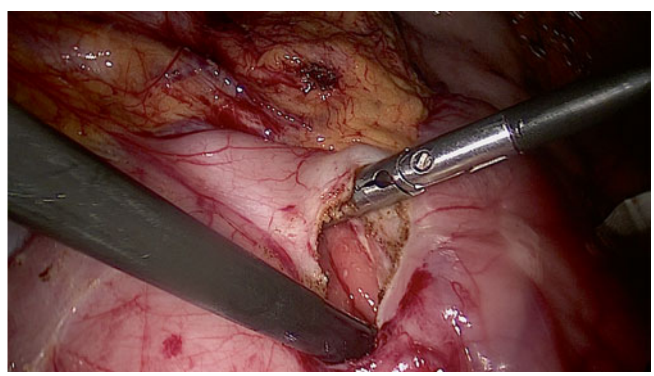

Fig. 18.27 Longitudinal opening of the pylorus

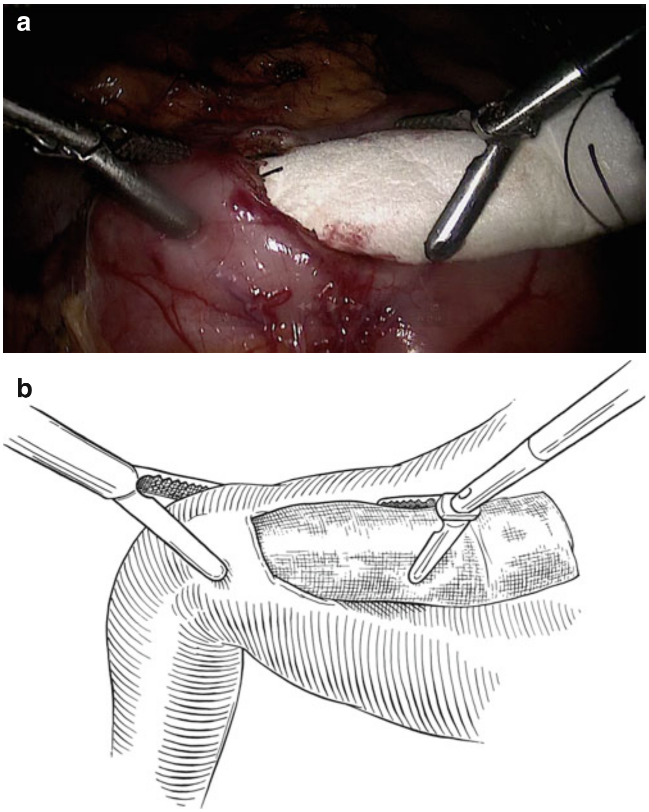

Fig. 18.28 (**a**, **b**) Insertion of a rolled-up sponge of absorbable material through the opening, to separate the anterior from the posterior wall

