5 Robotic Assisted Operations for Gastroesophageal Reflux

Daniel H. Dunn, Eric M. Johnson, Kourtney Kemp, Robert Ganz, Sam Leon, and Nilanjana Banerji

Introduction

Despite the fact that the management of patients with gastroesophageal reflux disease (GERD) has become complex with more precise diagnostic evaluations, surgical treatment options still remain limited. Medical management with proton pump inhibitors is the mainstay as well as the first line of treatment. All patients with a diagnosis of GERD are initially tried on medical management. In general, only those who fail treatment are offered surgical options for definitive treatment. Those patients with large sliding hiatus hernias, paraesophageal hernias, severe regurgitation, atypical laryngopharyngeal symptoms or pulmonary complications from reflux are exceptions to this fairly simple treatment algorithm.

For over a half-century, hiatus hernia repair and fundoplication have been implemented as the only surgical procedures for GERD. However, the results of such operative approaches continue to be unsatisfactory in the estimation of many gastroenterologists. Patients are told to avoid operation at all costs. Recurrence rates of 25 % in 5 years are common. Reoperation for recurrent symptoms or complications of the hiatus hernia repair and Nissen fundoplication is similarly frequent. However, no other surgical procedures have been developed to replace fundoplication for the surgical management of GERD [1].

As with many other surgical procedures, over time, the operative management for GERD has evolved into a minimally invasive approach. Laparoscopic approach (as compared to the open procedures) has resulted in fewer post-operative complications such as wound infections and pneumonia. Hospital length of stay (LOS) has been reduced to an average of 1–1.5 days. Symptom relief and re-operation rates have improved. Additionally, patients have benefited

D.H. Dunn, M.D. (✉)
Esophageal and Gastric Care Program, Virginia Piper Cancer Institute, Abbott Northwestern Hospital, 2545 Chicago Avenue, Minneapolis, MN 55404, USA
e-mail: docdunn3@comcast.net

E.M. Johnson, M.D.
Department of Surgery, Abbott Northwestern Hospital, 2545 Chicago Avenue, Minneapolis, MN 55407, USA
e-mail: embjohnson@comcast.net

K. Kemp, M.D.
Specialists in General Surgery, Maple Grove Hospital, 9825 Hospital Drive, Suite 105, Maple Grove, MN 55369, USA
e-mail: kkemp@sgsmn.com

R. Ganz, M.D., F.A.S.G.E.
Department of Gastroenterology, Abbott Northwestern Hospital, 5705 West Old Shakopee Road, Bloomington, MN 55437, USA
e-mail: rganz@mngastro.com

S. Leon, M.D.
Minnesota Gastroenterology, 5705 West Old Shakopee Road, #150, Bloomington, MN 55437, USA

N. Banerji, Ph.D.
Neuroscience and Spine Clinical Service Line, Abbott Northwestern Hospital, Minneapolis, MN, USA
e-mail: Nilanjana.Banerji@allina.com

K.C. Kim (ed.), *Robotics in General Surgery*, DOI 10.1007/978-1-4614-8739-5_5,

from less post-operative pain and have been able to return to work in 1–2 weeks. Short and long-term results have improved, as our understanding of gastroesophageal reflux has improved [2, 3].

Robotic technology has been available for many years but it was not until use of the robot for prostatectomy was reported in 1988 that the robot really had a place in the surgical management of diseases. However, the predominant use of robotic procedure is for urologic operations. The adoption of this technology by other surgical specialties has been considerably restricted because of the relatively narrow operative field required by robotic instrumentation. As a consequence, pelvic anatomy and operative interventions for pelvic malignancies are ideally suited for robotic technology. Similar limited field of operations are also encountered in esophageal operations and are consequently ideal for the use of robotic procedures. Thus, robotic procedures for hiatus hernia repair, Nissen fundoplication, Heller myotomy and trans-hiatal esophagectomy with an abdominal approach without thoracoscopy or thoracotomy have been performed safely with reasonable success [4, 5].

The robotic surgical procedures described in this chapter were performed with the da Vinci robotic instrument (Intuitive Surgical, Palo Alto, CA) for management of paraesophageal hiatus hernias, giant hernias, and recurrent hiatus hernias as well as the more standard anatomy seen with most patients with gasroesophageal reflux. The operations described here are hiatus hernia repair with and without mesh, Nissen fundoplication, partial posterior fundoplication or the 270° wrap (Toupet) procedure, and the anterior fundoplication of Dor, and Collis gastroplasty.

Pre-operative Diagnostic Evaluations

Most patients with GERD undergo a period of self-medication with over the counter treatments for management of typical symptoms of heartburn or regurgitation for many years, before they present themselves to their primary physician. Primary care physicians are well versed in the initial management of GERD. It is usually only those patients who are resistant to standard medical treatments or escalate to manifestation of uncontrolled and/or additional symptoms of regurgitations, nighttime reflux, cough, or hoarseness are referred to the gastroenterologist. The gastroenterologist usually initiates the diagnostic evaluation protocol for patients who develop severe GERD-related complications or have uncontrolled or atypical symptoms.

Esophagogastroduodenoscopy

Esophagogastroduodenoscopy (EGD) is usually the first diagnostic procedure performed in the diagnostic work-up for complicated GERD. The endoscopy gives valuable information regarding the anatomy of the esophagus and gastroesophageal junction. The presence and size of hiatus hernia and presence and degree of esophagitis can be classified by the Hill and LA grading systems. Barrett's esophagus can be documented and strategy for treating or surveillance can be established. Long-term risk assessment can be discussed with the patient. Strictures, eosinophilic esophagitis, Cameron erosions and esophageal cancer can be diagnosed before beginning a long-term approach to treatment.

pH Monitoring

The 48-h pH-monitoring test (Bravo) is used to obtain objective data regarding the degree of acid reflux. Either 24- or 48-h tests can be used; however, the 48-h test is generally considered more reliable. The percentage of time of esophageal acid exposure to $pH<4.0$ is recorded as a DeMeester score (normal <14.72). Patients with high DeMeester scores are considered positive for significant reflux.

pH-monitoring is not used in every patient. In general, patients with very large hernias or large paraesophageal hernias may be considered operative candidates whether or not they had significant GERD or abnormal Bravo tests. Likewise pH-monitoring is not used in patients with known

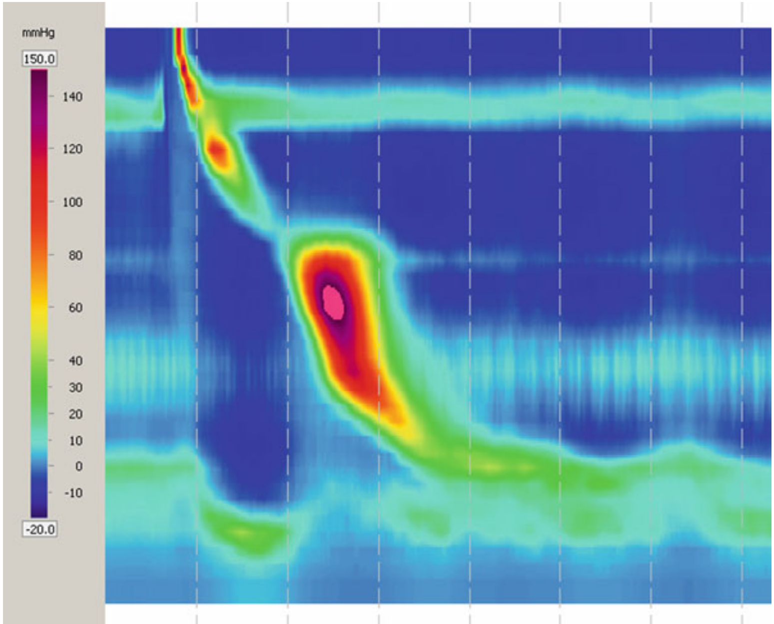

Fig. 5.1 High-resolution manometry of a typical patient with GERD showing normal esophageal motility and decreased lower esophageal sphincter pressure

Barrett's esophagus. pH-monitoring is particularly helpful in making a diagnosis of gastroesophageal reflux in patients with atypical symptoms or patients who do not respond to medical management.

pH-monitoring using multichannel intraluminal impedence-ph (MII-pH) monitoring has gained acceptance in several GI laboratories [6]. The MII-pH monitoring can distinguish non-acid as well as acid reflux thereby facilitating correlation of the reflux episodes with symptoms. Most GI laboratories choose one method and use that method exclusively. At our Institution the preferred diagnostic procedure of gastroenterologists is the Bravo pH monitoring test.

Manometry

Esophageal manometry is used to determine esophageal motor function as well as lower esophageal sphincter pressure and relaxation with swallowing. Manometry is used in most patients with typical symptoms of heartburn. In patients with dysphagia, regurgitation, atypical symptoms or abnormal findings on endoscopy such as a dilated esophagus, stricture or esophageal diverticulum, manometry is critical. A typical picture of a low resting mean pressure of the lower esophageal sphincter and normal esophageal motility is usually observed in most of patients with typical GERD symptoms (Fig. 5.1).

Preferably, a team of gastroenterologists with a special interest in GERD should evaluate the outcomes of these studies.

In our clinical experience, a group of patients thought to have a clear diagnosis of GERD was confirmed to have achalasia on manometry, with high-resolution manometry (HRM) showing typical pictures of failed swallows, low peristaltic pressures, or no peristalsis (Fig. 5.2).

