

# Surgery for Gastroesophageal Reflux Disease

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## Glossary

**Fundoplication** Total or partial surgical plication of the gastric fundus around the distal esophagus obtained by division of short gastric vessels and tension-free wrapping to increase competency of the lower esophageal sphincter.

**Crural repair** Restriction of an enlarged esophageal hiatal orifice obtained by application of interrupted, non-absorbable stitches and occasionally by a mesh to prevent mediastinal migration of the fundoplication.

**Magnetic sphincter augmentation** Biomedical device formed by a collar of magnetic beads that is placed around the distal esophagus to prevent distension and opening of the lower esophageal sphincter secondary to increased intragastric pressure.

## Nomenclature

**GERD** Gastro-Esophageal Reflux Disease

**LES** Lower Esophageal Sphincter

**MSA** Magnetic Sphincter Augmentation

**PPI** Proton-Pump Inhibitors

## Historical Background

Gastroesophageal reflux disease (GERD) was not recognized as a significant clinical problem until 1950 when Philip Allison first attributed to gastroesophageal reflux the spectrum of symptoms previously thought to be related to the presence of a hiatal hernia. At that time, in the absence of effective medical therapy, it seemed reasonable to repair the hernia through the chest by reducing the stomach in the abdominal cavity and by approximating the crura. The true modern antireflux surgery was born by serendipity through the intuition of Rudolf Nissen and his experience gained with resection of the distal esophagus for cancer. The key observation was that plicating the gastric fundus around the esophagogastric anastomosis in an effort to prevent leakage was highly effective also in preventing peptic esophagitis of the esophageal remnant. This proof-of-concept led to manage primary reflux esophagitis by a 360° fundoplication around the distal esophagus, and the first trans-abdominal fundoplication was performed in Basel, Switzerland, in 1955. Almost simultaneously, at Mayo Clinic in Rochester, Minnesota, Code and co-workers established the presence of a high-pressure zone in the distal esophagus, the lower esophageal sphincter (LES), that was soon recognized as the major barrier against gastroesophageal reflux in man. GERD was then accepted as a disease independent of hiatal hernia, and the Nissen procedure combined with crural repair was quickly adopted worldwide as the surgical procedure of choice. Later on, a partial 270° posterior fundoplication was described by André Toupet in France. With the advent of laparoscopy, antireflux surgery has evolved into a minimally invasive procedure with short hospital stay and rapid recovery, making it a more attractive therapeutic option for the patients. However, concurrent introduction of proton pump inhibitors (PPI) in the 1990s led to a downward trend in the utilization of surgical fundoplication. Recent statistics have demonstrated a rise in the utilization of antireflux surgery from 2004 until 2009 but a steady decline since then. In 2013, the rate of surgical fundoplications performed for GERD was 0.05% (Khan et al., 2016).

## Rationale and Indications

Despite the substantial benefit of medical therapy on typical GERD symptoms, about 40% of patients remain partially responders or non-responders to PPI therapy. There are also increasing safety concerns regarding the long-term use of PPI and diffuse awareness that a mechanical defect of both the LES and the crural diaphragm require surgical repair to prevent disease progression. GERD remains a chronic debilitating disease, and refractory symptoms have a significant and negative impact on both health-related quality of life and healthcare resource utilization (Toghanian et al., 2011). In addition, intestinalized metaplastic cardiac mucosa at the esophago-gastric junction may progress to Barrett's adenocarcinoma (Chandrasoma et al., 2011). Surprisingly, antireflux surgery has not been fully embraced by the medical community or the public. Early surgical restoration of the antireflux barrier, including reconstruction/augmentation of the lower esophageal sphincter and crural repair, has the potential to stop the progression of the disease in patients with a mechanically defective sphincter, presence of hiatus hernia, and refractory volume regurgitation despite high-dose PPI therapy. The ideal surgical technique should improve function and provide relief of symptoms and complications of

gastroesophageal reflux disease while permitting physiological swallowing and avoiding side-effects such as bloating and inability to belch and vomit. Antireflux surgery prevents gastroesophageal reflux by restoring the intra-abdominal position of the esophago-gastric junction, by remodeling the hiatal orifice, and by limiting distension of the LES (Pandolfino et al., 2005). In well selected patients, antireflux surgery can reduce GERD-related symptoms, complications, and esophageal acid exposure. Laparoscopic fundoplication may also be indicated in patients with idiopathic pulmonary fibrosis, but well powered controlled studies are needed. Finally, large hiatal hernia is a frequent indication to laparoscopic antireflux repair because of the concomitant obstructive symptoms, exertional dyspnea, aspiration pneumonia, recurrent anemia, and the increased risk of intrathoracic gastric volvulus that may be associated to serious morbidity and mortality.

