Medical Devices: Evidence and Research

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REVIEW

Spotlight on the Linx™ Reflux Management System for the treatment of gastroesophageal reflux disease: evidence and research

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Background: The initial approach to gastroesophageal reflux disease (GERD) management typically involves lifestyle modification and medical therapy utilizing acid reducing agents such as histamine blockers and proton pump inhibitors. In severe cases refractory to such treatments, surgical therapy may be indicated. The gold standard for surgical treatment of GERD is the laparoscopic Nissen fundoplication. In recent years, a new technique known as magnetic sphincter augmentation (MSA) has been developed using the Linx™ Reflux Management System. This is an implantable ring of magnetic beads that is placed around the esophagus at the gastroesophageal junction to restore lower esophageal integrity. The aim of this review is to discuss the current literature regarding indications, surgical technique, efficacy, and complications of MSA using the Linx device.

Methods: A standardized literature search was performed yielding 367 abstracts. After elimination due to duplicates between databases and irrelevance, 96 articles remained. The information found to be significant and non-redundant was included in this review.

Conclusion: After several years of clinical application, the Linx device has been shown to not only be effective for the management of GERD but also be as effective as fundoplication. With respect to safety, the most common complication of MSA is dysphagia. This often resolved without intervention, but esophageal dilation or device explanation are occasionally necessary. Not fully appreciated in earlier reviews, erosion of the device into the esophagus appears to be the most significant complication of the device after extended follow-up. While very rare, the potentially severe consequences of this phenomenon suggest that the device should be used with some restraint and that patients should be made aware of this potential morbidity. Fortunately, in the few cases of device erosion described in the literature reviewed, the Linx device was easily and safely removed.

Keywords: Linx, magnetic sphincter augmentation, GERD, Nissen fundoplication

Introduction

Gastroesophageal reflux disease (GERD) is a pathological process in which the reflux of gastric contents into the esophagus produces aggravating symptoms such as burning epigastric pain, regurgitation, and dysphagia. Extra-esophageal symptoms such as cough, laryngitis, and wheezing also commonly occur. If left untreated, GERD may result in long-term complications including esophageal stricture, ulceration, Barrett's esophagus, and esophageal adenocarcinoma.[1] Given the intrusive nature of these symptoms, GERD has been shown to have negative effects on patients' overall quality of life (QoL). The net social impact of this is likely significant, as the prevalence of GERD in Europe and North America has been found to be between 10% and 40%.[1,2]

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Medical management of GERD involves the use of H2-antagonists and proton pump inhibitors (PPIs). PPIs act to increase intragastric pH by direct inhibition of the proton pump H^+/K^+ ATPase on parietal cells. H2 blockers also act on parietal cells, but they block histamine from triggering an acid secreting pathway. This, in turn, allows gastric and esophageal mucosa to heal and provides symptom relief.[2]

Unfortunately, complete treatment response by medical therapy cannot be achieved for many patients, and it is estimated that up to 40% of patients with GERD fail to respond to aggressive acid suppression therapy.[2–6] This has been associated with decreased lower esophageal sphincter (LES) tone, but may also be found in patients with GERD for whom this is not the case. Some patients with normal LES on positional and fasting motility studies have been found to instead have transient LES relaxations (TLESRs). As defined by Dodds et al in 1982, TLESRs are transient openings of the LES when challenged by gastric distention or dilation.[7] Since this discovery, it has been demonstrated that a variable response to PPI therapy may be related to the patient's etiology of GERD, with patients suffering from TLESR having a relatively poor response to PPI therapy. [7]

Regardless of GERD etiology, surgical therapy is considered for patients with persistent symptoms despite optimal PPI therapy. First described by Rudolf Nissen in 1956,[8] the fundoplication has been the most widely implemented surgical technique for the management of GERD for decades. The procedure involves hiatal dissection with full mobilization of the esophagus and fundus, re-approximation of the diaphragmatic crura, and a 360° wrap of the fundus around the distal esophagus.[9] In 1991, Dallemagne performed the Nissen fundoplication via laparoscopy (LNF). This approach has been shown to have a comparable safety profile, improved patient satisfaction, and shorter hospital stays compared to the open approach.[10] Multiple studies have shown that symptomatic relief is achieved in up to 90% of patients with benefits persisting at least 10 years for most patients.[11,12] As a result of these findings, LNF has become the gold standard for surgical management of GERD.