One particular patient had been treated for GERD for many years, had done reasonably well on PPI's, and had a very large paraesophageal hiatus hernia with 70 % of her stomach in the chest. She had regurgitation as a predominant symptom along with heartburn. A diagnostic EGD procedure indicated esophagitis. However, review of the HRM was indicative of a combination of type II and III achalasia. Based on the

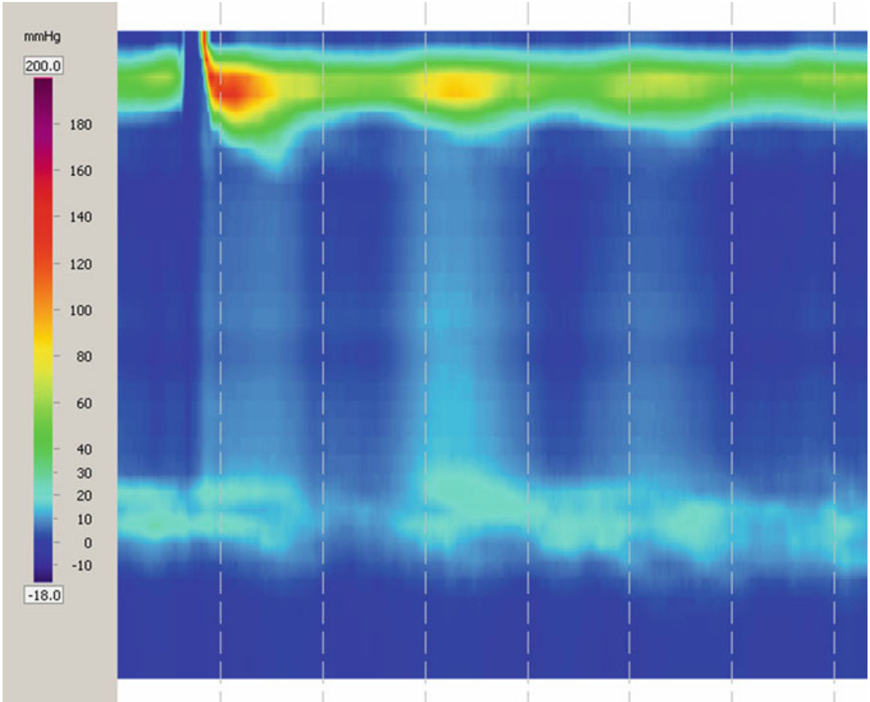

Fig. 5.2 High-resolution manometry of typical patient with Classic Achalasia showing poor to no peristalsis, the common cavity affects and high resting lower esophageal sphincter pressure without relaxation

manometry results, this patient was treated for achalasia with a Heller myotomy and Dor fundoplication.

If patients have significant esophageal dysmotility on HRM and symptoms of dysphagia without anatomic obstruction, in our practice we selectively use this information to perform a partial 270° fundoplication (Toupet procedure) (Fig. 5.3). A loose wrap may function just as well for these patients since a partial wrap has been shown to be as durable as a loose full wrap in several studies [7–9].

Operative Procedure

There is an obvious difference in the operative time required for patients undergoing robotic-assisted procedures vs. laparoscopic procedures for management of gastroesophageal reflux with robotic surgery requiring a longer time for completion in comparison to the same procedures performed laparoscopically. In addition, the room time (defined as "time in to time out") is significantly longer with the robotic procedure. In our experience, there exists a learning curve for surgeons, and the room time as well as operative time decreases as the operative team gains experience. The pre-operative time, i.e. time from a patient entering the room to incision time, makes up most of the extra time for the robotic procedure. The operating table needs to be turned away from the anesthesiologist and the logistics of tube and monitoring placement is time consuming. It is best to have an anesthesia team during the initial period of implementation of these procedures, as the set up for esophageal surgery is different from robotic pelvic operations. The docking time from first incision to the surgeon beginning on the console decreases with experience. In our experience, following the first 10–15 cases the docking time stabilizes in the range of 10–15 min.

For experienced laparoscopic surgeons who perform anti-reflux operations frequently the

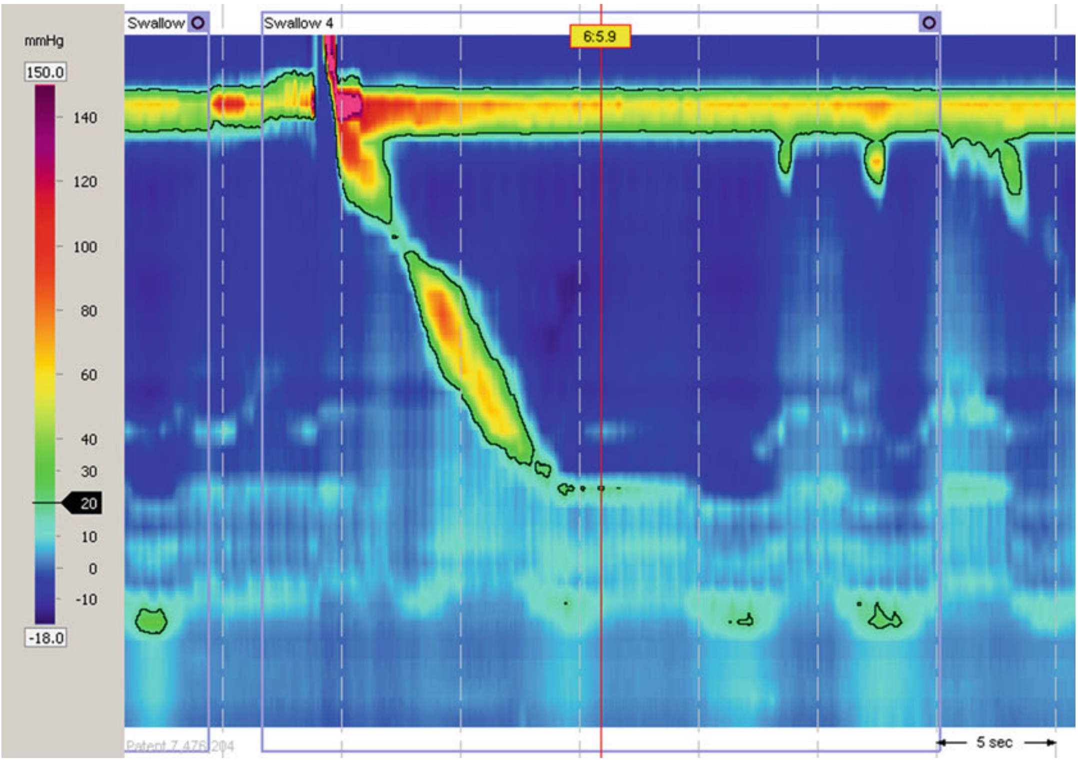

Fig. 5.3 High-resolution manometry of patient with GERD showing poor esophageal motility with hiatus hernia and low lower esophageal sphincter pressure

adjustment to using robotic technology is not challenging. Surgeons should be well versed in laparoscopic fundoplication procedures before performing robotic assisted fundoplications. A robotic general surgeon experienced with anti-reflux operations should proctor the first robotic case. Each robotic program must determine the credentialing criteria for privileging surgeons for these procedures. If possible, the first several cases should be performed with an experienced laparoscopic surgeon as an assistant. After the surgeon and operating room team have gained experience, the procedure can be performed assisted by surgical technologists, residents, or physician assistants. As mentioned previously, operative time decreases with experience. The learning curve for using the robotic technology is in the first 10–15 cases for experienced laparoscopic surgeons.

The operation begins with the laparoscopic placement of the ports. The configuration of the port placement is different from the laparoscopic procedure. Placement of the camera port is critical. The typical position of 12 cm caudad and 2 cm to the patient's left of the xiiphoid for women or small men and 15 cm caudad and 2 cm to the left for large women or men does not always function efficiently. The body habitus is important and with experience the distance from the xiphoid to the camera port becomes shorter. This distance is especially important for patients with large hiatus hernias because of the mediastinal dissection needed to reduce the contents of the hernia sac. The position of the robotic arms is determined by the position of the camera port. This distance is constant, again demonstrating the importance of the first trocar placement for the camera. The 8 mm trocars for the arms of the robot are placed 4 cm cephalad to the 12 mm camera port and 8 cm to either side of the camera port.

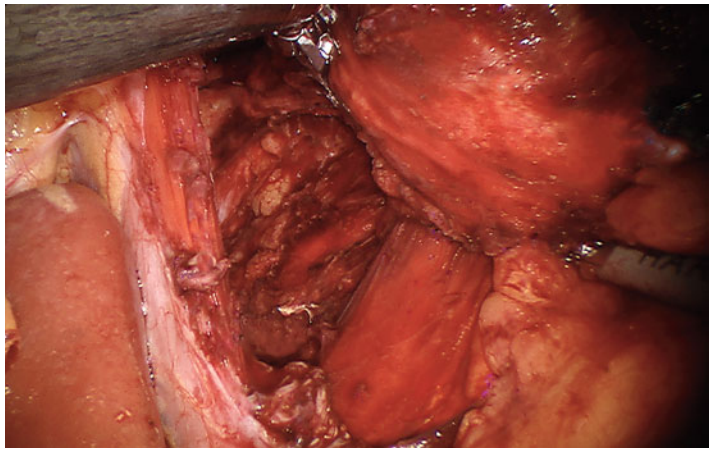

Fig. 5.4 Dissection of the hiatus in-patient with GERD and moderate hiatus hernia

The liver retractor port is placed at a convenient position beneath the right costal margin. We use a standard liver retractor from this position; however, a Nathanson retractor can be used in a sub-xiphoid position. The last port is placed in a convenient left lateral subcostal position. This port is used by the assistant for retraction and passing needles as well as for the stapler for patients who are having a Collis gastroplasty.

Once all the ports and the liver retractor are placed, the robot is brought into the field. The patient is placed into a reverse Trendelenburg position and the camera port and two robotic arms are attached to the appropriate trocars. In our surgical practice, we do not routinely use the third arm of the robot. The operating surgeon then goes to the console and initiates the robotic part of the operation.

Dissection of the hiatus with the robot is similar to a laparoscopic approach. The advantage of robotic technology is that the camera can be positioned and secured in place by the operator. If necessary, the camera can literally be placed through the hiatus to gain better visualization for large paraesophageal hernias. This placement is important for maximum mobilization of the esophagus in the mediastinum, so that an adequate length of esophagus, usually 3 cm below the diaphragm, can be obtained for the wrap (Fig. 5.4).

Once the hiatus is dissected and the esophagus circumferentially mobilized preserving the anterior and posterior vagus nerves, the short gastric arteries are taken down to mobilize the greater curvature of the stomach for a Nissen fundoplication. The number of short gastrics taken depends on the amount of fundus needed for the wrap or if a Collis gastroplasty is indicated. The harmonic scalpel is used for all of the dissection including the mediastinum, mobilization of the esophagus and takedown of short gastric arteries.

