Robotic Esophageal Myotomy for Achalasia

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53.1 Introduction

Achalasia, originally called "cardiospasm," was described by Thomas Willis in 1679 [1]. In 1930, Hurst introduced the Greek term for "lack of relaxation" and named this disease achalasia [2]. Achalasia occurs in 0.4–0.6 per 100,000 population. It is most commonly seen in the third decade of life and affects men and woman equally. Achalasia is characterized by abnormal relaxation of the lower esophagus and absence of progressive peristalsis in the body of the esophagus [3].

In patients with achalasia, histopathologic studies of the lower esophagus have shown depletion of the ganglion cells and inflammation of the myenteric plexus [4, 5]. In achalasia, there is preservation of the cholinergic excitatory nerves of the lower esophageal muscle with impairment of the nonadrenergic noncholinergic inhibitory nerves [6]. Although the cause of achalasia is unknown, a number of hypotheses have been proposed. Most authors believe that inflammation is the primary cause for ganglion cell loss [7, 8]. There has been evidence for inflammation of the myenteric plexus with both an infectious as well as an autoimmune etiology [9].

DNA hybridization studies have shown the presence of varicella-zoster virus in the myenteric plexus and increased serum antibodies to the virus in patients with achalasia [7]. Eosinophilic cationic protein (ECP), which is a cytotoxic and neurotoxic protein released by eosinophils, has been detected in the lower esophageal muscle of patients with achalasia [10]. Furthermore, some authors have described eosinophilic infiltrates in the Auerbach plexus of the esophageal muscle in patients with achalasia [11, 12]. Evidence for the autoimmune etiology of achalasia stems from the demonstration of mucosal antibodies in patients with achalasia. Furthermore, class II human leukocyte antigen DQw1, which is seen in other autoimmune disorders, has been seen in patients with achalasia [9]. It is entirely possible that there may be different causes for the destruction of the myenteric plexus in different patients who present with symptoms of achalasia. After all, achalasia represents an esophageal muscle dysfunction which may be caused by different pathophysiologic pathways, all leading to the destruction of the myenteric plexus.

Achalasia presents with an indolent course of gradually increasing progressive dysphagia. The natural history of this disease is that of progressive esophageal dilation and "a spiral downward" with the final loss of esophageal function. With increasing dilation, the progressive widening of the esophagus results in lower peristalsis and increased dysfunction. Soon, the esophagus transforms from a conduit to a reservoir. When the dilated dysfunctional esophagus has become an intrathoracic reservoir, the patient experiences more of the complications of repeated aspiration and pulmonary infection, airway obstruction, and even the development of squamous cell carcinoma [13, 14]. As the natural history of this disease is one of increasing symptoms and complications, relief of the distal esophageal obstruction should be the goal as soon as the diagnosis of achalasia has been confirmed.

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53.2 Diagnosis

Although contrast upper GI studies and endoscopy are helpful, we believe that esophageal manometry is the "gold standard" in the diagnosis of achalasia. The diagnosis of achalasia is confirmed by the following:

- The presence of high pressure in the distal esophagus (increased pressure at the HPZ).
- Lack of relaxation of the lower esophagus to swallowing.
- Absence of peristalsis in the body of the esophagus.

53.3 Treatment

As the function of the lower esophageal myenteric plexus cannot be restored, the treatment of achalasia is palliative. The therapeutic options include the following:

- Medical therapy
- Botulinum toxin injections
- Pneumatic dilation
- Surgery

Historically, the lack of success with and the invasive nature of surgery has led patients and practitioners to search for other options.

53.3.1 Medical Therapy

Beta-agonists, nitrates, anticholinergics, and calcium channel blockers have been used. With these medications, clinical improvement is often limited and the side effects are significant [15–18]. Medical therapy has a very limited role in the care of patients with achalasia.

53.3.2 Botulinum Toxin Injection

Transendoscopic injection of botulinum toxin has been shown to be effective in 65% of patients [19]. Although simple, this technique suffers from the need for repeated injections, temporary benefit, and results in more difficult dissection at the time of surgery should a surgical approach be necessary. Most importantly, as in patients with achalasia, the ganglia of the Auerbach plexus are destroyed, it is difficult to understand the effect of either medical therapy or the injection of botulinum toxin on nonexistent ganglia. This reasoning has led some investigators to speculate that the symptom relief seen with botulinum toxin may in part stem from dilation of the esophageal muscle during endoscopy and may occur even without the injection of the toxin.

53.3.3 Pneumatic Dilation

Interestingly, the original patient described by Willis used a whalebone to dilate the distal esophagus every day for 15 years [1]. The experience with the more modern techniques of pneumatic dilation also attest to the transient nature of the relief which is obtained with dilation of the esophagus in patients with achalasia. Although presently most patients undergo balloon dilation initially, it is clear that this technique has a limited role in the long-term management of achalasia. With more successful and minimally invasive surgical options, this technique will be reserved more for patients in whom surgical myotomy is contraindicated [20]. It would seem that if dilating the esophageal muscle has the endpoint of forcibly rupturing the esophageal muscle fibers by nature of dilating across the mucosa, either the muscle will only stretch temporarily leaving the mucosa intact or a more forceful transmucosal tear of the esophageal muscle will result in mucosal rupture. Balloon dilation for achalasia has shown good to excellent transient results in 70% to 85% of patients. Review of the largest series reporting dilation for achalasia have shown the need for repeated dilations in 17% of patients, reflux in 22% of patients, perforation in 1.4% of patients, and a mortality rate of 0.3% [21].

53.3.4 Surgery

The fact remains that achalasia is a mechanical problem which stems from the destruction of the distal esophageal nerve bodies and, therefore, the ideal therapeutic strategy would be a mechanical approach for the relief of obstruction. The history of surgical therapy for achalasia is characterized by increasingly more successful and less invasive procedures which have been developed as a direct result of better understanding of the following:

- The pathophysiology of achalasia.
- The anatomy of the gastroesophageal junction and the nature of "antireflux barrier."
- Advancement in technology: optics, surgical instrumentation, and robotics.

The first surgical procedures for the treatment of achalasia were described by Marwedel and Wendel [22, 23]. These procedures consisted of a transabdominal anastomotic cardioplasty of the gastroesophageal junction and were similar to pyloroplasty which was described by Heinke and Mikulicz. At the end of the nineteenth century and the beginning of the twentieth century, achalasia was thought to represent "cardiospasm," a term which was proposed by Mikulicz. Therefore, the surgical therapy was designed to be similar to the surgery for pyloric obstruction. Obviously, the poor understanding of the nature of achalasia at the time had resulted in the design of an inadequate surgical procedure

which did not address the nature of the disease. Although this technique relieved the esophageal obstruction, it was associated with significant gastroesophageal reflux and was eventually abandoned. In 1913, Heller performed a transabdominal anterior and posterior esophageal myotomy [24]. This procedure was later modified to a single anterior esophageal myotomy by Zaaijer in 1923 [25]. In relation to the Mikulicz cardioplasty, the modified Heller myotomy was similar to performing a pyloromyotomy versus a pyloroplasty. Like the earlier procedure, the complete distal esophageal myotomy as described by Heller and Zaaijer was based on the incomplete understanding of the nature of achalasia and the antireflux barrier at the gastroesophageal junction. Just like the earlier procedure, the modified Heller myotomy relieved the obstruction at the GE junction, but was associated with severe gastroesophageal reflux and esophagitis. Interestingly, in order to decrease post-myotomy reflux, originally Dor and Toupet described their respective techniques for anterior and posterior cardioplasty as modifications of the Heller procedure [26, 27]. During the 1950s, the high rate of reflux associated with this procedure led to the widespread interest in hydrostatic esophageal dilation.