While effective in reducing the symptoms of GERD, the Nissen fundoplication requires extensive anatomical manipulation, is technically demanding, and is associated with side effects including difficulty swallowing, bloating, early satiety, and inability to vomit or belch.[13,14] Anatomic failure of the fundoplication with recurrent GERD has been shown to occur in 2–17% of cases.[15] As a result, it has been found that as few as 1% of GERD patients will opt for this surgery.[16] This has created a "treatment gap" containing patients with symptoms refractory to medical management that are not severe enough to push them toward fundoplication.[17] In an attempt to fill this gap, efforts have been made to develop other surgical methods to manage GERD.

The development of the Linx™ Reflux Management System (Torax Medical, St. Paul, MN, USA) began in 2002. It is designed to provide a permanent solution to GERD by augmenting the LES with a standardized, reproducible, and reversible laparoscopic procedure that does not alter gastric anatomy.[1] In 2008, Bonavina et al published an early feasibility study demonstrating the safety and efficacy of the Linx device.[18] In 2010, a long-term feasibility study reviewing outcomes at 1 and 2 years was published with similar results.[19] During the execution of a larger pivotal trial,[20] the US FDA subsequently granted premarket approval in 2012.[21]

Purpose

The objective of this review is to discuss current literature regarding the indications, efficacy, and complications of magnetic sphincter augmentation (MSA), as well as the comparative outcomes of MSA versus other surgical therapies for GERD.

Methods

A standardized literature search was performed in two databases: the PubMed interface of the Medline database and the ScienceDirect database. The following search terms were used in both databases: "Linx" or "Magnetic Sphincter Augmentation." In both databases, the search was limited to English language journal articles published between 1980 to January 2018. The search was further limited in the ScienceDirect database to articles under the category of "Medicine and Dentistry." Three hundred sixty-seven abstracts were ultimately identified. After elimination due to duplicates between databases and irrelevance, 96 articles remained. These were reviewed in detail by the authors of this paper. The information found to be significant and non-redundant was included in this review.

Indication for use

The Linx Reflux Management System was designed for the treatment of GERD. As per the global evidence-based Montreal definition, GERD is a condition that develops when the reflux of stomach contents causes troublesome symptoms and/or complications.[22,23] When approved for use in 2012, the FDA provided instructions for use of the Linx system stating that "the Linx system is indicated for patients diagnosed with GERD as defined by abnormal pH testing,

and who continue to have chronic GERD symptoms despite medical therapy for the treatment of reflux."[9] Specifically included in early indications for this procedure were GERD in the setting of normal esophageal motility, a BMI <35 kg/m^2, no previous foregut surgery, and no or a small (<3 cm) hiatal hernia.[9,24] Objectively, suitable patients could be identified as those with increased esophageal acid exposure on 24-hour pH monitoring who have persistent reflux symptoms despite maximal PPI therapy.[24]

Following the establishment of early guidelines for its application, the Linx device has been successfully used in a variety of other clinical settings.[24–26] The Linx procedure has since been suggested for patients who prefer surgery over long-term use of anti-reflux medications,[27] those with extra-esophageal manifestations, such as chronic cough or asthma, and those with GERD following gastric surgery.[25]

In recent years, there have been a growing number of publications describing potential adverse effects of chronic PPI treatment. These include increased risk of hip and spine fractures, community-acquired pneumonia, *Clostridium difficile* colitis, vitamin and mineral deficiencies, gastric fundic gland polyps, rebound acid secretion, and inhibition of the antiplatelet effects of clopidogrel.[28] Due to these potential long-term complications, as well as common side effects, such as headache, abdominal pain, diarrhea, and nausea, some patients may opt for surgical management in order to avoid long-term PPI use.