The next step is taking the gastroesophageal fat pad and separation of the anterior vagus nerve from the esophagus and GE junction (Fig. 5.5).

Removing the fat pad clears the distal esophagus and cardia of excess tissue, which might interfere with an exact placement of the wrap, but more importantly with this procedure the GE junction can be better visualized. As the anterior vagus is preserved after it is mobilized from the esophagus with the GEJ fat pad the wrap can be brought underneath the vagus and this sling can serve to hold the wrap in place so that it does not slip (Fig. 5.6). The hiatus is then repaired with primary closure of figure of eight stitches with pledgets for reinforcement, if necessary (Fig. 5.7).

Bridging grafts, whether biologic or synthetic have a high failure rate and multiple complications associated with their use. Most of the time, a primary closure is possible. We use an onlay graft only if the closure needs reinforcement with GoreTex suture and U clips (Fig. 5.8a, b).

Following repair of the hiatus, the esophagus is examined to determine if a standard Nissen

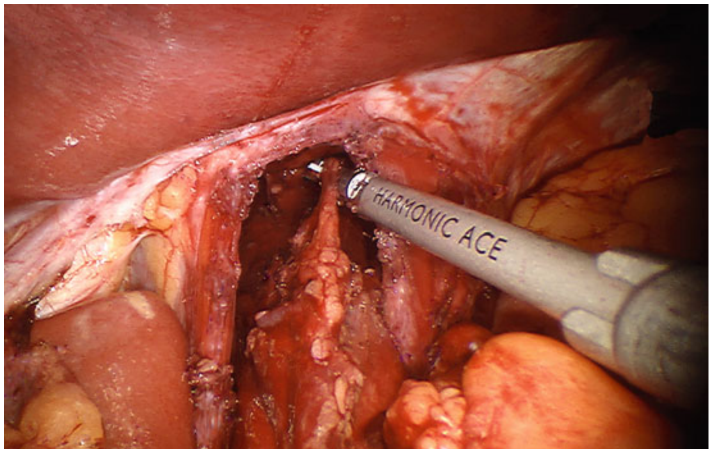

Fig. 5.5 Dissection of the Anterior Vagus Nerve showing the development of a sling, which will hold the fundoplication in place

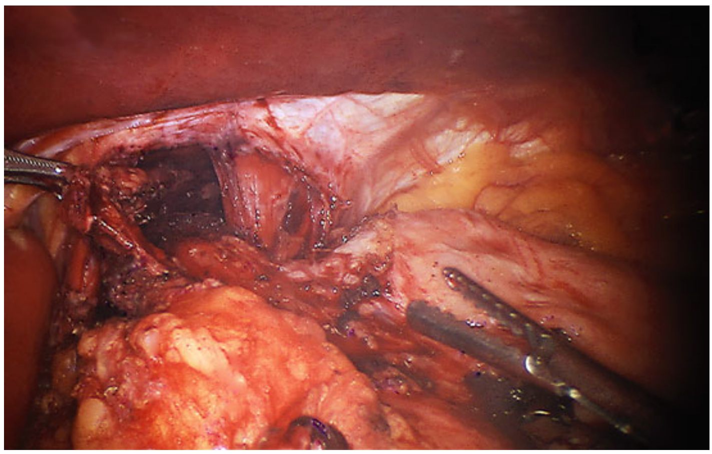

Fig. 5.6 Takedown of the gastroesophageal fat pad to clearly identify the junction of the longitudinal esophageal muscle and the serosa of the stomach

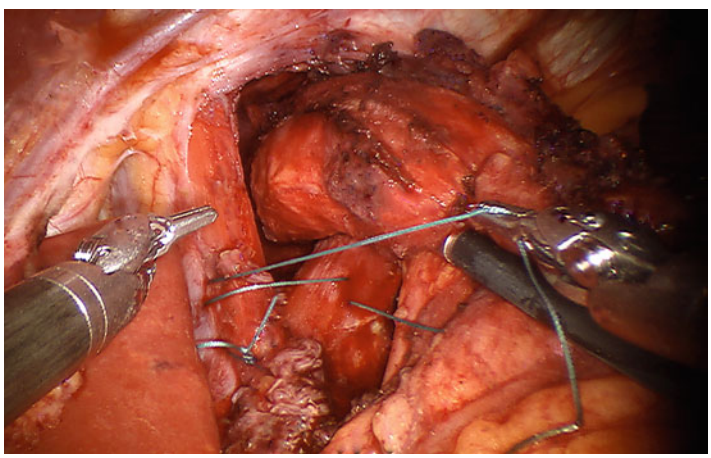

Fig. 5.7 Primary closure of the hiatus with figure of 8 suturing, without use of onlay or pledgets as reinforcement

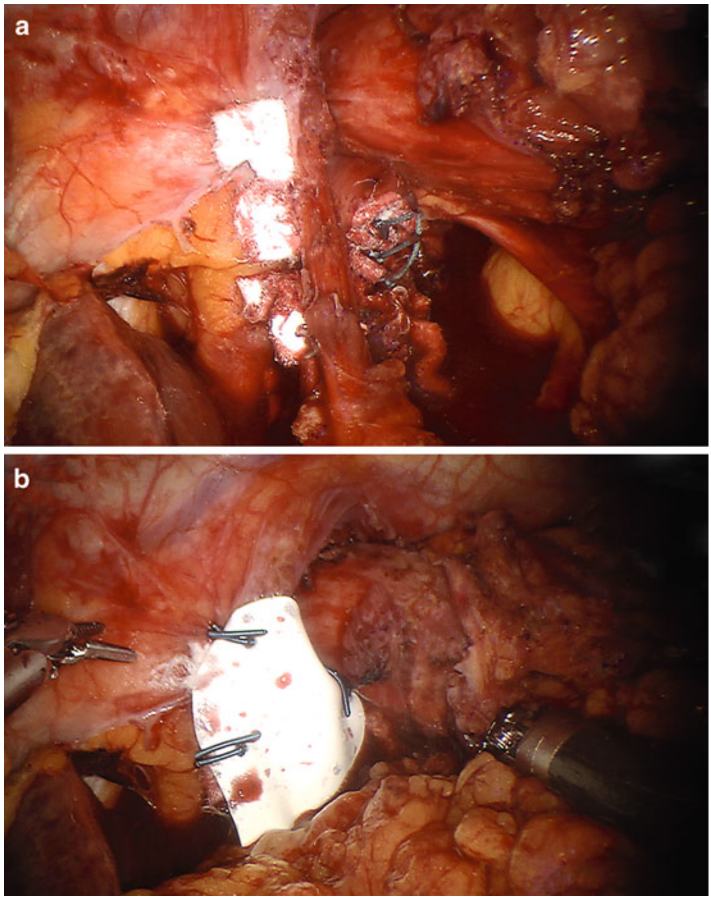

Fig. 5.8 (**a** and **b**) Hiatus Hernia repair with primary closure and reinforcement with an onlay Gore-Tex graft

fundoplication can be performed. If the esophagus can be brought down to at least 3 cm below the diaphragmatic hiatus without tension, a 3 stitch Nissen fundoplication over a 50–56 fr. dilator is performed. We often will tack the wrap to the diaphragm at the end of the procedure (Figs. 5.9, 5.10, and 5.11). The robot is then undocked and the liver retractor removed, followed by evacuation of the pneumoperitoneum and incision closure.

Partial Fundoplication (The Toupet Procedure)

The principal indications for our patients undergoing a 270° fundoplication (or the Toupet procedure) were dysphagia or esophageal dysmotility diagnosed on HRM. Partial fundoplication is no different from the full wrap until the actual suturing of the wrap. The reduction and repair of hernia as well as mobilization of the esophagus and greater curvature of the stomach are all similar to the standard Nissen fundoplication. In the Toupet procedure, the fundus is brought around behind the esophagus and sutured with three stitches to the esophagus at 10 o'clock position. Left side of the fundic wrap is sutured to 2 o'clock position on the esophagus. This leaves the anterior esophagus open and approximately 270° of the posterior esophagus wrapped (Figs. 5.12 and 5.13).

Dor (Anterior) Fundoplication

We have had minimal experience in using the anterior fundoplication i.e. the Dor fundoplication for patients having GERD as their indication

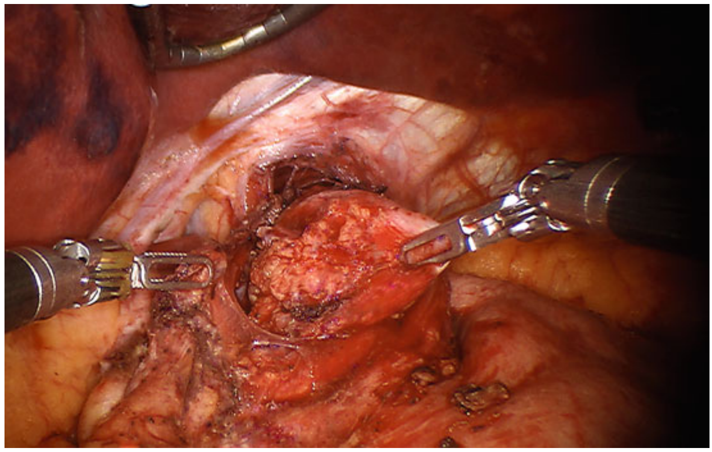

Fig. 5.9 Mobilizing the fundus and bringing it around the back of the esophagus under vagus nerve sling and mobilized gastroesophageal fat pad