Over the years, surgical therapy for achalasia has been controversial. The controversy has centered on the ideal operative approach, the extent of esophageal myotomy, and the need for the addition of an antireflux procedure. With minor changes, presently the same controversies continue. Prior to the advent of laparoscopic or thoracoscopic approaches to achalasia, the most commonly performed procedure for this disease was the transthoracic modified Heller myotomy with or without an antireflux procedure. The transthoracic approach was preferred to the transabdominal approach due to the technical difficulties of exposing the gastroesophageal junction and the distal esophagus by an open abdominal procedure. One group of surgeons felt that with experience and appropriate intraoperative measures, they were able to perform transthoracic esophageal myotomy *without* an antireflux procedure with very low rates of postoperative reflux [28–30]. Another group of surgeons advocated solving the problem of new postoperative gastroesophageal reflux with Heller's myotomy by adding a partial fundoplication to the myotomy procedure [31–33].

The proponents of myotomy combined with the antireflux procedure reasoned that:

- Residual achalasia occurred as the result of incomplete myotomy which could be obviated by a generous extension of the myotomy onto the stomach cardia.
- Without a generous myotomy, the extent of the myotomy and therefore the success of the procedure was difficult to judge at the time of surgery.
- Judgment of the appropriate extent of myotomy was associated with a steep learning curve.

Therefore, to avoid the problem of incomplete myotomy and to prevent severe gastroesophageal reflux following the myotomy, these authors recommended complete lower esophageal myotomy with a long extension onto the cardia of the stomach with the addition of an antireflux procedure. Furthermore, these authors observed that in addition to preventing postopertive reflux, the fundoplasty prevented the formation of a mucosal diverticulum following myotomy, a condition which may have added to the problem of chronic dysphagia in these patients with compromised esophageal motility. Due to the dysphagia associated with the Nissen fundoplication in patients with esophageal dysmotility, most authors have preferred partial wraps such as Dor or Toupet or the Belsey fundoplasty [34].

On the other hand, the surgeons who have advocated myotomy without an antireflux procedure most notably Ellis et al., have emphasized that in their experience, fundoplication recreates the resistance to esophageal emptying and that depending on the degree of resistance, fundoplication can lead to progressive esophageal dilation and ultimately the same sequalae as with untreated achalasia. Furthermore, these authors have asserted that in their experience, if the esophageal myotomy is carried on to the cardia by 5–10 mm, an antireflux procedure is not required [28–30].

The present understanding of the gastroesophageal antireflux barrier has served to explain the different observations and the discrepancy in the experience of the proponents versus the opponents of an added antireflux procedure to the modified Heller myotomy. The antireflux barrier, which corresponds to the high-pressure zone on esophageal manometry, seems to be the result of:

- Anterior and lateral intussusception of the esophagus into the stomach, extending 270° from the right limb of the right crus to the left limb of the right crus of the diaphragm.
- The crural sling exerts pressure in an anterior to posterior direction onto the GE junction and creates a slight anglation. This anglation at the GE junction serves to hold the intussuscepted esophagus in place and provides a slight resistance to reflux at the GE junction.
- The entire "antireflux" mechanism is held in place by the phreno-esophageal ligament and the tissues at the esophageal hiatus.
- Disruption of the esophageal hiatus either with a hiatal hernia or at the time of surgical dissection, leads to the straightening of the GE junction, reduction of the anterior esophageal intussusception and the creation of gastroesophageal reflux.

In retrospect, it appears that by trial and error and careful surgical observation, surgeons who performed modified esophageal myotomy for achalasia had discovered that in

patients with an intact antireflux barrier, in whom the esophagus is intussuscepted into the stomach by a few centimeters, the esophageal muscles seemed to extend beyond the perceived GE junction onto the cardia of the stomach. Furthermore, with experience these surgeons had discovered that by grasping the intrathoracic esophagus and pulling in a cephalad direction, one could temporarily reduce the intussusception and carry the myotomy down to the true junction of the esophagus and the stomach. In fact, using esophageal manometry, we have demonstrated that if the last few circular muscle fibers of the distal esophagus are not divided, the elevated HPZ pressure in patients with achalasia does not decrease. As a result of this information, it can be surmised that residual achalasia following surgery is a direct result of an incomplete myotomy. In retrospect, by nature of not disrupting the three-dimensional relationship at the esophageal hiatus and performing a very careful and limited myotomy, the surgeons who did not add an antireflux procedure have been able to preserve the antireflux barrier and accomplish the goal of the myotomy without the need for an antireflux procedure. On the other hand, surgeons who opened the esophageal hiatus and performed an extensive dissection of the gastroesophageal junction thus disrupting the normal antireflux barrier, needed to add an antireflux procedure to the myotomy in order to prevent postoperative reflux. It is important to note that in order to visualize an adequate length of esophagus, a transabdominal approach invariably needs to disrupt the anatomy at the gastroesophageal junction and the antireflux barrier. Consequently, all transabdominal approaches to esophageal myotomy have required the addition of an antireflux procedure.

The emergence of video endoscopic techniques changed the approach to the surgical therapy of achalasia. Laparoscopic techniques allowed for better transabdominal visualization and manipulation of the gastroesophageal junction. Until the advent of laparoscopy, visualization of the GE junction by virtue of its location deep under the costal arch required extensive retraction. Even with the use of self-retaining retractors, visualization of the GE junction remained suboptimal. As the direct result of the inability to see, open transabdominal myotomy was associated with poor results. The extensive use of laparoscopy for fundoplication in patients with gastroesophageal reflux disease provided greater facility and familiarization with the anatomy of the gastroesophageal junction. It was not difficult to extrapolate the techniques used for fundoplasty to the procedure of esophageal myotomy which, if performed transabdominally, required an antireflux procedure at any rate. Unlike conventional surgery, video endoscopic techniques were associated with lower morbidity and pain, as well as shorter hospital stays. Therefore, these minimally invasive techniques with the promise of better long-term results were more favorable to nonsurgical approaches and found acceptance among patients and medical practitioners.

In 1991, Shimi et al. reported the first laparoscopic experience for Heller Myotomy, and Pellegrini et al. reported a series of patients who had undergone esophageal myotomy using the thoracoscopic approach [35, 36].

53.3.4.1 Laparoscopic Approach

The object of the laparoscopic esophageal myotomy and anterior fundoplication is to perform myotomy of the lower 6 cm of the esophagus and the proximal 2 cm of the stomach. In order to access the intrathoracic esophagus, this procedure requires full dissection of the right crus of the diaphragm and the entire esophageal hiatus. Consequently, following myotomy, a partial anterior gastric fundoplication is performed as an antireflux procedure. Invariably, all series reporting the laparoscopic approach to Heller myotomy have shown excellent relief of dysphagia [37]. In one series of 133 patients who had undergone laparoscopic myotomy with a partial fundoplication, Patti et al. reported 11% persistent dysphagia, 17% new gastroesophageal reflux, and 5% mucosal perforations which were amenable to laparoscopic closure [38]. The majority of difficulties with the laparoscopic approach were related to reflux and the technical aspects of the fundoplication. In a series of 69 patients undergoing laparoscopic myotomy and fundoplication for achalasia, Finley et al. reported a median operative time of 1.9 hours, one mucosal perforation which was amenable to laparoscopic repair, 96% patient satisfaction for relief of dysphagia, and a 9% rate of new postoperative gastroesophageal reflux [39].