### Preoperative Assessment

All patients who are potential candidates for an antireflux procedure should undergo a thorough preoperative assessment to determine the GERD phenotype. An appropriate work-up should include the following: symptomatic evaluation, esophagogram, esophageal manometry, and ambulatory pH monitoring. In selected patients, gastric emptying scintigraphy should be obtained. Both typical (heartburn, regurgitation, dysphagia) and atypical (chest pain, chronic cough, asthma, pharyngodinia) symptoms should be carefully investigated and graded regarding their frequency and intensity, but it must be kept in mind that clinical history alone is unreliable. A study including a multivariate analysis of factors predicting outcome after laparoscopic Nissen fundoplication showed that the main predictors of success were the presence of typical symptoms, an abnormal 24-h pH score, and a good clinical response to acid suppression therapy with proton-pump inhibitors (Campos et al., 1999). An upper gastrointestinal series is useful to diagnose and characterize a coexisting hiatus hernia, to assess esophageal length and caliber, and to identify concomitant motility disorders, diverticula, and strictures. Endoscopy is typically the first test performed to confirm a symptom-based diagnosis of GERD and to exclude gastric and duodenal disorders. Endoscopic biopsies are useful to detect the presence of Barrett's esophagus. Pitfalls of the endoscopic approach are that esophageal mucosal damage is absent in about two-third of the patients and that interobserver variations are common with low-grade esophagitis. Ambulatory esophageal pH monitoring is the most reliable test for the diagnosis of GERD because it allows to determine the degree of esophageal acid exposure, the circadian pattern of reflux, and the temporal correlation between symptoms and reflux episodes. It provides also baseline data that are useful after surgery in case of persistent or recurrent symptoms. High-resolution esophageal manometry is the gold-standard test to assess esophageal motility and to exclude major peristaltic disorders that may indicate the need to tailor the fundoplication (Gyawali et al., 2018). A recent diagnostic innovation is the endoluminal functional lumen imaging probe (EndoFLIP). This technology is based on high resolution impedance planimetry during volume-controlled distension to measure the luminal cross-sectional area and the distensibility of the esophago-gastric junction. Testing with endoFLIP may be useful also intraoperatively to tailor the degree of crura repair and fundoplication (Ilcyszyn and Botha, 2014).

### Techniques of Laparoscopic Antireflux Surgery

The most commonly performed operations for GERD are the Nissen total fundoplication, the Toupet partial fundoplication, and the magnetic sphincter augmentation (MSA) procedure. Laparoscopic fundoplication, first reported in 1991, has been rapidly adopted worldwide and established as the procedure of choice for GERD. More recently, the magnetic sphincter augmentation (MSA) device has emerged as a feasible alternative to fundoplication (Bonavina et al., 2008). The procedure has been approved by FDA in 2012. The MSA device (Linx™ Reflux Management System, Torax Medical, Minneapolis, USA) consists of a series of biologically compatible titanium beads with magnetic cores sealed inside. The beads, which are interlinked with independent titanium wires, can move independent of each other and form an expandable, ring-like dynamic implant that does not compress the esophageal wall. After implantation, the MSA is encapsulated in a fibrous tissue sheath outside the esophageal wall. The device, while augmenting the LES, allows for expansion to accommodate a swallowed bolus or the escape of peak gastric pressure associated with belching or vomiting. The device has recently received FDA approval for magnetic resonance imaging up to 1.5 Tesla.