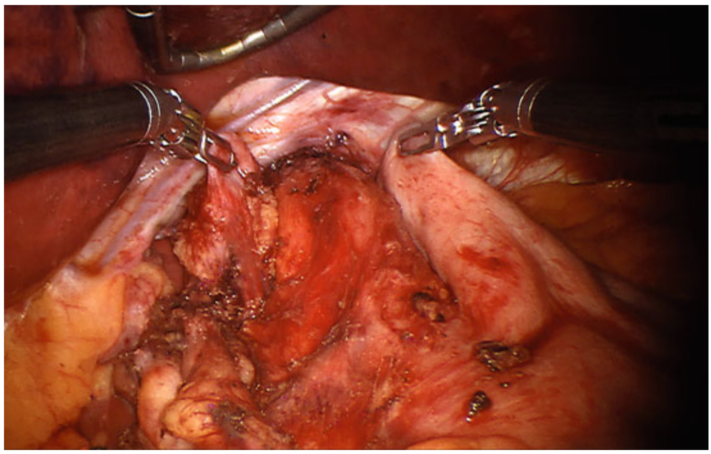

Fig. 5.10 Preparing the fundoplication for suturing to the esophagus

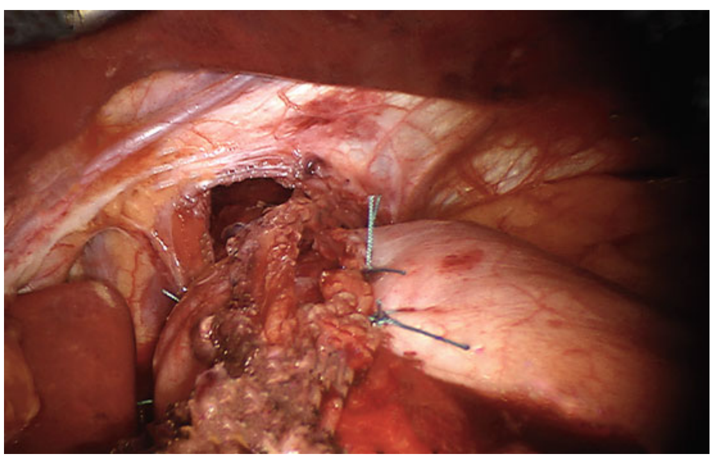

Fig. 5.11 Completed 360° Nissen fundoplication

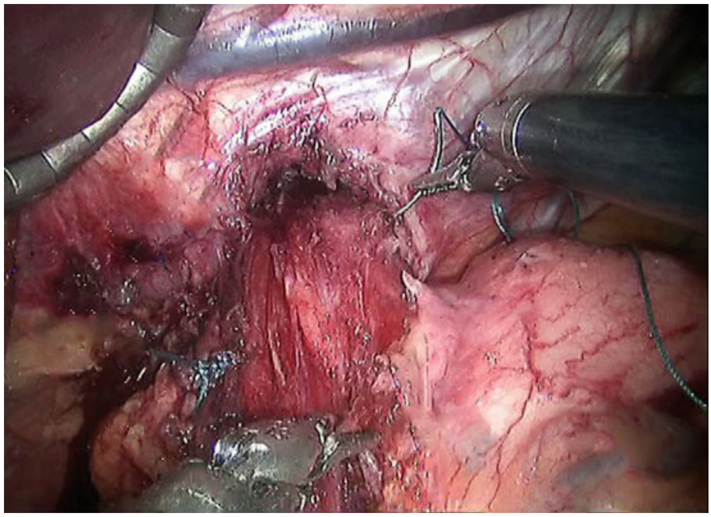

Fig. 5.12 270° fundoplication for patients with esophageal dysmotility or patients who refuse a 360° fundoplication because of unwanted side effects

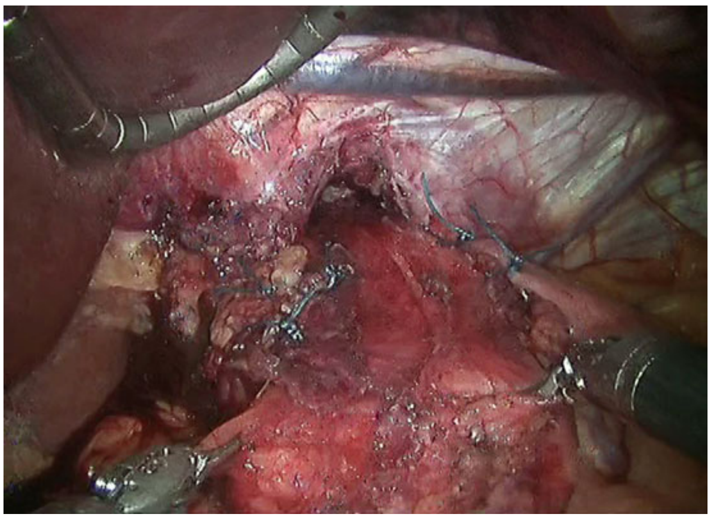

Fig. 5.13 Toupet, the 270° fundoplication

for operation. We have used the anterior fundoplication almost exclusively for patients with achalasia. The Dor fundolplication has been an effective procedure for the reduction of symptomatic GERD following esophageal myotomy. The Dor fundoplication has been suggested as an alternative for a full Nissen fundoplication (Figs. 5.14 and 5.15).

Several studies have shown similar results comparing an anterior wrap to a 360° wrap, with fewer side effects for the anterior fundoplication in comparison to the full fundoplication [10].

Collis Gastroplasty

Our surgical practice has used the Collis gastroplasty procedure for the past 3 years almost exclusively for the management of patients with large paraesophageal hiatus hernia or giant sliding hernia with foreshortened esophagus. The esophagus is mobilized as much as possible and the hiatus is closed. The gastroesophageal junction must be at least 3 cm below the diaphragm without tension; otherwise a Collis gastroplasty is performed. This is especially important in patients with a BMI > 35. To perform the Collis, a

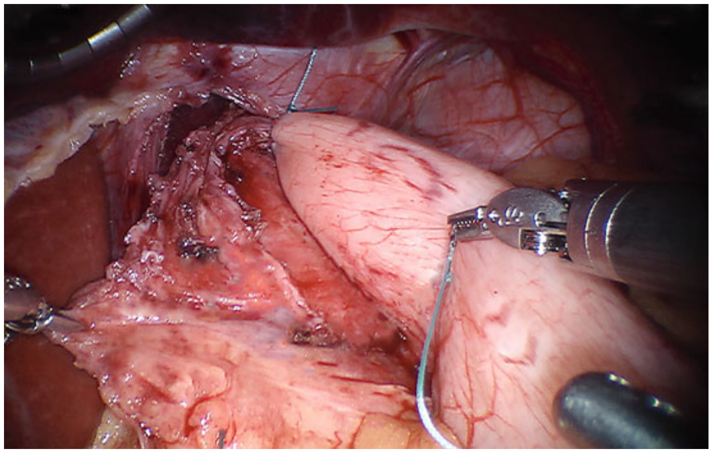

Fig. 5.14 Anterior 180° fundoplication or Dor fundoplication. For this case the anterior fundoplication was performed with a Heller myotomy

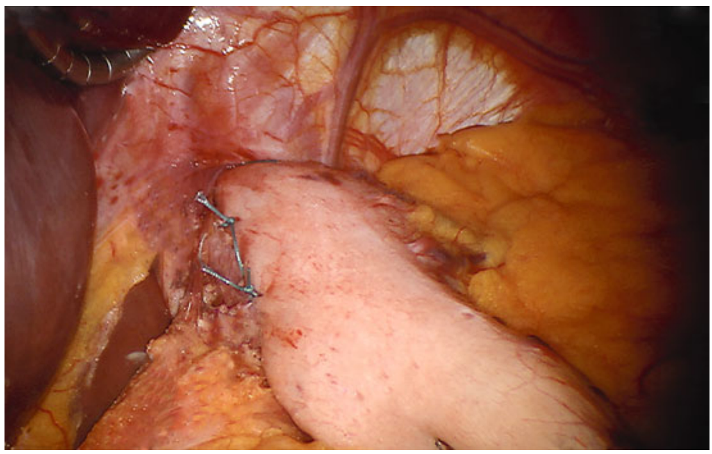

Fig. 5.15 Completed 180° anterior fundoplication

second surgeon, surgical resident, or physician assistant is required because the procedure requires stapling of the cardia of the stomach. A wedge resection of the cardia using one of the GIA stapling devices is used to lengthen the esophagus (Fig. 5.16a).

A 46–50 fr. dilator is placed into the esophagus to prevent narrowing of the "neo-esophagus" (Fig. 5.16b).

We have used the Echelon stapler with a green load of both 60 and 45 mm. In our experience, the 45 mm is much easier to manipulate in the upper abdomen. It is used through the assistant's port in the lateral upper abdomen. The standard 8 mm trocar is changed to a 12 mm trocar to accommodate the stapler. The amount of cardia removed depends on the anatomy. A relatively small wedge of cardia can be removed and accomplish the lengthening procedure.

The first two staple lines are directed at the dilator that is positioned nest to the lesser curvature of the stomach (Fig. 5.17). The third staple line is parallel to the esophagus and held against the dilator (Fig. 5.18a, b). After the wedge resection is performed (Fig. 5.19), the remaining fundus is wrapped around the neo-esophagus (Figs. 5.20 and 5.21). A Nissen fundoplication is then performed which allows a tension free wrap with reduced chance for recurrence due to herniation or a slipped Nissen (Fig. 5.22).