53.3.4.2 Thoracoscopic Approach

During the thoracoscopic approach, the esophagus is approached through the left chest. The myotomy is carried down to the gastroesophageal junction. During this approach, either the gastroesophageal junction is left intact or the left rim of the right crus is opened and subsequently reapproximated following the myotomy. With the thoracoscopic approach, an antireflux procedure has not been necessary. Whereas the complications of the laparoscopic approach have been related to reflux and the antireflux procedures, the thoracoscopic approach has suffered from the difficulty of residual achalasia and the steep learning curve associated with obtaining a complete myotomy [40]. The most important complication following the thoracoscopic approach has been incomplete myotomy and persistent dysphagia. Pellegrini et al. have reported that after thoracoscopic myotomy, dysphagia was relieved in 70% of patients, 12% of patients had residual achalasia, and mild reflux was seen in 20% of patients. Stewart et al. reported esophageal perforation in 12% of patients undergoing the thoracoscopic esophageal myotomy and conversion to thoracotomy in 21% of patients [40]. The mean hospitalization for this group of patients was 6 days. In the same group at 42 months, 31% of patients had relief of dysphagia and 23% of patients had new

gastroesophageal reflux. Patti et al. reported a 6% conversion to a thoracotomy, a 73% rate of relief of dysphagia, and a 25% rate of incomplete myotomy [38]. The data has shown the laparoscopic procedure to have a lower conversion rate to an open procedure and to be associated with lower morbidity and shorter hospitalization. Most importantly, the laparoscopic Heller myotomy with an anterior fundoplasty has shown excellent relief of dysphagia at the expense of the higher rate of new gastroesophageal reflux. Due to these results at the present time, the laparoscopic approach has become the initial approach of choice for patients undergoing the surgical palliation for achalasia [41].

Our experience with both laparoscopic as well as thoracoscopic approaches to esophageal myotomy has led to the following conclusions:

- Although easier, the laparoscopic approach necessitates the disruption of the esophageal hiatus and extensive mobilization of the esophagus. Due to this fact, the antireflux procedure is added to the myotomy. The clinical results reveal an excellent relief of dysphagia. However, the complications associated with this technique relate to the high rate of gastroesophageal reflux disease even with an antireflux procedure and the problems associated with the added antireflux procedure itself.
- When performing a thoracoscopic Heller myotomy without disrupting the esophageal hiatus, the thoracoscopic approach is associated with a much lower rate of new postoperative gastroesophageal reflux disease. However, this procedure is hampered by the technical difficulties of performing a complete myotomy. Consequently, this technique has suffered from lower rates of dysphagia relief. We have reasoned that adapting the procedure performed through a left thoracotomy and described by Ellis et al., where through a transthoracic approach a Heller myotomy was performed without the need for an antireflux procedure, to videoendoscopic techniques, there would be excellent relief of dysphagia with low incidence of new gastroesophageal reflux disease.

Our experience with the thoracoscopic approach to esophageal myotomy has been in two phases.

53.3.4.3 Phase I: VATS with Intraoperative Manometry

The first thoracoscopic Heller myotomy by the senior author was performed in 1992. As the result of the initial thoracoscopic experience, it was obvious that with the loss of tactile input during VATS, assessment of the completeness of the esophageal myotomy was very difficult. This problem was resolved by the use of intraoperative esophageal manometry.

Online direct intraoperative monitoring of the pressure at the distal esophagus by manometry was invaluable in confirming the completeness of the myotomy. As the last circular esophageal muscle fibers responsible for the high distal esophageal pressure were divided, the online esophageal monitoring would record a decrease in the pressure to the normal range. We reasoned that normal pressure reading (8–15 mmHg) at the esophagogastric junction reflected completeness of the myotomy and the intact nature of the antireflux barrier. Using this technique, the results were gratifying.

In an 8-year period 32 patients underwent VATS esophageal myotomy with intraoperative manometry. There were 5 intraoperative mucosal injuries which were repaired primarily. Post myotomy the mean esophagogastric junction pressure decreased from 26 ± 3.3 to 9.1 ± 0.9 mmHg. The median hospitalization for patients with and without a mucosal injury was 7 days and 4 days, respectively. Mean follow-up was 38 months. All patients experienced postoperative improvement in dysphagia. Fifty-six percent had no dysphagia, and 44% had mild to moderate dysphagia. The patients with postoperative dysphagia had a dilated esophagus on preoperative esophagography. Of these patients, 9/14 (64%) showed improvement of dysphagia at the time of follow-up. At the time of follow-up 84% of patients had good to excellent relief of dysphagia, and 28% of patients had mild reflux which responded to antacid therapy.

Although the results with VATS Heller myotomy were gratifying, this approach represented a technically challenging procedure which required significant experience with video-assisted thoracic surgery. It was obvious that in order for this approach to gain widespread acceptance, the procedure needed to be refined and become more "surgeon friendly." A number of obstacles remained.

- During video-assisted thoracic surgery, thoracoscopic instruments are introduced through a small hole in the chest wall. The instruments pivot at the entry point which makes fine control of the instrument tip, usually located at a remote location, difficult and cumbersome. The "chopstick" nature of the movements of the VATS instruments stems from the fact that the rigid shaft axis of the instruments is fixed at entry site on the chest wall. Consequently, the VATS instruments are limited to maneuvering in four directions (up, down, left side, and right side). Obviously, this technical feature of VATS presents the greatest limitation for complex dissection, especially in a remote confined space. By nature of pivoting at the chest wall, as the tip of the VATS instrument is moved further from the entry site, mobility of the instrument and its maneuverability in relation to the remotely positioned tissue decreases. Indeed it is as though the surgeon is operating at the apex of a pyramid with instruments which are pivoted at the base of that structure.
- Another shortcoming of the VATS technique is in the lack of three-dimensional visualization. Although a surgeon with facility and experience with VATS uses the two-dimensional information from the video monitor and

combines the visual input with tactile input in order to form a three-dimensional mental image, the fragile nature of the tissues, the confined space, and the paucity of tactile information when performing an esophageal myotomy results in a very poor mental three-dimensional image. Binocular three-dimensional vision with adequate depth perception is crucial to the task of separating the esophageal mucosa from the muscle and dividing the esophageal muscle fibers.

By addressing these shortcomings, the robot represented the ideal tool for the accomplishment of robotic video endoscopic transthoracic Heller myotomy. The beneficial features of the robotic platform are the following:

- The endowrists. The endowrist is a cable-driven wrist at the end of the robotic arm. The placement of the robotic arm through the VATS hole is comparable to the chopstick maneuvers of the conventional VATS instruments. The endowrist at the distal end of the robotic arm is then positioned in the confined space and brings four more degrees of freedom and six more directions of movement to the maneuverability already possible by the movement of the robotic arm pivoting at the entry site. The movement of the endowrist allows for movement of the distal instruments much like the movements of the surgeon's wrist during conventional surgery.
- Downscaling**.** The DaVinci robotic system is designed to provide downscaling from the motion of the surgeon's hands to that of the robotic arm. This is invaluable in dissecting the fine and fragile tissues of the distal esophagus. Furthermore, a fixed Hz motion filter is used to filter out the tremor in the surgeon's hand and enhance the accuracy of the surgical dissection.
- Binocular vision**.** The binocular robotic camera provides superb three-dimensional visualization and by nature of being mounted on the central robotic arm, it is manipulated by the surgeon. The result of this is an immobile field of vision with high resolution and magnification and total control of movements by the surgeon. The ability to manipulate the camera and the robotic arms recreates the surgeons own natural head, eye, and wrist motions as used during open procedures and enhances hand-eye coordination.

53.4 Operative Technique

53.4.1 Anesthesia

Patients undergoing robotic video-assisted thoracic surgical Heller myotomy require single-lung ventilation. We prefer a left-sided double lumen endotracheal tube to a bronchial blocker. With a double lumen tube, lung collapse is superior and hilar manipulation does not result in movement of the blocker and inadvertent expansion of the lung. As is addressed in a separate chapter in this book, the facility of the anesthesiologist with the robotic techniques is crucial to the conduct of the operation. Following the induction of anesthesia, with the patient in the supine position, upper GI endoscopy is performed. The gastroesophageal junction is identified and a nasogastric tube is positioned under direct vision into the stomach. Decompression of the stomach facilitates retraction of the diaphragm and enhances visualization of the gastroesophageal junction. While the patient is in the supine position, the gastroscope is pulled back to the distal esophagus and secured for patient positioning. As has been described by Pellegrini et al., the gastroscope plays a significant role during the myotomy procedure [36]. First, it allows for identification of the left lateral wall of the esophagus without the need for extensive mobilization of a circumferential dissection of the esophagus. Second, it transilluminates the esophageal mucosa and helps in identification of the area of incomplete myotomy. Third, by application of intraluminal suction to the mucosa during the myotomy procedure, the mucosa is pulled toward the lumen of the esophagus thereby exposing the anterior plane between the esophageal mucosa and the muscle of the esophagus.