All laparoscopic antireflux operations are performed under general anesthesia with the patient placed in a reverse Trendelenburg position. Five trocars and an angled (30°) scope are necessary to provide adequate access to the abdominal cavity and optimal visualization of the esophagogastric junction. Trocar placement is critical for adequate surgical exposure; when the port are placed too low, the instruments may not reach the esophagogastric junction and the area of the short gastric vessels, especially in obese patient. Cautery and ultrasonic scissors are generally used during the procedures. In selected patients, laparoscopic fundoplication can be combined with reinforcement of the crural repair with mesh or with a lengthening (Collis) procedure.

The key technical steps for performing a total or partial fundoplication are depicted in Table 1. Dissection of the esophagogastric junction must be careful to avoid damage to the esophageal wall and vagal nerves. The lesser omentum is opened above and below the hepatic branch of the anterior vagus nerve. An accessory left hepatic artery running along the nerve is often encountered and should be spared. Division of the peritoneal reflection along the crura is continued anterior to the esophagus and allows safe and bloodless creation of a retroesophageal window. A penrose drain is then passed around the esophagus and used for traction throughout the procedure. Dissection of the lower mediastinum is routinely performed to obtain an intra-abdominal, tension-free esophageal segment of about 3 cm. Posterior cruroplasty is then accomplished using a few non-absorbable stitches. A 42 French

**Table 1** Key technical steps for performing a total or posterior partial fundoplication.

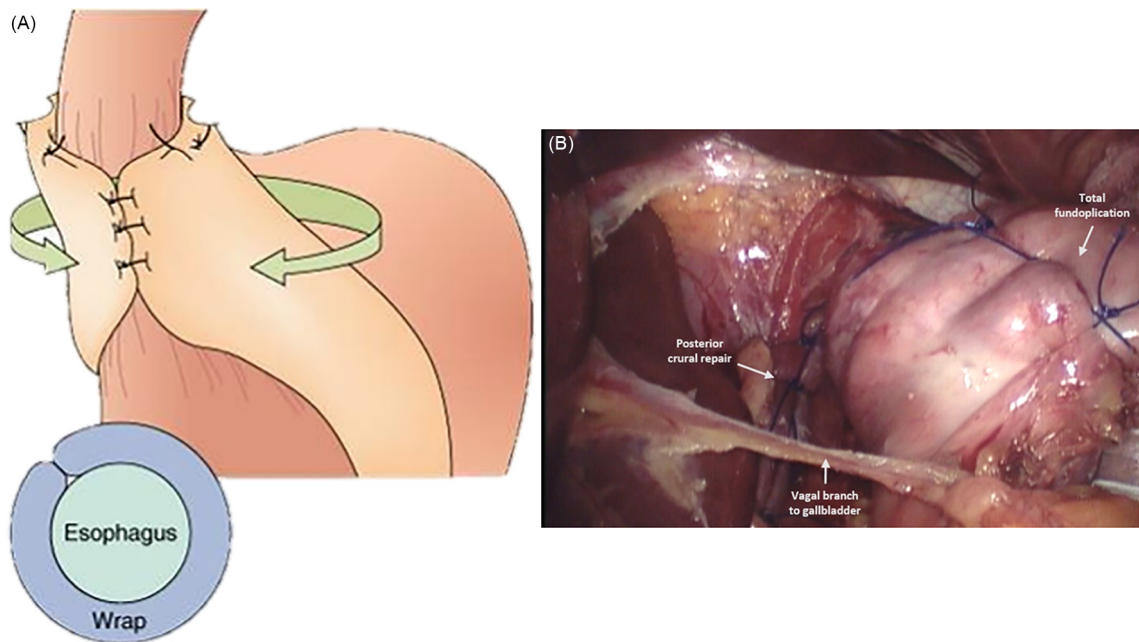
1. Opening the gastro-hepatic ligament and preservation of the vagal branch to the gallbladder
2. Incision of peritoneum and phreno-esophageal ligament overlying the esophagogastric junction
3. Identification of right and left crus of diaphragm and preservation of their peritoneal layer
4. Creation of a retroesophageal window and placement of a penrose drain around distal esophagus for traction
5. Division of short gastric vessels
6. Crura approximation with interrupted non-absorbable stitches
7. Wrapping the tension-free gastric fundus around the distal esophagus
8. Suture the wrap ends to each other (Nissen) or to both sides of the esophagus (Toupet)