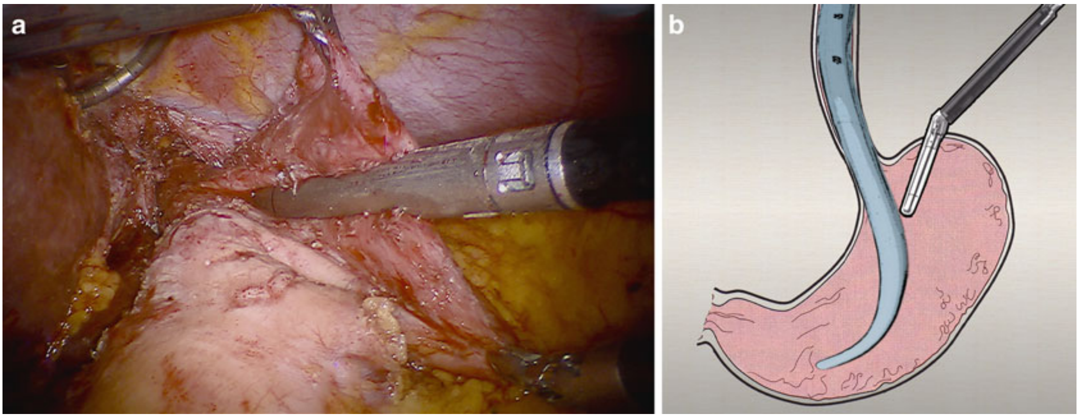

Fig. 5.16 Collis Gastroplasty—Photographs and corresponding illustrations of resecting a wedge of the gastric cardia and creating a neo-esophagus to lengthen the esophagus and prevent undue cephalad tension on the fundoplication. (**a** and **b**) Illustration of the first cut across the gastric cardia in the beginning of the lengthening of the esophagus

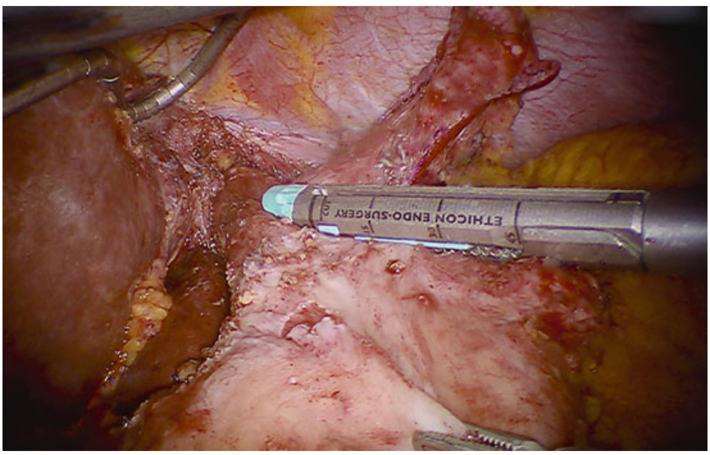

Fig. 5.17 Collis Gastroplasty—Photographs and corresponding illustrations of resecting a wedge of the gastric cardia and creating a neo-esophagus to lengthen the esophagus and prevent undue cephalad tension on the fundoplication. The “second cut” using an Echelon 45 mm green load to create a neo-esophagus. Illustration showing the “second cut” ending at the point where the stapler is at the edge of the dilator to prevent narrowing of the Neo-esophagus

Re-operative Robotic Procedures for Recurrent Gastroesophageal Reflux, Recurrent Hiatus Hernia, Incarcerated Hiatus Hernia and Esophageal Dysmotility

Re-operative procedures for recurrent hiatus hernia can be challenging. For a majority of cases, these procedures can be performed using robotic technology. There are some important aspects of these re-operative procedures that need to be emphasized.

It is prudent to note that tactile sensation is not possible with the robot. Haptic memory allows surgeons to successfully tie knots with the robot without being able to feel the tension. Surgeons can experience what it feels like when the knot or suture is tight, thereby allowing them to keep the suture intact. This also allows them to gauge how much pressure or pull they can exert while

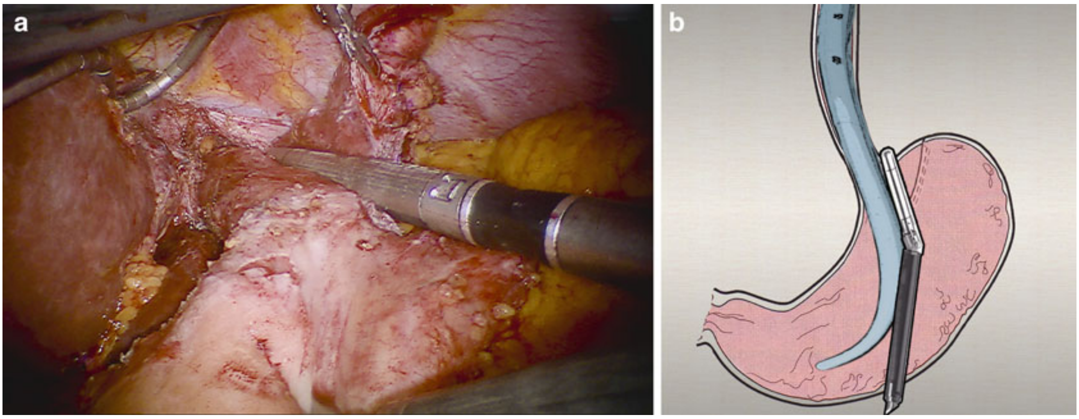

Fig. 5.18 Collis Gastroplasty—Photographs and corresponding illustrations of resecting a wedge of the gastric cardia and creating a neo-esophagus to lengthen the esophagus and prevent undue cephalad tension on the fundoplication. (**a** and **b**) The "third cut" using an Echelon 45 mm green load to finish the creation of the neo-esophagus. Accompanying illustration showing the completed segmental resection of a portion of the cardia of the stomach leaving the remaining fundus for the fundoplication

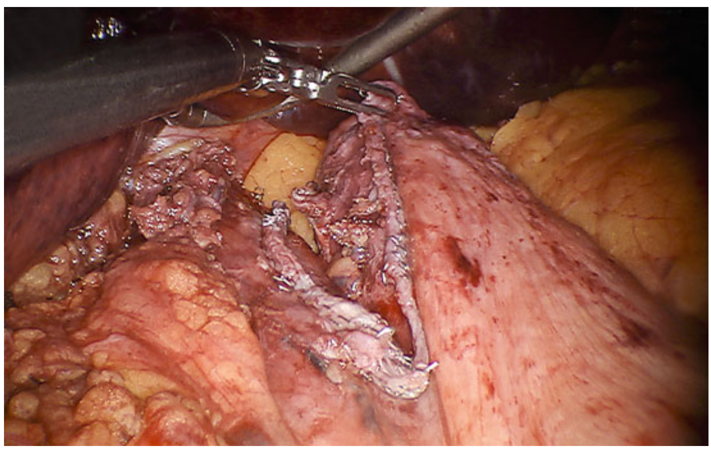

Fig. 5.19 Collis Gastroplasty—Photographs and corresponding illustrations of resecting a wedge of the gastric cardia and creating a neo-esophagus to lengthen the esophagus and prevent undue cephalad tension on the fundoplication. Completed wedge resection for esophageal lengthening with illustration

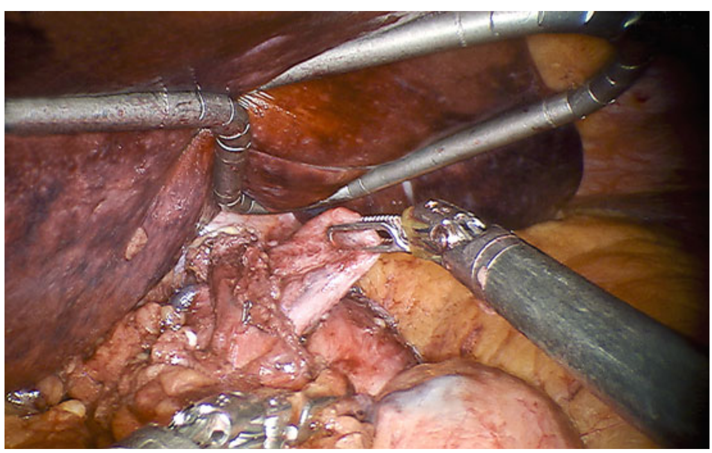

Fig. 5.20 Collis Gastroplasty—Photographs and corresponding illustrations of resecting a wedge of the gastric cardia and creating a neo-esophagus to lengthen the esophagus and prevent undue cephalad tension on the fundoplication. Bringing the fundus around the esophagus and under the anterior vagus nerve after the segmental gastric resection

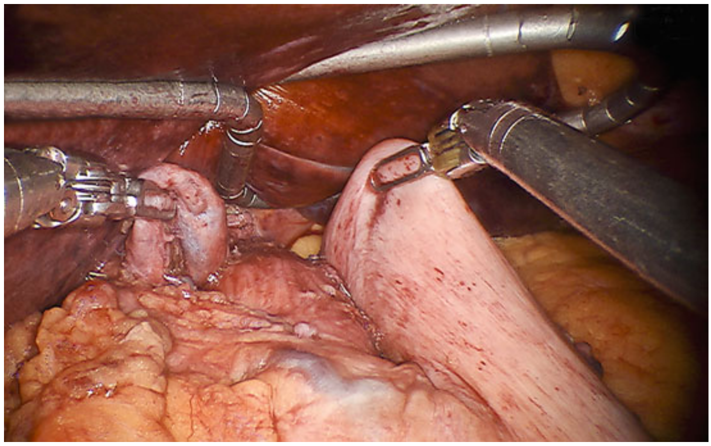

Fig. 5.21 Collis Gastroplasty—Photographs and corresponding illustrations of resecting a wedge of the gastric cardia and creating a neo-esophagus to lengthen the esophagus and prevent undue cephalad tension on the fundoplication. Bringing the *right* and *left portions* of the fundus in apposition for finishing the fundoplication

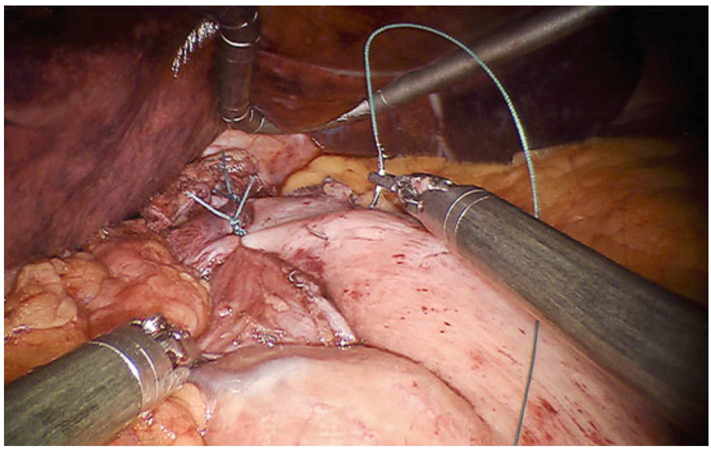

Fig. 5.22 Collis Gastroplasty—Photographs and corresponding illustrations of resecting a wedge of the gastric cardia and creating a neo-esophagus to lengthen the esophagus and prevent undue cephalad tension on the fundoplication. Final stitch of Collis gastroplasty and 3 stitch Nissen fundoplication

dissecting tissue. The challenge with re-operative robotic surgery is that during a repeat procedure surgeons are not able to assess the tensile strength of the structures that they are dissecting. Therefore, it is much more likely to tear tissue during a re-operation. If the wrap has migrated into the chest through the hiatus, dissection can be extremely difficult and the ability to have tactile sensation may be more important than benefits of the robot (Fig. 5.23). In these instances, a laparoscopic approach might be preferred.