53.4.2 Patient Positioning

The patient is placed in an extended right lateral decubitus position. The table is fully flexed to enlarge the space between the ribs. The surgeon stands behind the patient. A monitor is positioned at the patient's feet and a second monitor is positioned in front of the patient facing the surgeon. The robot is positioned in front of the patient (Fig. 53.1).

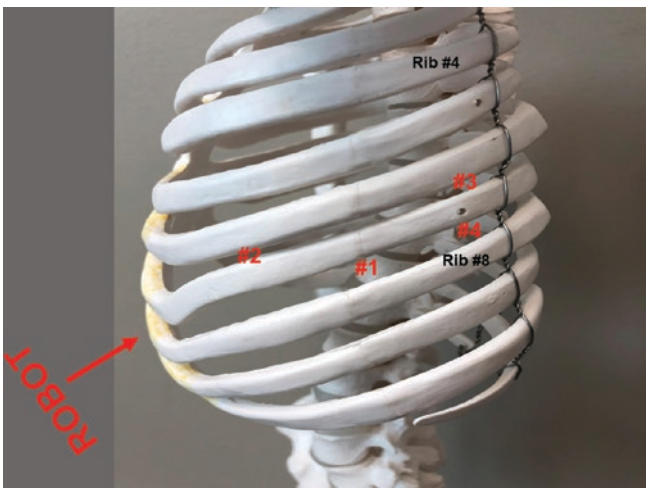

Fig. 53.1 Positioning the robot and trocars for the robotic thoracoscopic approach

During the robotic portion of the procedure, the robot is brought into the operative field from an anterior to posterior direction facing cephalad at a 30-degree angle to the axis of the patient.

53.4.3 Myotomy

After the patient is prepped and draped, a 2 cm incision (#1) is made in the seventh intercostal space in the midaxillary line. This incision will serve as a camera port during the VATS and robotic portion of the operation. A second 2-cm incision (#2) is made in the sixth intercostal space anteriorly in the midclavicular line. A third 2-cm incision (#3) is made in the sixth intercostal space posteriorly in the posterior axillary line. A fourth 2-cm incision (#4) is made one interspace below incision #3 in the seventh intercostals space posteriorly. It is paramount that incisions #1, #2 and #3 be positioned approximately one hand-breath away from one another in order to prevent interference with the robotic arms. As has been described in Chap. 54 of this book, we prefer the Olympus EndoEye Video Endoscopic System. A 10 mm 0° end viewing scope is positioned initially viewing cephalad over the diaphragm using conventional video-assisted thoracic surgical techniques and viewing the monitor located in front of the patient and facing the surgeon, the inferior pulmonary ligament is divided and the lung is retracted superiorly. The table is positioned in "Trendelenburg" in order to allow the lung to fall into the apex of the chest. The camera is then rotated 180° in order to view the distal esophagus at the diaphragm. The surgeon and the surgical team then rotate their field of vision and use the video monitor at the patient's feet for the next phase of the procedure. In order to retain intuitive spatial relationships, it is imperative that the surgical team view the surgical site in the same direction and axis as the videoendoscope. The gastroscope is rotated towards the patient's left, its tip is flexed thus allowing the surgeon to visualize the distal esophagus without the need for further dissection. An endoscopic fan retractor (Ethicon Endosurgery, Inc.) is introduced through incision #2 and used to retract the diaphragm at the gastroesophageal junction in a caudad direction. The retractor is fixed to the table using a self-retaining holder (Mediflex, Velmed, Wexford, Pennsylvania). Using conventional endosheers (Ethicon Endosurgery, Cincinnati, OH) with cautery attachment, the pleura overlying the esophagus is divided. An endostitch instrument (Autosuture, US Surgical, Norwalk, CT) with a 2–0 Ethibond suture is used to place retraction sutures on the two edges of the pleura. The sutures are then brought out through the anterior and posterior incisions (incisions #2 and #4) and fixed to the drapes. This maneuver creates a pleural sling and elevates the esophagus from its normal mediastinal location into the left pleural space. The esophageal hiatus is identified and the left lateral limb of the right crus of the diaphragm is divided using the endosheers with cautery. The dissection is discontinued with the visualization of the phrenoesophageal ligament on the underside of the diaphragm. Using the endostitch instrument with a 0 Ethibond suture, full-thickness retraction sutures are placed on the cut edges of the diaphragm and brought out through the anterior and posterior incisions respectively (#2 and #4). The sutures are fixed to the drapes. This maneuver allows for the full visualization of the esophagogastric junction. At the end of the procedure, the cut edges of the left limb of the right crus of the diaphragm are re-approximated using an endostitch instrument with 0 Ethibond suture. Usually, three such sutures are necessary to repair the crus of the diaphragm. By avoiding disruption of the anterior crural arch and by restoring the integrity of the left limb of the right crus of the diaphragm, the crural sling is preserved and the antireflux barrier remains intact. At this point, the VATS camera is removed and the robot is positioned. The Robot is brought in from the posterior aspect of the patient. It is positioned caudad to cephalad with 30° rotation in the cephalad direction on the patient's axis. The camera port is positioned in the camera incision (#1) and a 30° down viewing scope is positioned viewing caudally onto the distal esophagus. The right robotic arm with a hook end-effector instrument connected to a cautery is placed through the anterior incision (#2) and its endowrist is positioned directly over the distal esophagus. A left robotic arm with a DeBakey forceps as its distal end-effector instrument is positioned through the posterior incision (#3) and its endowrist is positioned directly over the distal esophagus. A metal suction with a blunt tip is positioned through incision #4. The suction is used by the assistant to evacuate cautery smoke, control bleeding, and provide downward force on the esophageal mucosa during the myotomy. With binocular view and natural depth perception and the facility of the endowrist movements, the performance of esophageal myotomy is quite accurate and uncomplicated. The muscular wall of the esophagus is exposed and the muscle is divided with a hook cautery at the midpoint of the exposed esophagus. The anatomic plane between the mucosa and the muscle is identified. The blunt metal suction is positioned on the mucosa. Endoluminal suction is also applied using the video gastroscope. The robotic forceps are used to elevate the muscle layers. The combination of these maneuvers allows for the hook cautery (blended coagulation current set at 30 watts) to be used to divide the muscle fibers of the esophagus. As the distal aspect of the esophagus and the intussuscepted portion of the esophagus into the proximal stomach is approached, the robotic forceps are used to reduce the intussusception by pulling the esophagus in a cephalad direction. The hook cautery then completes the myotomy approximately 1 cm onto the cardia of the stomach. Myotomy is discontinued when the submucosal