esophageal bougie is generally used to calibrate the cruroplasty and the fundoplication. Division of short gastric vessels allows to mobilize the gastric fundus and provides a tension-free fundoplication to avoid tightness and/or twisting of the esophagus. After removal of the fat pad at the angle of His, the gastric fundus is gently pulled toward the right side of the esophagus. Geometry of the fundoplication is of paramount importance: the wrap should be symmetric and should include both the posterior and anterior gastric fundus (Fig. 1). Interrupted non-absorbable stitches are used to secure the two ends of the wrap to each other (Nissen, 360°) or to both sides of the esophagus (Toupet, 270°). The difference between the two techniques is that the Toupet fundoplication leaves uncovered 90° of the anterior esophagus; in addition, coronal stitches fix the top of the wrap to the diaphragm, one on the right and the other on the left side (Fig. 2).

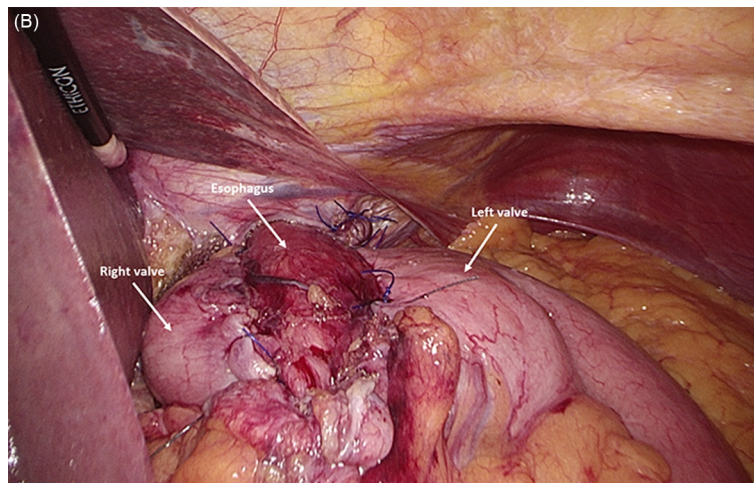
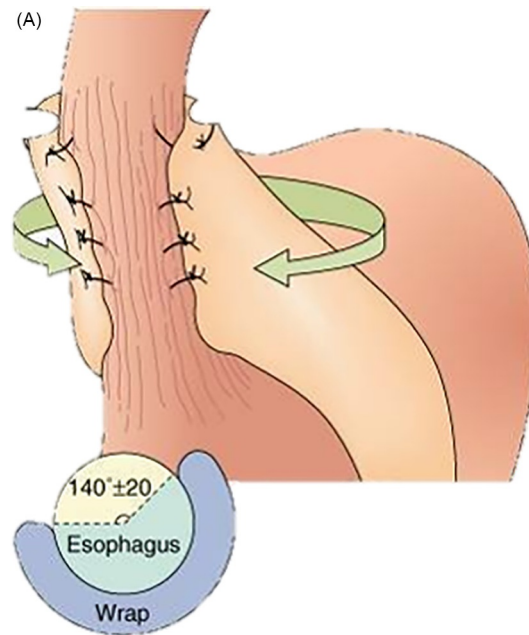
The key technical steps for performing a MSA implant are depicted in Table 2. In patients with normal anatomy of the esophago-gastric junction or small reducible hiatus hernia, dissection should be minimal, the phreno-esophageal ligament should be preserved, and the lower mediastinum is not violated. The peritoneum is divided on the anterior surface of the gastroesophageal junction below the insertion of the inferior leaf of the phreno-esophageal ligament and above the hepatic branch of the anterior vagus. The posterior fundic wall is separated from the left crus without dividing any short gastric vessel. The gastro-hepatic ligament is opened above and below the hepatic branch to the vagus in order to dissect the retro-esophageal window. Once the posterior vagus nerve is identified, a tunnel is created between the vagus and the esophageal wall, and the esophagus is encircled with a soft silicon drain. At this point of the procedure, the circumference of the esophagus is measured to determine the appropriate size of the MSA device to be implanted. In patients with evidence of hiatus hernia, a full hiatus repair is required before placement of the MSA device (Fig. 3).