Obese patients (BMI > 35) who have recurrence should be considered for gastric bypass. In this situation the Nissen or Toupet is taken down and a gastric bypass performed in the standard fashion. Since short gastrics are usually taken with a Nissen fundoplication, care must be taken to preserve the left gastric branches to the fundus. If gastric bypass is not an option or the recurrent symptoms are of an obstructive nature, then reoperations should include a Collis gastroplasty, even if it appears that there is minimal tension on the esophagus after hernia reduction and repair.

Patients, who have unremitting dysphagia following Nissen fundoplicaton and manifest preoperatively unrecognized esophageal dysmotility, should have a takedown of the Nissen. For a redo

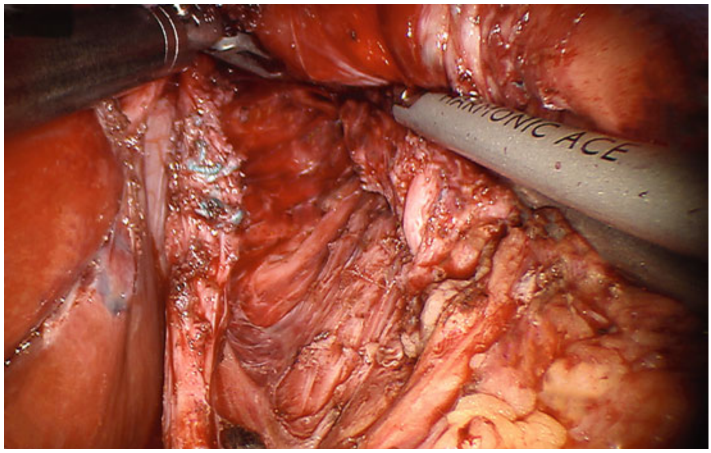

Fig. 5.23 Re-do hiatus hernia repair and takedown of Nissen fundoplication showing posterior vagus nerve, aorta and *right* and *left crus*

of this type, use of the robot is particularly advantageous because of the precise nature of dissection of the wrap as well as importance of adequate visualization (Figs. 5.24 and 5.25).

The same procedure should be performed for a Nissen that is too tight. Attempting to loosen the Nissen in this situation has the risk of still being too taut after the second operation. Therefore a partial fundoplication is a more reasonable approach in these instances (Fig. 5.26).

The ability to visualize anatomy with high definition optics used with robotic technology and articulated instruments for dissection in the chest is a definite advantage over the standard laparoscopic technology (Fig. 5.27).

These operations are often tedious and time consuming compared to a standard Nissen. In our opinion, the benefits of improved ergonomics of the robotic console cannot be matched with laparoscopic techniques (Fig. 5.28).

Outcomes of Robotic Assisted Operations for Gerd at Abbott Northwestern Hospital

Over a 4 year period from June 2007 to December 2011 175 patients, with 59 (33.72 %) men and 116 (66.28 %) women, have undergone robotic-assisted operations for symptomatic GERD management in the general surgery program of Abbott Northwestern Hospital (ANW) using the da Vinci Computer-Enhanced Robotic Surgical System (Table 5.1). Patients presenting with recurrent hiatus hernias, large sliding hiatus hernias, paraesophageal hiatus hernias and patients with recurrent hiatus hernia or other complications of previous hiatus hernia repairs are included in this cohort. Mean age of the patients was 51.61 ± 14.67 years (median 52; range 19–86) and average pre-operative BMI was 30.40 ± 5.16 (median 30; range 20–47).

A majority of the patients were referred from Minnesota Gastroenterology (MNGI) group. Prior to the first visit with the surgeons, patients were evaluated in a gastroenterology clinic for esophageal disorders. Ninety-five percent of patients was evaluated by a gastroenterologist. Diagnostic work-up included EGD, Bravo (48 h pH probe), high-resolution manometry (HRM) and UGI X-rays. Patient response to medical therapy was noted. All patients with heartburn as their major symptom had failed medical management.

For further outcome evaluations, patients were separated into two groups, namely, (a) patients with symptomatic GERD diagnosed with large (paraesophageal or sliding) hernias ($n = 70$) and (b) patients with symptomatic GERD with small or no evident hernias ($n = 105$) (Table 5.1). Eighty-one percent of patients who had small

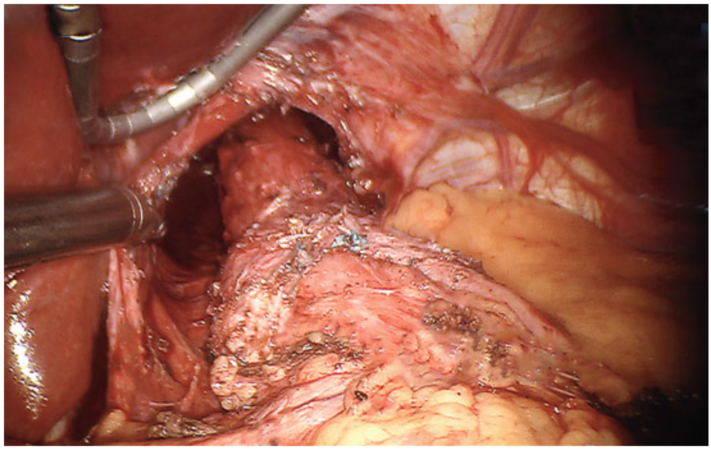

Fig. 5.24 Dehisced Nissen fundoplication

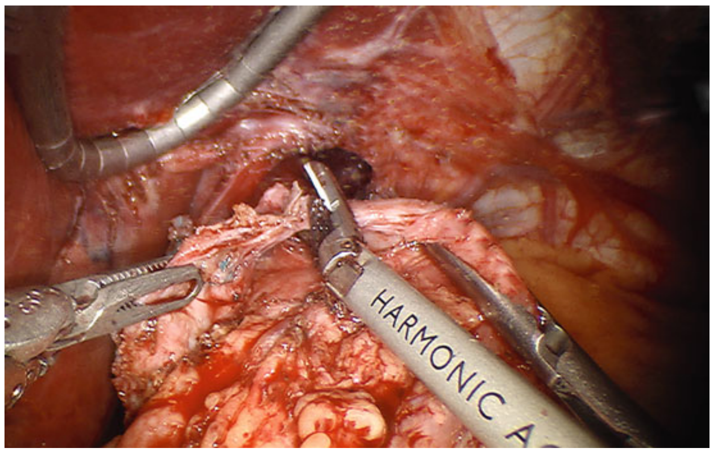

Fig. 5.25 Takedown of dehisced Nissen fundoplication

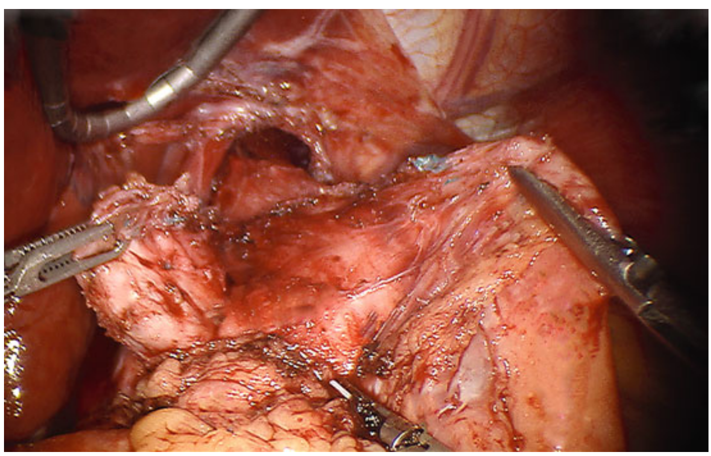

Fig. 5.26 Re-do Nissen fundoplicaton unwrapped

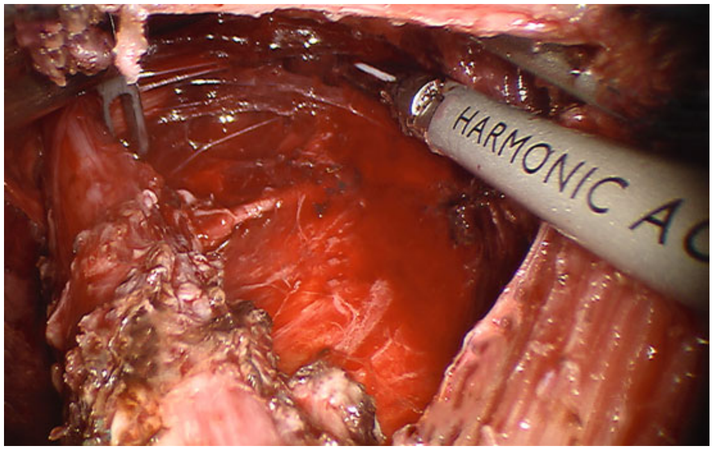

Fig. 5.27 *Left* and *right diaphragmatic crura*, aorta before re-do hiatus hernia repair and re-do Nissen fundoplication

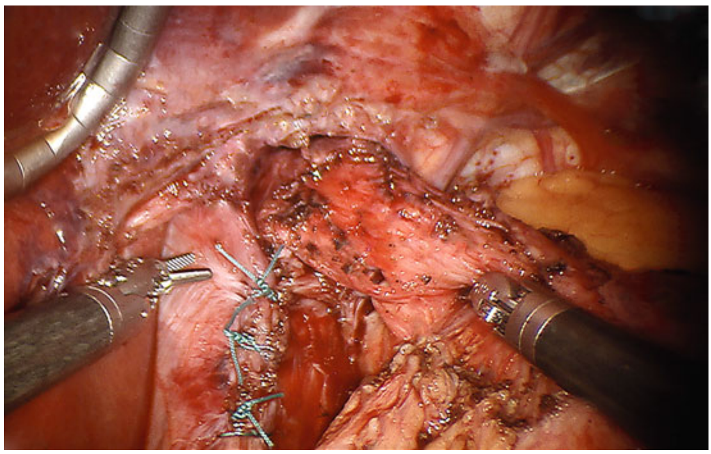

Fig. 5.28 Re-do Hiatus hernia repair

hernias or no hernias had typical symptoms of heartburn, regurgitation or aspiration. Patients with paraesophageal or large sliding hernias were more likely to have atypical symptoms with 44.3 % presenting with cough, recurrent aspiration, sore throat, hoarseness, dysphagia or substernal chest pain. In this group, typical symptoms were present in 32.8 % cases. Presenting symptom information was not available for 22.9 % GERD patients with large hernias and 3.8 % GERD patients with small hernias (Table 5.1).