vascular plexus of the stomach wall is visualized. At this point, an assistant positioned at the head of the patient advances the gastroscope past the GE junction into the stomach. The ease of movement of the gastroscope into the stomach and the lack of resistance further confirms the complete division of the esophageal muscles at the GE junction. Furthermore, the gastroscope is retroflexed to view the GE junction from a caudad to cephalad direction. Observation of the transilluminated mucosa of the proximal portion of the gastric cardia from the light of the robotic camera serves as the final confirmation for the completion of the esophageal myotomy. Following the completion of the myotomy, the chest is filled with saline and the gastroscope is used to insufflate air into the stomach and esophagus in order to rule out any mucosal perforation. Any mucosal perforations are easily repaired by the endoscopic techniques and the use of 4–0 Prolene sutures. The robotic arms are retracted and the robot is moved away from the table. At this juncture, the conventional VATS EndoEYE camera is inserted through the camera port and the left limb of the right crus of the diaphragm is re-approximated as described earlier. At this point, a 2 cm square piece of Vicryl mesh (Ethicon, Inc., Somerville, NJ) is positioned at the distal aspect of the mediastinum. This absorbable mesh is attached to the edges of the mediastinal pleura using the endostitch with 2–0 Ethibond sutures. We have found that the Vicryl mesh which is absorbed and replaced by scar tissue approximately 8 weeks following implantation, reestablished the integrity of the pleura on the left lateral aspect of the esophagus and repositions the distal esophagus into the mediastinum. Furthermore, this maneuver with the resultant scarring of the pleura prevents the formation of a mucosal diverticulum at the distal portion of the esophagus. It has been hypothesized that the mucosal diverticulum may be one of the causes of chronic dysphagia even with an adequate myotomy when a fundoplasty is not performed. In fact, some authors have proposed that one of the benefits of the fundoplasty is the prevention of a mucosal diverticulum by placing external pressure on the mucosa. Prior to the employment of this technique, we had observed mucosal outpouching at the distal esophagus and the level of the gastroesophageal junction in a number of patients. This technique seems to have addressed that issue without any negative sequalae. Following pleural closure, the diaphragmatic retractor is removed. The lung is reinflated under direct vision. A 28-French straight chest tube is inserted through incision #1 and positioned posteriorly in the pleural space. ON-Q Pain Buster catheters are positioned in a subpleural tunnel extending from the second to the eighth intercostal spaces as were described in Chap. 54 and the incisions are closed as described in the same chapter for video-assisted surgery. The gastroscope is used to confirm the appropriate position of the nasogastric tube. The patient is extubated in the operating room. Postoperatively, we routinely obtain an upper GI contrast study with water-soluble contrast in order to rule out mucosal perforation and to confirm completeness of the distal esophageal myotomy. With a satisfactory study, a soft diet is started, the chest tube is removed, and most patients are discharged on the second postoperative day (Video 53.1).

Using the Robotic Transthoracic Approach, 11 patients with achalasia underwent a Left lateral Heller Myotomy without fundoplication. This was the minimally invasive replication of the Left Thoracotomy approach described by Ellis et al. [28]. There were no mucosal injuries, or conversion to thoracotomy. Median hospitalization was 4 days. Relief of dysphagia was seen in 90%. New Reflux was seen in 4% and median PPI use was seen in 12% [41].

53.4.4 Robotic Laparoscopic Approach

The next phase was to adapt the robotic thoracoscopic approach to a lateral Heller myotomy without fundoplication to a robotic laparoscopic approach (Video 53.2).

53.4.5 Surgical Technique

The procedure is performed on a laparoscopic platform (Fig. 53.2). Preoperative UGI endoscopy is performed and the gastroesophageal junction is examined by the retroflexed endoscope. Two laparoscopic CO_2 insufflators are used. Port #1 (Camera Port) is placed inferior to the umbilicus. Pneumoperitoneum is created. The table is placed in a steep reverse Trendelenberg position. Port #2 is placed in the right paraumbilical region at the right mammary line. An Endo-Paddle Retract retractor (Medtronic Inc., Norwalk, Conn.) is placed through Port #2 and fixed to the table using a self-retaining system (Mediflex, Velmed Inc., Wexford, Penn) The advantage of the Endopladdle retract device is that it is used to exert constant fixed upward traction onto the apex of

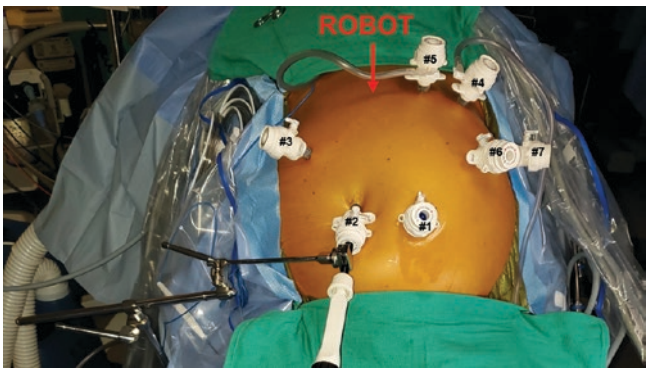

Fig. 53.2 Positioning the robot and trocars for the robotic laparoscopic approach

the esophageal hiatus, and thereby, facilitates visualization and instrument maneuverability within the hiatal opening. Port #3 is placed halfway between the costal arch and the umbilicus as laterally on the right side of the abdomen as possible. This port will carry the left robotic arm. Using the videoendoscope, the left and right limbs of the right crus are identified. Port #4 is placed in the subcostal region halfway between the umbilicus and the xiphoid just to the left of the midline. This port is aligned with the left limb of the right (esophageal) crus of the diaphragm. Port #5 is placed in the subcostal region two finger-breaths to the right and caudad to port #4. Port #5 is aligned with the right limb of the right crus of the diaphragm. The laparoscopic insufflator is disconnected from port #1 and attached to port #4. A second insufflator is attached to port #5. The use of two high flow insufflators facilitates rapid extra corporeal knot placement while preserving pneumoperitoneum and exposure of the esophageal hiatus. Port #6 is placed halfway between the costal arch and the umbilicus as laterally on the left side of the abdomen as possible. This port will carry the right robotic arm. At times a seventh port is needed to retract the contents of the hiatal defect. In such an instance port #7 is placed in the mammary line halfway between ports #1 and #6.

The surgical robot (daVinci, Intuitive Surgical, Sunnyvale, Ca.) is docked using "side docking" technique (Fig. 53.3). A 30° down-viewing robotic binocular camera is used and it is introduced through port #1. The right robotic arm with a hook cautery instrument is introduced through port #3. The left robotic arm with a Debakey grasper instrument is introduced through port #2. The entire dissection uses electrocautery and meticulous hemostasis. An endo-kittner is introduced through port #5 by the assistant and is used to provide appropriate counter traction and exposure at the esophagogastric junction. A 30° camera is used.

The left limb of the esophageal crus is identified, and the muscle is divided for ½ of the thickness of the crus. Care is taken not to enter the pleura which resides just under the crus. The left limb is not transected completely. This allows for partial retraction of the muscle away from the lateral aspect of the gastroesophageal junction while at the same time facilitating repair of the left limb at the end of the procedure. The hook cautery is set at 30 cut/30 coagulation with blend setting. The stomach in retracted inferiorly, thereby straightening the GE junction. Care is taken to stay on the left lateral aspect of the gastroesophageal valve. By preserving the gastroesophageal valve and the phreno-esophageal ligament, the antireflux mechanism is kept intact. The muscle of the esophagus is divided to the level of the mucosa. The hook cautery them completes the myotomy approximately 1 cm onto the cardia of the stomach. Myotomy is discontinued when the submucosal vascular plexus of the stomach wall is visualized (Fig. 53.4). At this point, an assistant positioned at the head of the patient advances the gastroscope past the GE junction into the stomach. The ease of movement of the gastroscope into the stomach and the lack of resistance further confirms the complete division of the esophageal muscles at the GE junction. Furthermore, the gastroscope is retroflexed to view the GE junction from a caudad to cephalad direction (Fig. 53.5). Observation of the transilluminated mucosa of the proximal portion of the gastric cardia from the light of the robotic camera serves as the final confirmation for the completion of the esophageal myotomy. The retroflexed view further confirms that the myotomy is lateral to the gastroesopahageal valve. Following the completion of the myotomy, the area is filled with saline and the gastroscope is used to insufflate air into the stomach and esophagus in order to rule out any mucosal perforation. Mucosal perforation is easily repaired by the endoscopic techniques and the use of 4–0 Prolene sutures.

Following a satisfactory myotomy, the partially transected left limb of the esophageal crus is reapproximated with two O- Ethibond sutures with 2 cm squared absorbable pledgets cut from vicryl mesh (Ethicon, Inc.Sommerville, NJ).