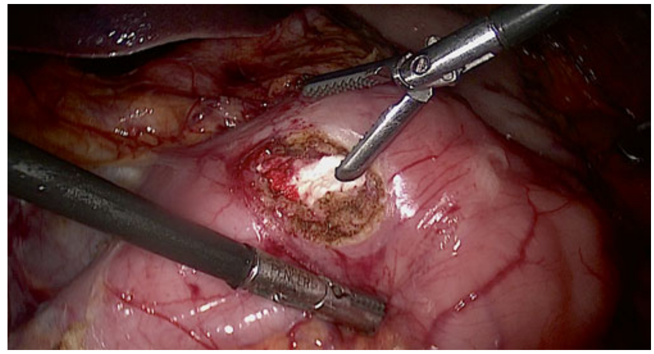

Fig. 18.29 The inserted sponge

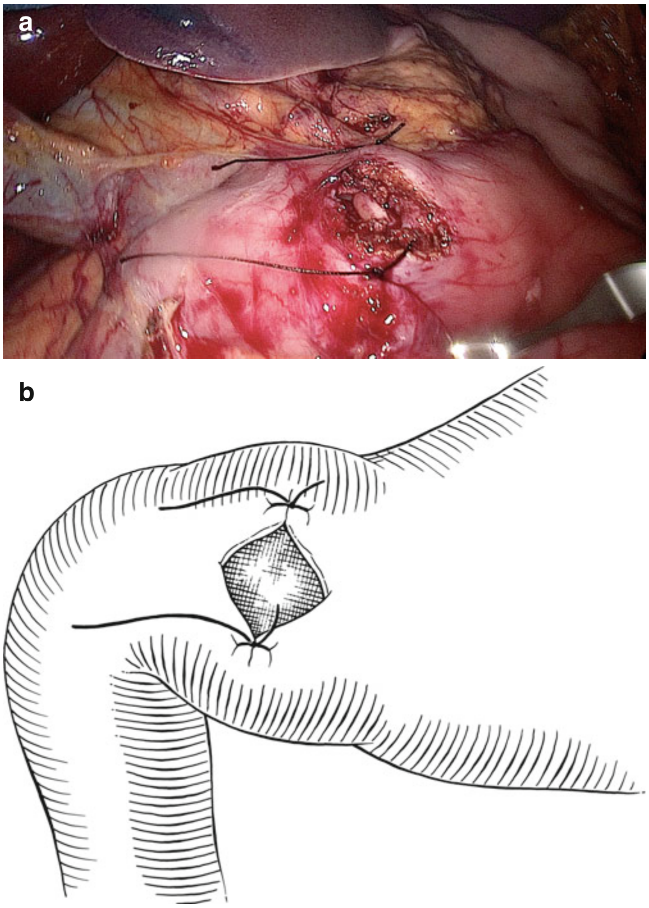

Fig. 18.30 (**a**, **b**) Beginning to close the opening with a suture at each end

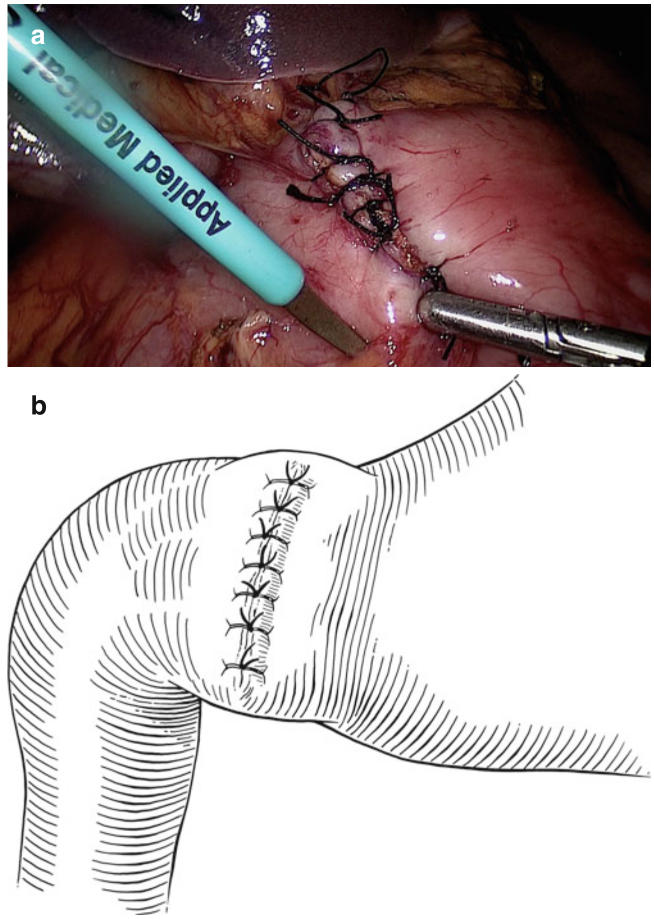

Fig. 18.31 (**a**, **b**) Transverse closing of the opening with interrupted 2-0 silk sutures

18.2.2 Transthoracic Component

After completion of the abdominal portion of the operation, the patient is positioned in a left lateral decubitus. The right chest is entered through a posterolateral thoracotomy in the fifth intercostal space.

The inferior pulmonary ligament is divided in order to allow complete retraction of the right lung. The pleura above and below the azygous vein is opened, and the vein is transected using an Endo GIA™ stapler with a vascular cartridge. The esophagus is then dissected from about 3 cm above the azygous vein all the way to the diaphragm, joining the dissection performed laparoscopically. During the mediastinal dissection, 10–15 lymph nodes are usually retrieved. The stomach is then pulled up, and the upper portion of the stomach is transected with an Endo GIA™ stapler at the level of the angle of His, towards a window opened along the lesser curvature between the second and the third branches of the left gastric artery. Figure 18.32 shows the stomach placed behind the esophagus before its transection.