### Clinical Outcomes of Laparoscopic Antireflux Surgery

Laparoscopic fundoplication is a safe, effective, and durable antireflux procedure when performed in specialized centers (Richter et al., 2018). A multicenter European trial comparing medical therapy with fundoplication performed in selected centers by expert



**Fig. 1** (A) Schematic drawing of the total (360°) Nissen fundoplication. (B) Intraoperative image of the completed crural repair and Nissen fundoplication.

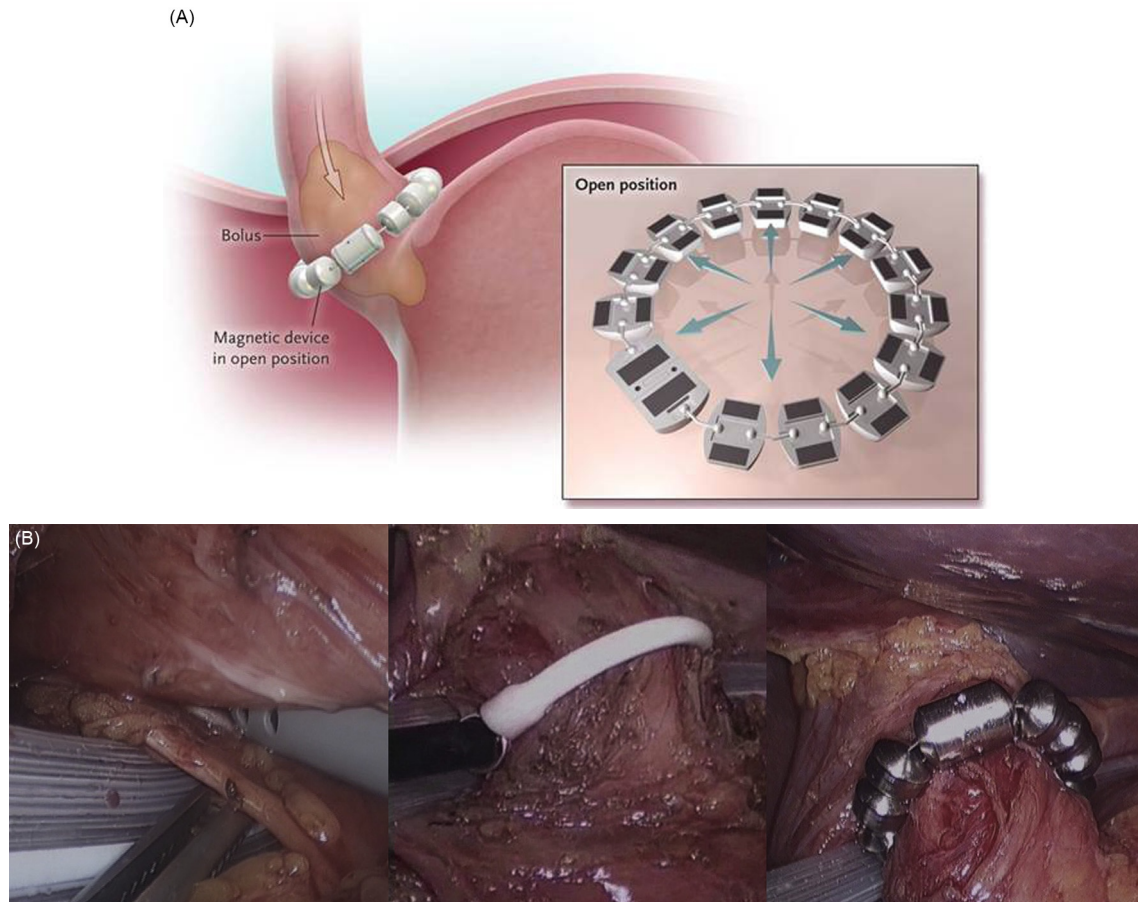


**Fig. 2** (A) Schematic drawing of the partial (270°) Toupet fundoplication. (B) Intraoperative image of the completed crural repair and Toupet fundoplication.