The most common approach to Heller myotomy by either robotics or laparoscopy is an anterior myotomy. With this

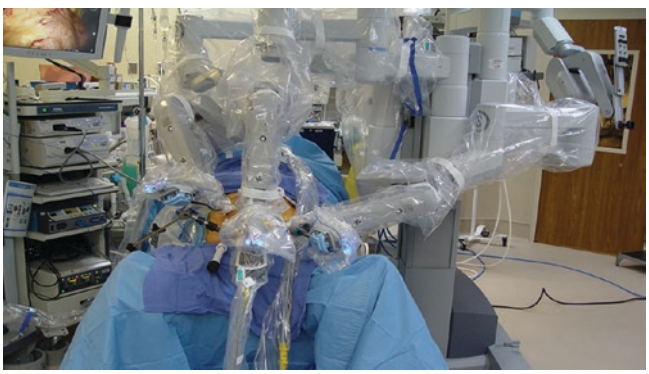

Fig. 53.3 Side docking of the robot for the robotic laparoscopic approach

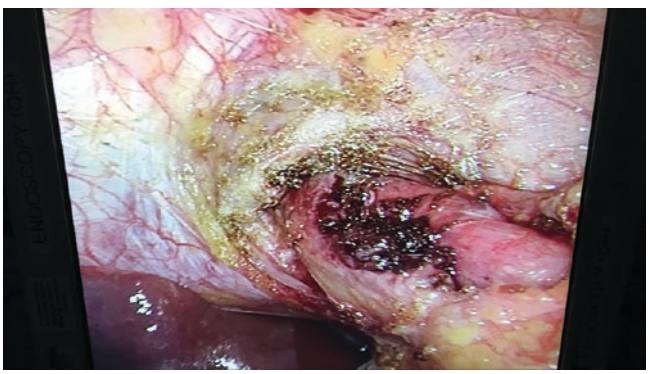

Fig. 53.4 Laparoscopic view of the completed lateral esophageal myotomy prior to the re-approximation of the left limb of the esophageal crus

procedure, there is disruption of the gastroesophageal junction and the phrenoesophageal ligament, thereby requiring a partial fundoplication. Dor fundoplication is most commonly used. As has been noted earlier in this chapter, greater understanding of the gastroesophageal antireflux mechanism and the gastroesophageal valve has led investigators to hypothesize that cutting the esophageal muscle anteriorly at the 12 o'clock position will open the valve at its midpoint and result in significant reflux. Based on this reasoning, cutting the esophageal muscle at the 3 o'clock position or in the left lateral aspect of the gastroesophageal junction just under the left limb of the crus will lead to the preservation of the gastroesophageal valve and thereby obviate the need for an antireflux procedure and attendant complications (Fig. 53.6).

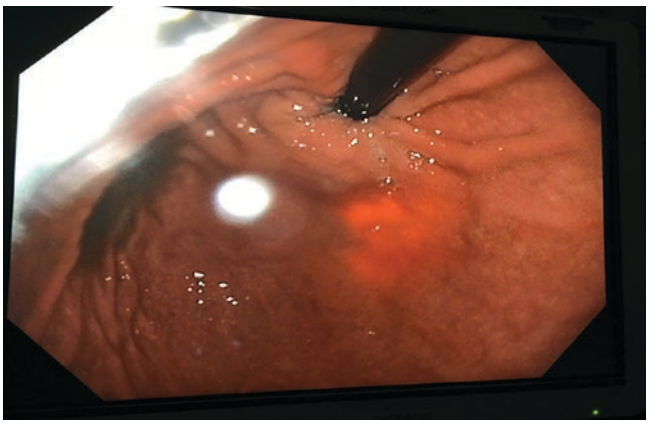

Fig. 53.5 Retroflexed endoscopic view of the gastroesophageal junction from within the gastric lumen. Following a complete myotomy the esophageal mucosa is transilluminated with the light from the laparoscopic robotic camera. The myotomy is lateral to the gastroesophageal valve which remains intact, thereby obviating the need for an additional antireflux procedure

53.5 Comparison of Robotic Lateral Heller Myotomy Without Fundoplication (RLHM) to Robotic Anterior Heller Myotomy With Dor Fundoplication (RAHM)

53.5.1 Hypothesis

The gastroesophageal valve consists of the anterior and lateral intussusception of the esophagus into the stomach, 270° from right limb to left limb of the right crus. The entire 3-D relationship is held in place by phrenoesophageal ligament and tissues at esophageal hiatus. Therefore, anterior myotomy results in division of the gastroesophageal valve at its midpoint, thereby resulting in an insufficient valve and significant reflux.

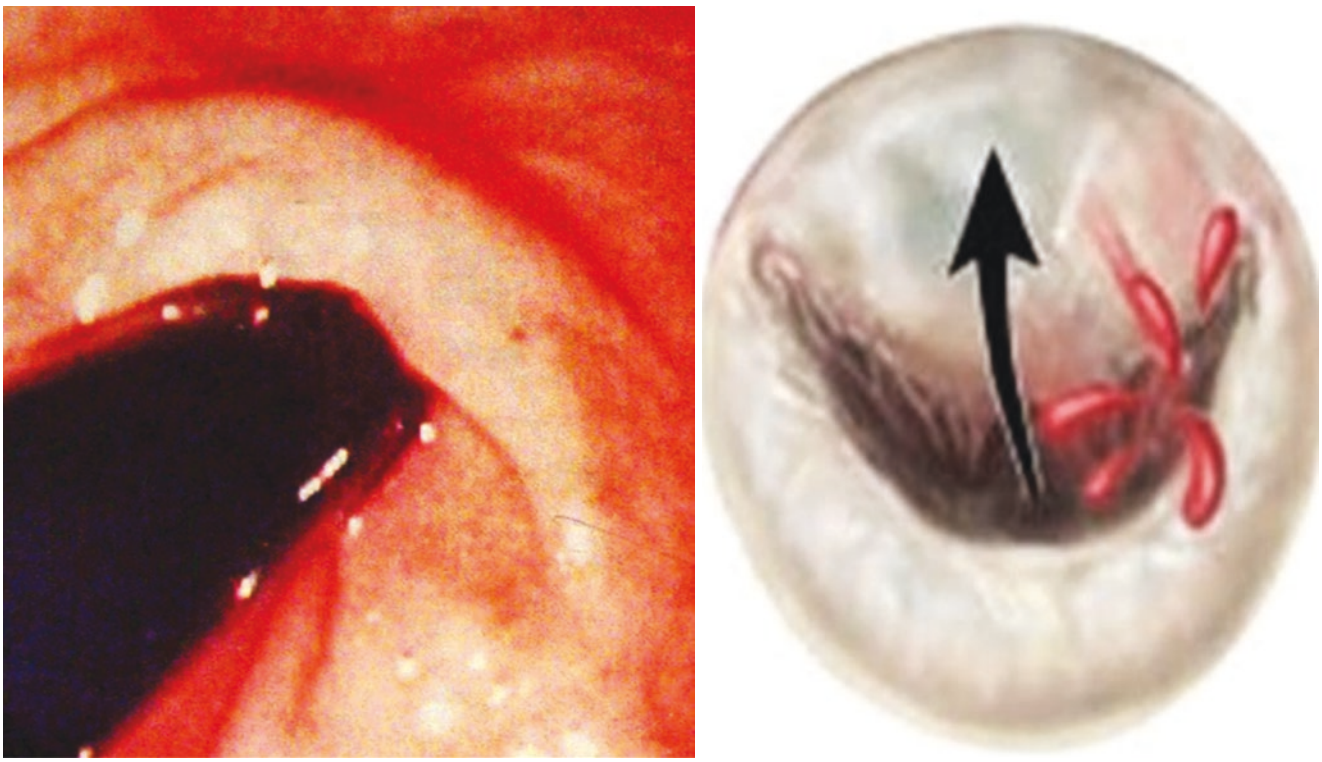

Fig. 53.6 Comparison of the gastroesophageal valve (GE) to the mitral valve. Cutting the mitral valve or the GE valve in the middle at the 12 o'clock position results in significant regurgitation or reflux. A lateral esophageal myotomy at the 3 o'clock position (likened to a mitral commissurotomy) preserves the GE valve and thereby obviates the need for an antireflux procedure

Lateral myotomy results in division of the esophageal muscle fibers lateral to the gastroesophgaeal valve, thereby resulting in less reflux.