The next step is transection of the esophagus. To avoid separating the mucosa from the muscle layers, the esophagus is clamped with a Satinsky clamp before the transection (Fig. 18.33). The esophagus is then transected with electrocautery about 3 cm above the azygous vein (Fig. 18.34).

The esophagus is placed over the anterior wall of the stomach (Fig. 18.35), and full-thickness 3-0 silk stay sutures are placed to align the esophagus and the stomach. Stay sutures of 3-0 silk are also placed laterally and anteriorly in the esophagus to avoiding sliding of the mucosa when the stapler is inserted (Fig. 18.36). A gastrotomy is then made in the anterior wall of the stomach, just distal to the esophageal transection line. The superior edge of the gastrotomy is sutured to the posterior wall of the esophagus (Fig. 18.37). A 45-mm Endo GIA™ stapler with a vascular cartridge is then inserted, with one arm inside the stomach and one arm inside the esophagus (Fig. 18.38). By firing the instrument, a 4-cm anastomosis is made between the posterior wall of the esophagus and the anterior wall of the stomach. The staple line is then inspected for bleeding (Fig. 18.39). A nasogastric tube is passed down the esophagus into the stomach. The anterior aspect of the anastomosis is closed with an inner layer of 3-0 braided absorbable suture, followed by an outer layer of interrupted 3-0 silk sutures (Figs. 18.40 and 18.41). Finally, two chest tubes (one straight and one curved) are placed in the right chest cavity, and the chest wall is closed in layers.

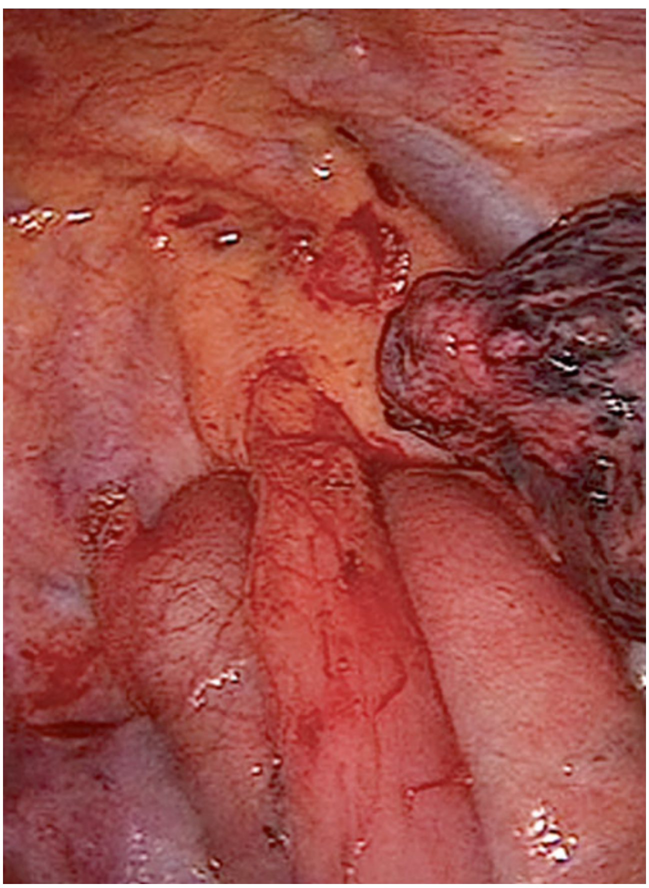

Fig. 18.32 The stomach placed behind the esophagus before its transection

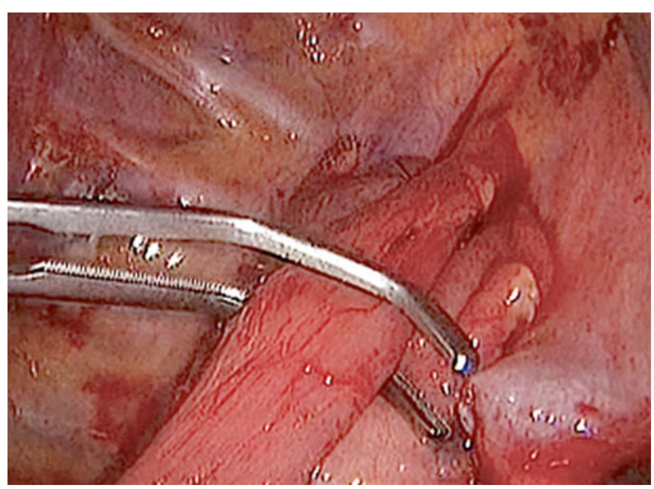

Fig. 18.33 Clamping of the esophagus with a Satinsky clamp to avoid separating the mucosa from the muscle layers during transection