In our case series, 91.4 % of patients with large hernias or paraesophageal hernias had a BMI > 30 and 57.1 % had BMI > 35. In comparison, 52.4 % of patients with small hernias had a BMI > 30 and 18.1 % had BMI > 35 (Table 5.1). Early in our experience we did not have a limit on the BMI for patients undergoing an anti-reflux procedure. It is apparent from our data and other published reports that the operative time, rate of hiatus hernia recurrence, and reoperations is increased in those patients with BMI > 35 [10].

Table 5.1 Characteristics and presenting symptoms for 175 patients undergoing robotic-GERD management procedures

	Large hiatal hernias ($n=70$)	Small hiatal hernias ($n=105$)
Age (years)	56 ± 24	49 ± 26
Pre-operative BMI		
<30	6 (8.6 %)	50 (47.6 %)
30–35	24 (34.3 %)	36 (34.3 %)
>35	40 (57.1 %)	19 (18.1 %)
Pre-operative PPI therapy	32 (45.7 %)	92 (87.6 %)
Presenting symptoms		
Typical symptoms[a]	23 (32.8 %)	85 (81.0 %)
Atypical symptoms[b]	31 (44.3 %)	16 (15.2 %)
Undetermined[c]	16 (22.9 %)	4 (3.8 %)

[a]Typical symptoms included are heartburn, regurgitation, sore throat, nighttime regurgitation and aspiration
[b]Atypical symptoms are cough, chest pain, esophageal spasm, dysphagia and bronchospasm
[c]Presenting symptoms were not documented for 20 patients

Table 5.2 Surgical outcomes in 175 patients

	Large hiatal hernias ($n=70$)	Small hiatal hernias ($n=105$)
Room time (mins)[a]	188 ± 70	190 ± 58
Operative time (mins)[b]	135 ± 42	120 ± 54
Mesh repairs	16 (22.9 %)	29 (27.6 %)
Median EBL (range) (ml)	34 (10–150)	30 (10–100)
Collis gastroplasty	18 (25.7 %)	8 (7.6 %)
Conversion to open	1 (1.4 %)	2 (1.9 %)
Transfusions	0	0
LOS (days)	2.4 ± 0.9	1.9 ± 0.5
Reoperations	3 (4.3 %)	11 (10.5 %)
30-day symptom reduction	64 (91.4 %)	90 (81.7 %)
30-day symptom relief	59 (84.3 %)	82 (78.1 %)

EBL estimated blood loss, *LOS* length of stay
[a]Room time is defined as time from patient entering the room until the time when the patient leaves the room
[b]Operating time is from first incision to all incisions closed at the end of the procedure. It includes "docking time, time on the DaVinci console, undocking, and closing incisions"

These patients are generally referred for gastric bypass or asked to lose weight to attain a BMI < 35. Patients with large hernias or paraesophageal hernias are more likely to have BMI > 35 than those patients whose primary symptom is heartburn.

Operative time was defined as time from incision to skin closure and room time was measured from time when a patient entered the room to he/she leaving the room. The room time included anesthesia time, which is invariably longer than the anesthesia time for laparoscopic operations for GERD. The patient must be turned, which puts anesthesiologists at the foot of the bed. The ventilator tubing must be stretched and secured the length of the patient. An arterial line is frequently used because of the difficulty in monitoring the patient in this position. The operative time also includes the docking time, which is the time needed for placing the robotic ports and docking the robot. In our experience, the room time and operative time between patient with large and small hernias were comparable with no statistically significant difference between room times (unpaired *t*-test, $p=0.84$) or operative times (unpaired *t*-test, $p=0.05$) (Table 5.2).

We found that there were other factors that lengthened the operative time. Patients with BMI > 35 had a longer mean operative time at 146 min compared to 120 min for patients with BMI < 30. Presence of large hiatus hernias and paraesophageal hernias, which included more involved hiatus hernia repairs often times with, mesh increased mean operative time by 37 min. All reoperations were associated with increased operative times. In this group, there was a wide variation in the range of operative times depending on the number of recurrences and type of procedure done for the previous operation(s).

In the two groups of patients presenting with large and small hernias, mesh repairs were performed in 22.9 % ($n=16$) and 27.6 % ($n=29$), respectively (Table 5.2). The repair of the diaphragmatic hiatus is controversial and without any strong evidence to recommend a standard approach. With any hiatus dissection, even without a hiatus hernia, the takedown of the phrenoesophageal attachments will unavoidably disrupt the hiatal opening. This can be repaired with primary closure without mesh or reinforcing synthetic pledgets. However, several surgery-based repair approaches have been recommended when the hiatus hernia is large and the hiatus dilated. While these recommendations are not specific for patients operated on with robotic technology, the repair of the hiatus with placement of sutures can be much more precise in our experience. We utilize figure of eight sutures with reinforcing pledgets as our preferred method. Additionally, if the closure is tenuous we recommend the use onlay biologics or goretex. Grafts that bridge the gap in the hiatus have not worked well in our experience.

Total estimated blood loss for the procedures was in an acceptable range for our cohort of 175 patients (Table 5.2).

Eighteen patients with large paraesophageal hiatal hernias at presentation were treated with Collis gastroplasty. A review of data indicated that increased use of Collis gastroplasty resulted in an improvement of outcomes for our patients with large paraesophageal hiatus hernia and foreshortened esophagus. While there are several who espouse negligible need for performing such esophageal lengthening procedures, there is little doubt that Collis gastroplasty in selected patients reduces the incidence of recurrent hiatus hernia [11, 12]. Collis gastroplasty has significantly reduced the re-operation rate and hiatus recurrence rate for our patients undergoing anti-reflux procedures. We routinely use Collis gastroplasty for re-do Nissen fundoplication with the assumption that recurrent symptoms following anti-reflux operations is largely due to recurrent hernias resulting from undue tension at the diaphragmatic hiatus. Of the 26 combined fundoplication and Collis gastroplasty operations we have performed, there has been only one recurrent hernia.

There were no major intra-operative complications related exclusively to the use of the robot or to the changes in the position of the anesthesiologist relative to the patient as well as any of the monitoring equipment. Three patients had to be converted to open procedures for difficult exposure or dissection (Table 5.2). There was one post-operative death. This was a cardiac death in an elderly patient with a prolonged operation for a large paraesophageal hiatus hernia. On post-operative day 1, the patient had a cardiac event from which he did not recover. One patient had DVT, which required heparinization but no pulmonary complications were evident.

In our patient population, robotic assisted anti-reflux procedures did not decrease the hospital length of stay (LOS) compared to laparoscopic anti-reflux procedures. Patients undergoing laparoscopic Nissen fundoplication and hiatus hernia repair had a mean LOS of 1.1 days [13]. The longer stay with the robotic procedures was due in part to the gradually increasing co-morbidities of our more recent patients and the increase in the numbers of patient with large hernias and paraesophageal hernias. The mean LOS for individuals undergoing Nissen procedures without a paraesophageal hiatus hernia repair was 1.9 days whereas Nissens with a paraesophageal hiatus hernia repair had a mean LOS of 2.4 days (Table 5.2). Interestingly, a statistically significant difference was noted in the LOS between GERD patients with large (paraesophageal or sliding) hernias as compared to patient with small or no hernias (unpaired *t*-test; $p < 0.0001$).

Fourteen (8.0 %) patients required reoperations and all reoperations were performed with the robotic technology (Table 5.2). Three patients who had paraesophageal hernias developed recurrent hernias and became symptomatic. Of the 11 remaining reoperations (for patients with small hernias), two required reoperations within the first week after their first procedure. One patient, with a BMI > 35, had immediate incarceration and obstruction of the fundoplication through the hiatus within 5 days of operation. A second patient was readmitted to the hospital for unrelenting chest pain and dysphagia 7 days following operation and a takedown of the fundoplication was required. Another fundoplication was not performed and the hiatus hernia repair was left intact.

There were six patients who underwent reoperation for symptomatic reflux and/or recurrent hernia within 2–10 months of their first operation. Of these patients, two had significant esophageal dysmotility that was either unrecognized preoperatively or the severity of the condition underestimated. Of the recurrent hernias, one individual had mesh repair and Nissen fundoplication, four patients had primary hiatus hernia repair and Nissen fundoplication, and one patient had a primary hiatus hernia repair with a Collis gastroplasty. Six of the ten patients who had recurrent hernia as an indication for reoperation had BMI > 35.

Early symptomatic relief was achieved in 80.6 % (141 of 175) of our patients. Long-term relief and need for continued PPIs and other reflux medications is currently being evaluated. The patients who had regurgitation or atypical symptoms such as cough, sore throat or hoarseness had slightly better symptomatic relief than those who had mostly heartburn as their main symptom. Patients who had large symptomatic hernias either paraesophageal or sliding type hernias also had improvement in some of the less well defined symptoms of chest discomfort, chest pain, chest pressure and dysphagia.

Discussion

Laparoscopic fundoplication is considered the gold standard surgical management option for GERD [14]. It is an operation, which in experienced hands has a negligible mortality, very low operative morbidity, and excellent short-term results [15]. However, discouraging long-term (>5 year) outcomes have prevented gastroenterologists from recommending fundoplications solely for (a) patients with intolerable symptoms or paraesophageal hernias which may be causing obstructive symptoms, (b) patients bleeding from Cameron erosions, or (c) those who might be having episodes of torsion of the herniated stomach. Patients whose main symptoms are related to regurgitation are not helped by medical management and thus present to operative intervention more often because of lack of alternative medical management options. Fundoplication is very effective for the management of patients with regurgitation.