**Table 2** Key technical steps for performing the magnetic sphincter augmentation procedure.

1. Opening the gastro-hepatic ligament and preservation of the vagal branch to the gallbladder
2. Incision of peritoneum and phrenoesophageal ligament overlying the esophagogastric junction
3. Identification of right and left crus of diaphragm
4. Creation of a retroesophageal window and placement of a penrose drain around the distal esophagus
5. Identify the posterior vagus nerve and create a tunnel between the nerve and the posterior esophageal wall
6. Limit dissection of the gastrophrenic ligament and keep short gastric vessels intact!
7. Phrenoesophageal ligament preservation and no crura repair is an option if no hiatus hernia is present and intra-abdominal esophageal length is adequate
8. Minimal hiatus dissection or full hiatus dissection with crura repair are alternative options
9. Measure the esophageal circumference to decide the proper size of the device
10. Insert the device and lock the anterior clasps

surgeons showed that 92% of medical patients and 85% of surgical patients remained in remission at 5 years of follow-up (Galmiche et al., 2011). However, despite a remarkably low morbidity and mortality rates, the operation is still underused due to the perceived risk of long-term side effects and fear of failure, which impacts referral patterns. Also, wide variability in clinical outcomes related to inter-individual surgical expertise and/or not validated technical modifications, have restricted the adoption of this procedure mainly to patients with long-lasting severe disease and large hiatal hernias (Richter and Dempsey, 2008). In an effort



**Fig. 3** (A) Schematic drawing of the Magnetic Sphincter Augmentation device. (B) Intraoperative image showing the tunnel created between the posterior vagus nerve and the esophageal wall (left); sizing of the esophageal circumference with a dedicated instrument (center); device in situ at the end of the procedure.

to reduce the potential side-effects of the Nissen operation, the 270° Toupet fundoplication has emerged as a primary antireflux procedure in several institutions. Two systematic reviews and meta-analyses showed that the Toupet fundoplication decreases dysphagia, dilatation and reoperation rates, and prevalence of gas-bloating with similar reflux control compared to Nissen fundoplication (Broeders et al., 2010). Observational cohort studies have suggested but not definitely proven that mesh augmentation of the hiatus and esophageal lengthening procedures are useful adjuncts to standard crural repair and fundoplication. Prevention of nausea and vomiting in the immediate postoperative period is critical to avoid early hernia recurrence. Dysphagia is the most common postoperative side-effect of a fundoplication, but this problem usually resolves after 6–8 weeks of soft diet. A wrap that is too tight or too long, a lateral torsion with corkscrew effect (tension from intact short gastric vessels or small fundus), or a wrap made with the body rather than the fundus of the stomach, or a recurrent hiatal hernia are common causes of persistent dysphagia that may require revisional surgery.

Patients implanted with the MSA device are typically discharged the same day or on the first post-operative day after a chest film has been performed to check the correct placement of the device. Routine take-home recommendations for the patient include to chew well, take small volume meals, and discontinue the use of PPI. A recent randomized crossover trial has shown that MSA is significantly superior to PPI in the control of moderate-to-severe regurgitation and in improving quality of life (Bell et al., 2019). The side-effect profile of the MSA procedure is quite similar to the Toupet fundoplication and more favorable compared to the Nissen. Device erosions have been encountered rarely and have never been associated with mortality. Compared to fundoplication, the MSA procedure is easily reversible, and the device can safely be explanted laparoscopically. A multicenter study including the first 1000 implants showed 1.3% hospital readmission rate, 5.6% need of postoperative endoscopic dilations, and 3.4% reoperation rate (Lipham et al., 2015).

### Fundoplication Versus Magnetic Sphincter Augmentation

Studies comparing the outcomes of laparoscopic fundoplication and MSA are observational and with a limited follow-up. In a meta-analysis of seven studies, both antireflux procedures have been shown safe and effective up to the 1-year follow-up. The rate of PPI cessation, the rate of dysphagia requiring endoscopic dilatation, and the disease-related quality of life were similar in the two patient groups. MSA was associated with less gas-bloat symptoms and an increased ability to vomit and belch (Aiolfi et al., 2018). In

a propensity-matched analysis including 114 MSA and 114 Nissen fundoplication patients, improvement in GERD-HRQL scores was significant in both groups compared to baseline; however, more MSA patients (93% vs 83%) reported that they would have undergone the procedure again (Warren et al., 2016). Finally, a propensity-matched study including 135 MSA and 103 Toupet fundoplication patients with a mean follow-up of 44 and 42 months, respectively, reported significant improvement in quality of life scores, comparable rates of PPI discontinuation, and comparable side effects and reoperation rates in both patient groups (Asti et al., 2016).