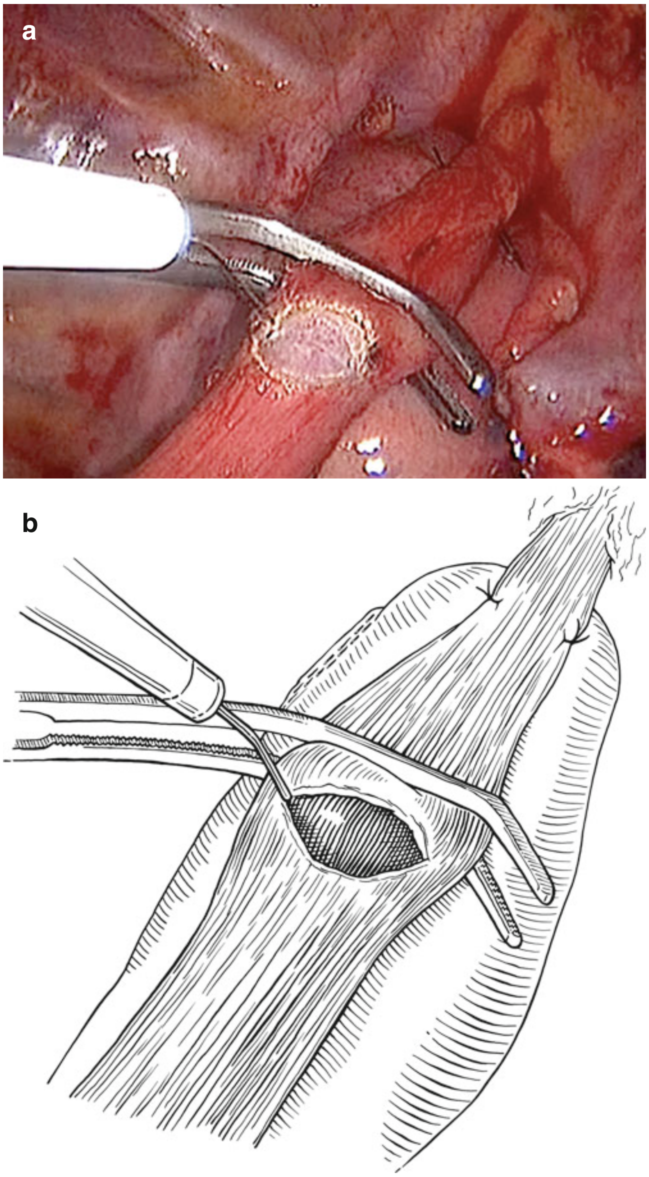

Fig. 18.34 (**a**, **b**) Transection of the esophagus with electrocautery about 3 cm above the azygous vein