The average length of stay in the hospital for patients having laparoscopic fundoplication is 1 day. The hospital stay may be extended to 2 days for elderly patients or patients with significant co-morbidities. Patients having more extensive operations such as large paraesophageal hernias or upside-down stomachs in the chest may require additional days in the hospital.

Generally, laparoscopic equipments are relatively sturdy, inexpensive and re-usable. The instruments are adaptable to a multitude of different laparoscopic procedures and the same cameras can be utilized in all laparoscopic operations. In other words, laparoscopy is a relatively economical way to perform a variety of general surgical procedures including fundoplication. This raises the question, why should we use robotic technology for operations performed effectively with laparoscopic techniques?

Robotic technology was first put to use in operations for prostate cancer. For this oncologic operation, robotic-procedures have proven advantages over open procedures with less operative blood loss, easier post-operative recovery, less post-operative pain, comparable oncological parameters, and decreased LOS [16]. Within a relatively short period of time robotic prostatectomy has become the standard for surgical management of prostate cancer. Currently, ~75 % of patients having operative procedures performed for management of prostate cancer undergo robotic assisted prostatectomy. This has been a major change in practice for urologists who have traditionally performed most procedures with open techniques. Accepting and adapting to robotic procedures was daunting for most and the early results indicated that the adaptation to a minimally invasive approach resulted in a significant number of complications. The learning curve for robotic prostatectomy was steep. The early results suggested that surgeons should be proctored for at least ten cases and a high level of proficiency was reached only at completion of ~50 procedures. Nevertheless, at present time, most surgeons consider robotic assisted prostatectomy as a major advance in patient care.

The adoption of robotic technology by the gynecological specialty has been a considerably simpler and safer process for patients and the transition from laparoscopic to robotic techniques in gynecology has proven to be remarkably straightforward. The learning curve for gynecologists using robotic technology has not been as steep and the number of cases to gain proficiency has been fewer. Consequently, gynecologic operations for benign disease have now overtaken the lead in numbers of patients having robotic-assisted operations. The operative blood loss, improved oncologic parameters, post-op pain, LOS and overall easier recovery have caused many gynecologic oncologists to adopt robotic technology [2].

Other surgical specialties notably cardiovascular, pediatric urology and thoracic surgery have had increasing numbers of cases and surgeons performing their operations robotically. Again, for many of these specialties the transition from open procedures to robotic was accompanied by a steep learning curve due to the lack of prior exposure to the use of laparoscopic technology. During the initial period of adoption of robotic technology, with the steep learning curve came increased morbidity for the patients. Robotic assisted operations for general gastro-esophageal management procedures have not increased as one might expect for procedures such as fundoplication, Heller myotomy, trans-hiatal esophagectomy and low-anterior resection or abdominal perineal resection [2, 17]. The lack of interest in performing robotic assisted operations could be due to many factors. The learning curve is thought to be quite steep. In actuality, for an experienced laparoscopic surgeon, robotic assisted operations are not difficult to learn and are somewhat easier to perform than the same laparoscopic operation. The surgeon is supported in the operative process by high definition optics and the three-dimensional vision in the robotic technology, which provides better visualization than laparoscopic technology. Suturing with complete dexterity is very similar to that for an open operation that is impossible to duplicate with the commonly used endo-stitch. During laparoscopic procedures, it is difficult for many surgeons to utilize laparoscopic needle drivers. Very few surgeons have completely mastered this technique.

The other advantage of robotic surgical-procedures is from an ergonomic viewpoint. The ergonomics of performing these operations, especially with difficult paraesophageal hiatus hernia repairs, is ideal. The arms are at rest at the surgeon's side with minimal movement. The shoulders are in a natural position without any strain. The head is positioned on a cushion with comfortable viewing ports for the camera. Much of the positioning of camera and instruments and all of the energy usage is accomplished with the surgeon's feet. Essentially, at the end of the day, the mere ergonomic advantages of operating with the robot can make it worthwhile even without the other obvious benefits, such as better visualization and more precise dissecting and suturing.

Robotic surgery is not for the casual user. It requires frequent usage, as do more complicated operations, no matter how they are performed. Recent discussions of the detrimental musculoskeletal and visual effects that are a result of poor ergonomic positioning and techniques for laparoscopic general surgical procedures require a serious look at the present state of laparoscopic surgery [18]. Surgeons who are considering devoting a major portion of their operative time in performing laparoscopic procedures should consider robotic technology for these same operations.

The cost of developing a robotic program is significant for any hospital system. There is no doubt that robotic technology is necessary for a well-developed prostate cancer program. It is also necessary for a cutting edge gynecologic oncology program and by patient demand it is becoming quite necessary for benign gynecologic procedures. The new robotic assisted operations for head and neck cancers, especially those procedures performed for tonsillar cancers and posterior pharynx and tongue cancers, has allowed patients to avoid the more disfiguring operations traditionally performed by head and neck surgeons. This leaves general surgeons with little of the burden of justifying the cost of a robotic general surgical program. The short-term results for the patients in our series are similar to our experience with the laparoscopic approach. The long-term results are unknown at this time. Perhaps the benefits for the surgeon mentioned above will be bolstered by a lower hiatus hernia recurrence rate, fewer patients on anti-reflux medications and result in fewer ergonomically caused injuries for the surgeon.

Conclusion

Robotic technology has become essential for the performance of complicated minimally invasive operations for many surgical specialties. The technology will find its place in the operative armamentarium of many more specialties and surgeons. The role of robotic technology for general surgeons is yet to be defined but the advances that have been made and some of the newer procedures performed such as single port cholecystectomy portend a bright future for the robotic technology.

Acknowledgment The authors are grateful to Gary Edelburg for procuring images incorporated in this chapter.

References

1. Broeders JA, Mauritz FA, Ahmed Ali U, Draaisma WA, Ruurda JP, Gooszen HG, Smout AJ, Broeders IA, Hazebroek EJ. Systematic review and meta-analysis of laparoscopic Nissen (posterior total) versus Toupet (posterior partial) fundoplication for gastro-oesophageal reflux disease. Br J Surg. 2010;97(9):1318–30.
2. Anderson JE, Chang DC, Parsons JK, Talamini MA. The first national examination of outcomes and trends in robotic surgery in the United States. J Am Coll Surg. 2012;215(1):107–14.
3. Niebisch S, Fleming FJ, Galey KM, Wilshire CL, Jones CE, Litle VR, Watson TJ, Peters JH. Perioperative risk of laparoscopic fundoplication: safer than previously reported-analysis of the American college of surgeons national surgical quality improvement program 2005 to 2009. J Am Coll Surg. 2012;215(1):61–8.
4. Dunn DH, Johnson EM, Morphew JA, Dilworth HP, Krueger JL, Banerji N. Robot-assisted transhiatal esophagectomy: a 3-year single-center experience. Dis Esophagus. 2013;26(2):159–66.
5. Mi J, Kang Y, Chen X, Wang B, Wang Z. Whether robot-assisted laparoscopic fundoplication is better for gastroesophageal reflux disease in adults: a systematic review and meta-analysis. Surg Endosc. 2010;24(8):1803–14.
6. Vela MF, Camacho-Lobato L, Srinivasan R, Tutuian R, Katz PO, Castell DO. Simultaneous intraesophageal impedance and pH measurement of acid and non-acid gastroesophageal reflux: effect of omeprazole. Gastroenterology. 2001;120(7):1599–606.
7. Hafez J, Wrba F, Lenglinger J, Miholic J. Fundoplication for gastroesophageal reflux and factors associated with the outcome 6 to 10 years after the operation: multivariate analysis of prognostic factors using the propensity score. Surg Endosc. 2008;22(8):1763–68.
8. Shaw JM, Bornman PC, Callanan MD, Beckingham IJ, Metz DC. Long-term outcome of laparoscopic Nissen and laparoscopic Toupet fundoplication for gastroesophageal reflux disease: a prospective, randomized trial. Surg Endosc. 2010;24(4):924–32.
9. Varin O, Velstra B, De Sutter S, Ceelen W. Total vs. partial fundoplication in the treatment of gastroesophageal reflux disease: a meta-analysis. Arch Surg. 2009;144(3):273–78.
10. Raue W, Ordemann J, Jacobi CA, Menenakos C, Buchholz A, Hartmann J. Nissen versus Dor fundoplication for treatment of gastroesophageal reflux disease: a blinded randomized clinical trial. Dig Surg. 2011;28(1):80–6.
11. Whitson BA, Hoang CD, Boettcher AK, Dahlberg PS, Andrade RS, Maddaus MA. Wedge gastroplasty and reinforced crural repair: important components of laparoscopic giant or recurrent hiatal hernia repair. J Thorac Cardiovasc Surg. 2006;132(5):1196–202.
12. Oelschlager BK, Petersen RP, Brunt LM, Soper NJ, Sheppard BC, Mitsumori L, Rohrmann C, Swanstrom LL, Pellegrini CA. Laparoscopic paraesophageal hernia repair: defining long-term clinical and anatomic outcomes. J Gastrointest Surg. 2012;16(3):453–59.
13. Graber J, Dunn D, Johnson E, Alden P, Bretzke M, Markman J. Laparoscopic gastric fundoplication for treatment of gastroesophageal reflux disease (GERD). Results from 150 consecutive cases. Minn Med. 2002;85(1):38–42.
14. Salminen P. The laparoscopic Nissen fundoplication–a better operation? Surgeon. 2009;7(4):224–27.
15. Peters MJ, Mukhtar A, Yunus RM, Khan S, Pappalardo J, Memon B, Memon MA. Meta-analysis of randomized clinical trials comparing open and laparoscopic anti-reflux surgery. Am J Gastroenterol. 2009;104(6):1548–61.
16. Bivalacqua TJ, Pierorazio PM, Su LM. Open, laparoscopic and robotic radical prostatectomy: optimizing the surgical approach. Surg Oncol. 2009;18(3):233–41.
17. Zhang P, Tian JH, Yang KH, Li J, Jia WQ, Sun SL, Ma B, Liu YL. Robot-assisted laparoscope fundoplication for gastroesophageal reflux disease: a systematic review of randomized controlled trials. Digestion. 2010;81(1):1–9.
18. Glickson J. Surgeons experience more ergonomic stress in the OR. Bull Am Coll Surg. 2012;97(4):20–6.