The MSA procedure offers the potential to replace either chronic PPI therapy or fundoplication in patients presenting with normal anatomy of the gastroesophageal junction or small hiatus hernia. The procedure is effective in decreasing esophageal acid exposure, typical reflux symptoms, and drug dependence, and significantly improves health-related quality of life. Despite the lack of comparative randomized clinical trials, the MSA procedure has gained a lot of interest among surgeons and gastroenterologists because of the minimal invasiveness, the standardization, and the easy reversibility. MSA has also been deemed moderately appropriate for patients with elevated esophageal acid exposure without a large hiatal hernia (Yadlapati et al., 2018). However, limitations of the MSA include the contraindication to MRI scanning >1.5 Tesla and the potential long-term consequences of a permanent foreign body implant.

## Failures of Antireflux Surgery

Failures of the index antireflux operation may be related to inappropriate patient selection, wrong procedure choice, technical errors, or improper perioperative management. In most circumstances, these failures can be prevented by strict adherence to established diagnostic criteria, avoidance of extemporary technical modifications not dictated by scientific evidence, and adoption of a standardized protocol to prevent postoperative nausea and vomiting. Eventually, revisional antireflux surgery is required in 3%–9% of patients (Symons et al., 2011; Markar et al., 2018). Laparoscopic revisional surgery is technically demanding, especially in patients with morbid obesity, previous laparotomic repair, and in the presence of a non-absorbable mesh. Revisional options include a redo fundoplication (partial or complete), the addition of a Collis gastroplasty to a re-fundoplication, a Roux-en-Y gastrojejunostomy, and eventually a gastrectomy/esophagectomy. Complete takedown of the old repair is a mandatory step before considering any remedial surgical option, except in patients with hernia of an intact fundoplication in whom reduction and crural repair alone should be considered. A stapled wedge resection of the gastric fundus provides a safe esophageal lengthening procedure in patients with a truly short esophagus. In patients with recurrent hiatal hernia it is also important to assess the quality of the crura and to consider relaxing incisions and/or mesh reinforcement. Impairment of esophageal motility as assessed by high-resolution manometry may indicate the opportunity to perform a partial 270° Toupet rather than a 360° Nissen fundoplication, or an esophageal myotomy and a partial anterior fundoplication in patients with previously misdiagnosed achalasia. Laparoscopic Roux-en-Y gastric bypass is a surgical option that should be considered in morbid obese patients. Pyloroplasty or even a total gastrectomy may also be considered in patients with severe gastric outlet obstruction or gastroparesis secondary to inadvertent vagotomy at the time of the index operation. Esophageal resection should be the last resort in patients with multiple previous repairs, extensive fibrosis and stricture refractory to multiple endoscopic dilatations, and evidence of dysplasia on Barrett's esophagus. Explant of the MSA device and concomitant fundoplication may be necessary for persistent symptoms, device erosion, or need to perform >1.5 Tesla magnetic resonance imaging (Warren et al., 2016). Revisional antireflux surgery requires adherence to established technical principles and should be performed in high-volume centers. Today, more redo operations are performed laparoscopically with reported low conversion rates and morbidity.

## Conclusion

GERD is complex and heterogeneous disease that has the potential to progress to Barrett's esophagus and adenocarcinoma. Overall management is still imprecise and requires a patient-centered and multidisciplinary approach. Systematic assessment of symptoms, anatomy, motility, reflux burden, and histology are mandatory to identify patients with evidence of progressive disease. Laparoscopic antireflux surgery is a cornerstone in the therapy of GERD and hiatal hernia. It should be performed in referral centers that provide comprehensive diagnosis and a spectrum of surgical techniques tailored to the individual patient.

**See Also:** Barrett's Esophagus. Esophageal Cancer Surveillance and Screening: Barrett's Esophagus and GERD. Gallbladder; Pediatric. Gastroesophageal Reflux Disease (GERD). Surgery for Benign Esophageal Disorders

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