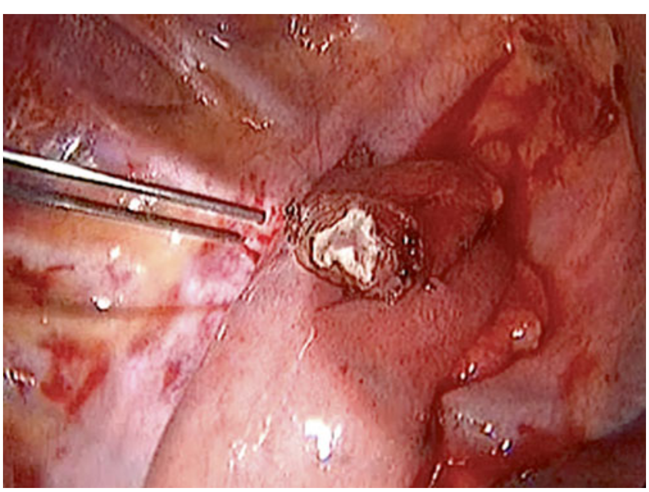

Fig. 18.35 Placement of the esophagus over the anterior wall of the stomach

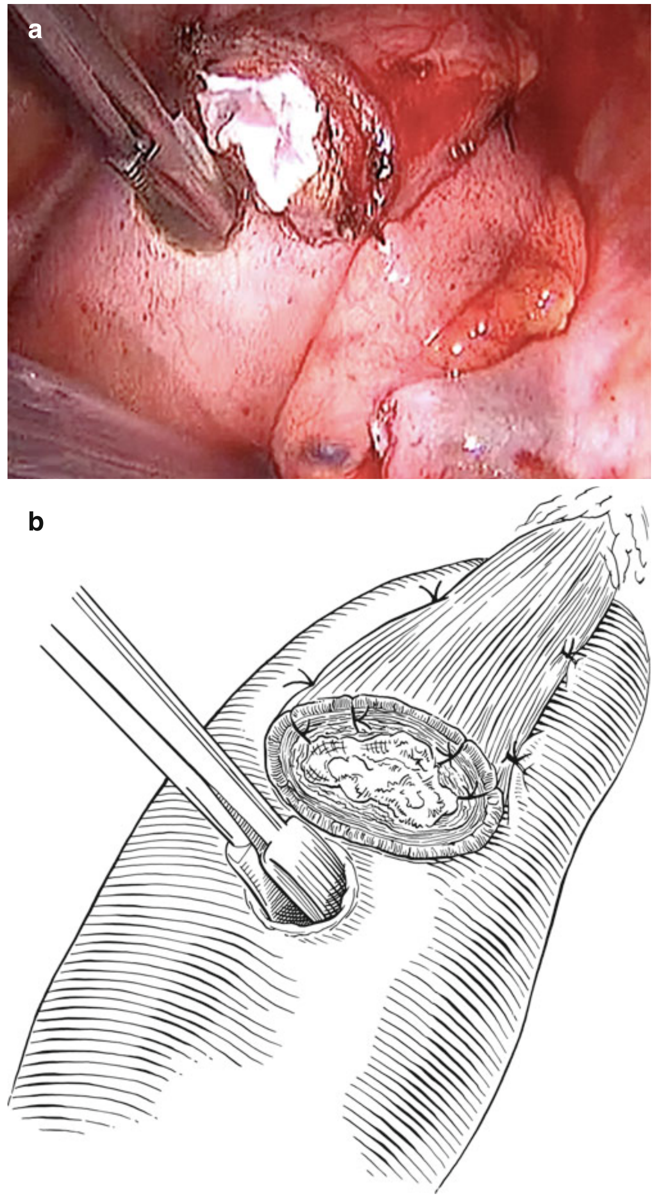

Fig. 18.36 (**a**, **b**) Placement of stay sutures laterally and anteriorly in the esophagus to avoiding sliding of the mucosa when the stapler is inserted

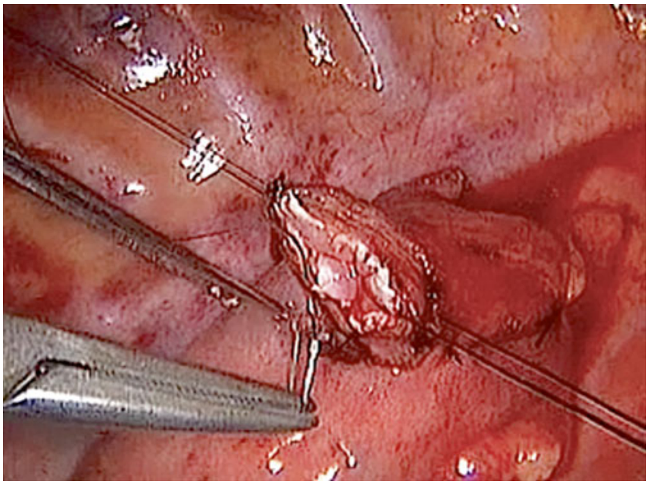

Fig. 18.37 Suturing of the superior edge of the gastrotomy to the posterior wall of the esophagus