53.5.2 Study Design

This was a prospective, randomized, double blind study.

Patients with achalasia were assigned to undergo Robotic Laparoscopic Anterior Heller Myotomy with Dor Fundoplication (RAHM) or Robotic Laparoscopic Lateral Heller Myotomy Without Fundoplication (RLHM).

Diagnosis of achalasia was made by esophagogram, endoscopy, and manometry. Exclusion criteria included previous myotomy and objective proof of ongoing GERD.

An investigator not involved in the surgical procedure used a random numbers table, then prepared, coded, and sealed envelopes with treatment allocation. All recruited patients and investigators involved in the evaluation of the study were blinded to the treatment throughout the study period. All patients underwent manometry, pH testing and subjective dysphagia score at 6 months. Data was presented as median and range.

53.5.3 Results

Forty-eight patients were enrolled. Table 53.1 illustrates patient characteristics.

The operative and postoperative data are shown in Table 53.2. The median OR time was significantly lower in patients who underwent Robotic Laparoscopic Lateral Heller Myotomy without a Fundoplication (RLHM).

On manometry, the Postoperative LES Pressure, was similar in the two groups (Table 53.3). However, the Length of LES Pressure Zone was significantly shorter in patients who underwent RLHM (Table 53.4).

On 24-hour pH monitoring the rate of pathologic GERD (Table 53.5), median acid exposure (Table 53.6), and the DeMeester score (Table 53.7) were similar in the two groups.

The Postoperartive Dysphagia Score was significantly lower in patients who underwent RLHM (Table 53.8). Postoperative Dysphagia Score is based on Scoring Severity and Frequency of Dysphagia from 0 to 5 each for a total Score of 0–10 [42].

This study showed that Robotic Laparoscopic Lateral Heller Myotomy Without Fundoplication is associated with a similar Rate of Pathologic Reflux as Robotic Laparoscopic Anterior Heller Myotomy with Fundoplication. However, Robotic Laparoscopic Lateral Heller Myotomy Without Fundoplication results in a Shorter Length of LES Zone and Greater Relief of Dysphagia. This procedure should be considered as the first line of therapy in patients with Achalasia.

Table 53.1 Patients and methods

	RAHM	RLHM	*P* value
Age	46 (27–73)	48 (21–71)	NS
Sex M/F	12/12	13/11	NS
Preoperative LES pressure	38 mm Hg (16–120)	35 mm Hg (18–120)	NS
Preoperative dysphagia score	8 (7–10)	9 (8–10)	NS

N = 48

Table 53.2 Operative and postoperative data

	RAHM	RLHM	*P* value
Median OR time	135 min (76–216)	85 min (60–132)	<0.0001
Conversion	0	0	
Median hospitalization	2 days (2–3)	2 days (2–3)	NS
Perforation	0	0	NS
Complication	0	0	NS
Death	0	0	NS

Table 53.3 Postoperative LES pressure on manometry

RAHM	RLHM	*P* value
3.7 mm Hg (7.9–17.2)	13.2 mmHg (9.8–16.6)	0.74 (NS)

Table 53.4 Length of LES pressure zone on manometry

RAHM	RLHM	*P* value
5.5 cm (4–9)	2.2 (1.5–2.8)	<0.0001

Table 53.5 Pathologic GERD on 24-hour PH study

RAHM	RLHM	*P* value
2/24 patients (8.3%)	1/24 patients (4.2%)	(NS)

Table 53.6 Median acid exposure on 24-hour PH study

RAHM	RLHM	*P* value
0.5% (0–15.3)	0.4 (0–17.8)	NS

Table 53.7 DeMeester Score on 24-hour PH study

RAHM	RLHM	*P* value
6.8 (5–83)	7.5 (2–125)	NS

Table 53.8 Postoperative dysphagia score

RAHM	RLHM	*P* value
3 (0–4)	1 (0–1)	<0.01

Total score = 0–10
Severity of dysphagia 0–5
Frequency of dysphagia 0–5

53.6 Comparison of Robotic Laparoscopic Lateral Heller Myotomy Without Fundoplication to Peroral Esophageal Myotomy (POEM)

In a retrospective study at our institution, patients who underwent RLHM, RAHM, and POEM were compared in terms of swallowing function at 1 month and 1 year by Eckardt scores (primary end point), as well as OR time, complications and new reflux (secondary end points).

The operative and postoperative results are shown in Table 53.9. The median operative time was significantly lower in patients who underwent RLHM. RLHM was associated with lower rate of mucosal injuries when compared to RAHM. Patients who underwent RLHM required much lower levels of pain medications compared to the POEM group.

Eckardt scores at 1 month are shown in Table 53.10. There was a significant decrease in the Eckardt score in all patients. However, the decrease in the Eckardt score was comparable between the RLHM and POEM groups and greater than the patients in RAHM group.

Eckardt scores at 12 months are shown in Table 53.11. Failure of myotomy was designated as an Eckardt score of greater or equal to 3. At 1 year, the patients in the RLHM Group had a significantly lower rate of failure compared to POEM and RAHM Groups.

The Postmyotomy LES Resting Pressure (LESRP) is shown in Table 53.12. The RAHM group had a significantly lower-than-normal LESP. The patients in the POEM group had an LESP at the high end of normal. The LESP in the RLHM group was in the middle of the normal measurements.

Relief of dysphagia was best with RLHM and POEM (Table 53.13).

Abnormal acid exposure on 24-hour pH testing was significantly lower with RLHM when compared to POEM or RAHM groups (Table 53.14).

Based on this retrospective study, Robotic Lateral Heller Myotomy Without Fundoplication is associated with excellent relief of dysphagia. In terms of relief of dysphagia RLHM is comparable to POEM. However, RLHM is associated with a lower incidence of new GERD than POEM and Robotic Anterior Heller Myotomy with Dor Fundoplication.

Robotic Lateral Heller Myotomy Without Fundoplication should be considered as first line therapy in patients with achalasia.

Table 53.9 Comparison of POEM, RAHM, and RLHM: operative and postoperative results

	POEM $N = 41$	RAHM $N = 44$	RLHM $N = 37$	P value
Median operative time	150	120	72	<0.001
Conversion	0	0	0	NS
Mucosal injury	N/A	8%	0	<0.001
Mean hospitalization	2.2 days	2.5 days	2.2 days	NS
Mean days of pain medication use	2.6	3.1	1.3	<0.001

Table 53.10 Eckardt scores at 1 month

	POEM	RAHM	RLHM
Preop	6.7+/ 2.4	5.5 ± 2.5	6.3 ± 1.8
Postop	0.9 ± 1.6	1.8 ± 1.3	0.8 ± 1.8
p value	<0.0001		<0.0001

POEM = Peroral endoscopic myotomy
RAHM = Robotic anterior Heller myotomy with fundoplication
RLHM = Robotic laparoscopic lateral Heller myotomy without fundoplication

Table 53.11 Eckardt scores at 12 months

	POEM	RAHM	RLHM
Preop	6.7+/ 2.4	5.5 ± 2.5	6.3 ± 1.8
Postop	1.2 ± 1.9	1.7 ± 2.6	0.8 ± 1.1
p value	<0.0001		<0.0001
Rx failure			
Eckardt score ≥3	1/41	0/44	0/37

POEM = Peroral endoscopic myotomy
RAHM = Robotic anterior Heller myotomy with fundoplication
RLHM = Robotic laparoscopic lateral Heller myotomy without fundoplication

Table 53.12 Post-myotomy lower esophageal (LES) resting pressure

	POEM	RAHM	RLHM
Postop	16	7.1	12
p value	NS	0.001	0.006

Table 53.13 Post-myotomy subjective relief of dysphagia

	POEM	RAHM	RLHM
Postop	100%	91%	100%
P value			<0.006

Table 53.14 Rate of abnormal acid exposure on 24-hour PH testing

	POEM	RAHM	RLHM
Postop	39%	32%	8%
p value			0.005

1 month following myotomy

Video Legends

Video 53.1 Myotomy (https://youtu.be/Rka3rwcfxLM)