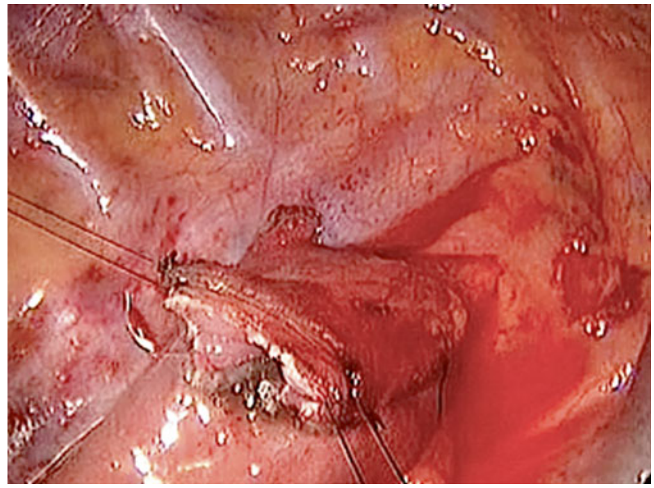

Fig. 18.39 Inspection of the staple line

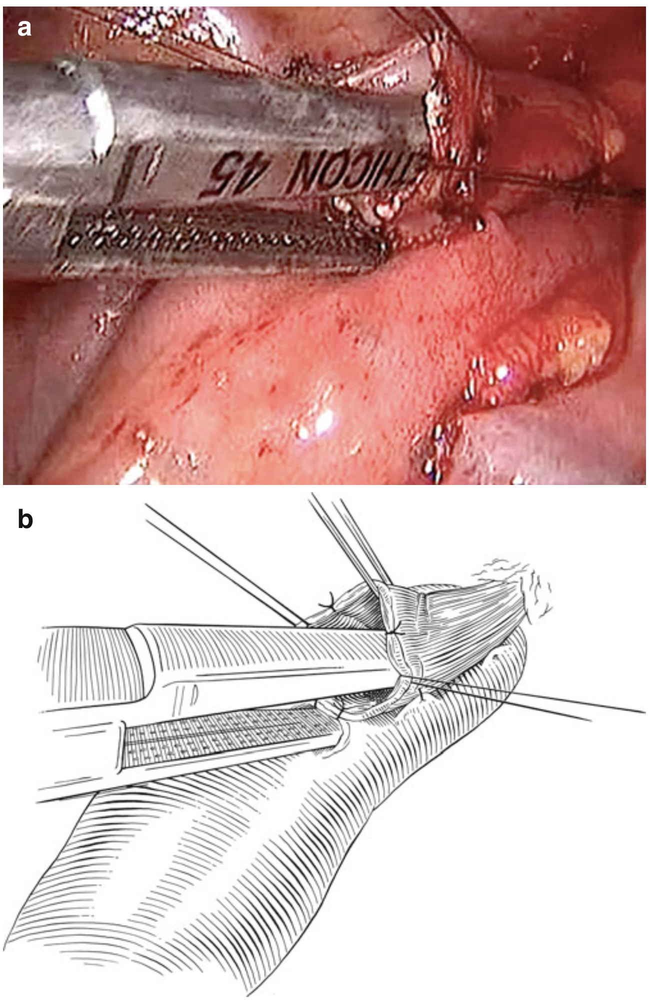

Fig. 18.38 (**a**, **b**) Insertion of the stapler, with one arm inside the stomach and one arm inside the esophagus

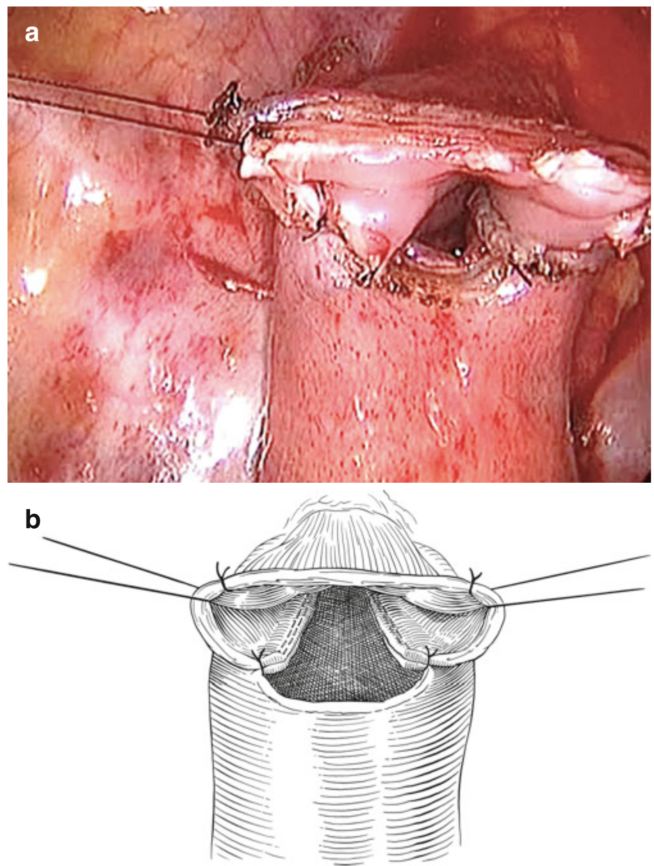

Fig. 18.40 (**a**, **b**) Closing the anterior aspect of the anastomosis

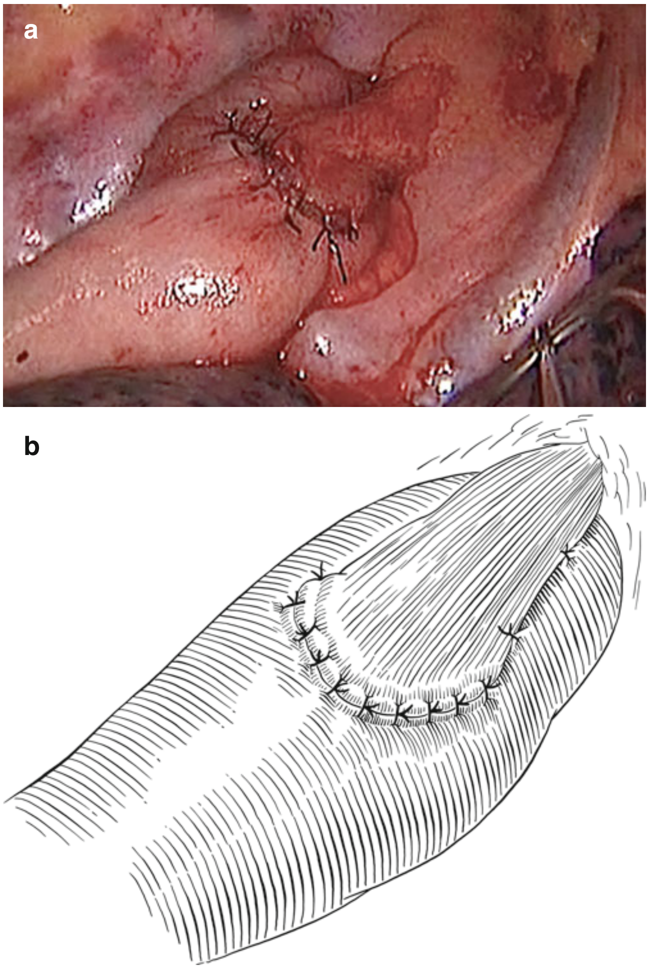

Fig. 18.41 (**a**, **b**) The final appearance of the anastomosis

18.3 Postoperative Course

The patient was extubated in the operating room and spent the first night in the intensive care unit. The epidural catheter was used for pain control for the first 5 days after the operation. The nasogastric tube was removed on postoperative day 3 and a liquid diet was started 1 day later. The patient was discharged on postoperative day 8 on a soft mechanical diet.

Pathology showed a T1b adenocarcinoma with no lymph node involvement (0/26). The margins of resection were free of tumor.

18.4 Hybrid Esophagectomy

The past two decades have seen the development of minimally invasive techniques for esophageal resection, with the goal of decreasing the morbidity and mortality of the open operation. Our preferred approach is a hybrid esophagectomy, which combines laparoscopy for the gastric preparation and a right thoracotomy. The laparoscopic approach follows the same principles as the open approach, but with a significant reduction in surgical trauma and no risk of later developing an incisional hernia. The advantages of a thoracotomy include wide exposure and easier performance of a lymph node dissection and esophagogastric anastomosis. We do perform a side-to-side stapled anastomosis as described by Dr. Collard and by Dr. Orringer (see Selected Reading). In our experience, this anastomosis has reduced both anastomotic leaks and strictures.

Acknowledgement Images taken with SPIES system. Courtesy of Storz.

Selected Reading

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