Video 53.2 Robotic thoracoscopic approach adapted to a lateral Heller myotomy without fundoplication to a robotic laparoscopic approach (https://youtu.be/WUEuHSioodY)

References

1. Willis T. Pharaceutice Rationalis: Siva Diatriba de Medicamentorum Operationbus in Humano Corpore. hagae-Comitis. London, 1674.
2. Hurst AF. Treatment of Achalasia of the Cardia (so called cardiospasm). Lancet. 1927;1:618.
3. Wood MG, Hagen JA. Primary esophgeal motor disorders. In: Pearson FG, et al., editors. Esophageal surgery. Philadelphia: Churchill Livingstone; 2002. p. 515–35.
4. Csendes A, Smok G, Bragetto I, et al. Gastrosophageal sphincter pressure and histological changes in distal esophagus in patients with achalasia of the esophagus. Dig Dis Sci. 1985;30:941.
5. Goldblum JR, Rice TW, Richter JE. Histopathologic features in esophagomyotomy specimens from patients with achalasia. Gastroenterology. 1996;111:648–54.
6. Holloway RH, Dodds WJ, Helm JF, et al. Integrity of cholinergic innervation in the lower esophageal sphincter in achalasia. Gastroenterology. 1986;90:924–9.
7. Robertson CS, Martin BAB, Atkinson M. Varicella-zoster virus DNA in the esophgeal myenteric plexus in cahlasia. Gut. 1993;34:299–302.
8. Jones DD, Mayberry JF, Rhodes J, et al. Preliminary report of an association between measles virus and achalasia. J Clin Pathol. 1983;36:655–7.
9. Wong RKH, Maydonovitch CL, Metz SJ, et al. Significant DQw1 association in Achalsia. Dig Dis Sci. 1989;34:349–52.
10. Fredens K, Tottrup A, Kristensen IB, et al. Severe destruction of esophageal nerves in a patient with achalais secondary to gastric cancer. A possible role of esophageal neurotoxic proteins. Dig Dis Sci. 1989;4:297–303.
11. Landes RT, Kuster GGR, Strum WB. Eosinophilic esophagitis in a patient with vigorous achalasia. Gastroenterology. 1978;74:1298–301.
12. Tottrup A, Fredens K, Fuch-Jensen P, et al. Eosinophil infiltration in primary esophageal achalasia: a possible pathogenic role. Dig Dis Sci. 1989;34:1894–9.
13. Sandler RS, Nyren O, Ekborn A, et al. The risk of esophageal cancer in patients with achalasia: a population based study. JAMA. 1995;274:1359–62.
14. Streitz JM, Ellis HF, Gibb PS, et al. Achalasia and squamous cell carcinoma of the esophagus: analysis of 241 patients. Ann Thorac Surg. 1995;59:1604–9.
15. Bortolotti M, Labo G. Clinical and manometric effects of nefedipine in patients with esophageal achalsia. Gastroenterology. 1981;80:39–44.
16. Traube M, Hongo M, Magyar L. Effects of nifedipine in achalsia and in patients with high-amplitude peristaltic esophageal contractions. JAMA. 1984;252:1733.
17. Short TP, Thomas E. An overview of the role of calcium agonists in the treatment of achalasia and diffuse esophageal spasm. Drugs. 1992;43:177–84.
18. DiMarino AJ, Cohen S. Effect of an oral beta 2-adrenergic agonist on lower esophageal sphincter pressure in normals and patients with achalasia. Dig Dis Sci. 1996;27:1063–111.
19. Guilliere C, Ducrotte P, Zerbib F. Achalasia: outcome of patients treated with intrasphincteric injection of botulinum toxin. Gut. 1997;41:87–92.
20. Eckardt VF, Aignherr C, Berhard G. Predictors of outcome in patients with achalsia treated by pneumatic dilation. Gastroenterology. 1992;103:1732–8.
21. Ferguson MK. Achalasia: current evaluation and therapy. Ann Thorac Surg. 1991;52:336–42.
22. Marwedel G. Die aufklappung des rippenbogens zur erleichterung operativer eingriffe in hypochondrum und im zwerchfellkuppelraum. Zentralbl Chir. 1903;30:938.
23. Wendel W. Zur Chirurgie des Osophagus. Arch Klin Chir. 1910;93:311.
24. Heller E. Extramukose Cardioplastik beim chronischen cardiospasmus mit dilatation des osophagus. Mitt Grenzgeb Med Chir. 1914;27:141.
25. Zaaijer HJ. Cardiospasm in the aged. Ann Surg. 1923;77:615.
26. Dor J, Humbert P, Dor V, et al. L'intetet de la technique de Nissen modifee dans la prevention de reflux apres cardiomyotomie extramuqueuse de Heller. Mem Acad Chir (Paris). 1962;88:877.
27. Toupet A. Technique l'oesophago-gastroplastic avec phrenogastropexie applique dans la cure radicale des hernia hiatales et comme complement de l'operation d'Heller dans les cardiospsmes. Mem Acad Chir. 1963;89:394.
28. Ellis FH Jr, Crozier RE, Watkins E. The operation foe esophageal achalasia: results of esophagomyotomy without an antireflux operation. J Thorac Cardiovasc Surg. 1984;88:344–51.
29. Okike N, Payne SW, Neufeld DM. Esophagomyotomy versus forceful dilation for achalsia of the esophagus: results in 899 patients. Ann Thorac Surg. 1979;28:119–25.
30. Pai GP, Ellison RG, Rubin JW. Two decades of experience with modified Heller's myotomy for Achalasia. Ann Thorac Surg. 1984;38:201–6.
31. Donahue PE, Samelson S, Schlesinger PK, et al. Achalasia of the esophagus: treatment controversies and the metod of choice. Ann Surg. 1986;203:505–11.
32. Little AG, Soriano A, Ferguson MK. Surgical treatment of Achalasia. Results with esophagomyotomy and Belsey repair. Ann Thorac Surg. 1988;45:489–94.
33. Malthaner RA, Todd TR, Miller L. Long term results in surgically managed esophageal achalasia. Ann Thorac Surg. 1994;58:1343–7.
34. Topart P, Deschamps C, Taillefer R, et al. Long-term effect of total fundoplication on the myotomized esophagus. Ann Thorac Surg. 1992;54:1046–52.
35. Shimi S, Nathanson LK, Cushieri A. Laparoscopic cardiomyotomy for Achalasia. J R Coll Surg Edinb. 1991;36:152.
36. Pelligrini CA, Leichter R, Patti M. Thoracoscopic esophageal myotomy in the treatment of Achalasia. Ann Thorac Surg. 1993;56:680–2.
37. Patti MG, Pelligrini CA, Arcerito M. Caomparison of medical and minimally invasive surgical therapy for primary esophageal motility disorders. Arch Surg. 1995;130:609–16.
38. Patti MG, Pelligrini CA, Horgan S. Minimally invasive surgery for achalasia. Ann Surg. 1999;230:587.
39. Finley RJ, Clifton JC, Stewart KC, et al. Laparoscopic Heller myotomy for achalasia: a clinical and scintigraphic swallowing followup. Can J Surg. 1999;42(Suppl):25.
40. Stewart K, Finley RJ, Clifton JC, et al. Thoracoscopic versus laparoscopic modified Heller myotomy for achalasia: efficacy and safety in 87 patients. J Am Coll Surg. 1999;189:164–70.
41. Gharagozloo F, Margolis M, Schwartz A, Tempesta BJ, Strother E. Robot-assisted thoracoscopic Heller myotomy without an antireflux procedure for achalasia. Chest. 1997;132(4):660A.
42. Youssef Y, Richards WO, Sharp K, Holzman M, Sekhar N, Kaiser J, Torquati A. Relief of dysphagia after laparoscopic Heller myotomy improves long-term quality of life. J Gastrointest Surg. 2007;11:309–13.