Due to the locally irritating effect of refluxed gastric contents, GERD has been identified as a cause of chronic cough in some patients. For those with an established correlation between episodes of reflux and cough, surgical treatment with implantation of the Linx device has been suggested as an appropriate therapy for the management of chronic cough refractory to medical managment.[29]

As with chronic cough, GERD has also been identified as potential cause of asthma. In 5–10% of cases of asthma, the symptoms of this disease are refractory to traditional therapy with bronchodilators, anticholinergics, and steroids. In a small study published in 2016, the Linx device was found to be useful in this unique clinical setting. The patient described in that publication had uncontrolled asthma and GERD despite maximal medical management for both of these conditions. After implantation of the Linx device, her asthma was well controlled such that her steroid therapy could even be discontinued.[26]

While there is controversy over the association between sleeve gastrectomy and GERD, several reviews have shown an increase in GERD symptoms after this procedure. If GERD refractory to medical management does occur after sleeve gastrectomy, the traditional management is conversion to a Roux-en-Y gastric bypass as the gastric fundus can no longer be used to perform a fundoplication.[25,30] MSA, an alternative and potentially safer procedure, has been found in some studies to be effective for GERD management in this specific postoperative setting.[25,31] It has also been suggested that perioperative insertion of the Linx device during sleeve gastrectomy may be a reasonable prophylactic measure.[32] Prevention of GERD in this patient population is especially important, as the disconnection of the stomach from the gastroepiploic arteries eliminates the possibility of performing a gastric pull-up procedure in the future. This limits the options for reconstruction if the patient were to develop esophageal pathology requiring resection as a result of their GERD.

As mentioned earlier, Roux-en-Y itself has been used for the management of GERD. However, symptoms of reflux occasionally persist after that procedure. While various techniques such as pouch revisions have been described, the use of the Linx device has also been suggested and found to be effective in this surgical setting.[33]

With respect to contraindications, it has been suggested that Linx implantation is not appropriate for patients with a history of dysphagia, previous upper abdominal surgery, previous endoluminal anti-reflux procedures, large sliding hiatal hernia, or those with Barrett's esophagus.[17] Furthermore, the 2017 SAGES report states the Linx system is not intended for use in patients with allergies to metals, such as iron, nickel, titanium, or stainless steel, and those who have defibrillators, pacemakers, or metallic implants in the abdomen.[9]

Technique and postoperative care

The Linx device is composed of a string of 10 or more beads containing a sealed core of magnetic neodymium iron boride, which are interlinked with independent titanium wires.[34] These magnets produce a very precise force of inward attraction (~40 g at full contraction, 7 g at full expansion), which augments the closure of the lower esophageal sphincter.[1,20] The beads are interconnected by small mobile wires that allow the device to expand to allow for the passage of a food bolus as well as physiologic functions such as belching or vomiting.

Various approaches to placement of the Linx device have been described, but the principle steps of the procedure are consistent. At the start of the procedure, a small 5-mm incision is created in the left subcostal region for initial port placement. After pneumoperitoneum is achieved, a 5-mm trocar is placed in the supraumbilical region left of

the midline, a 12-mm trocar is placed on the contralateral side, and a 5-mm trocar is placed in the right subcostal region. A 5-mm incision is created in the subxiphoid region through which the left lobe of the liver is elevated using a liver retractor. The patient is placed in steep reversed Trendelenburg position. Attention is then directed to exposure of the gastroesophageal (GE) junction. In order to do this, traction is applied to the stomach, and the peritoneal reflection is divided along the anterior surface of the GE junction. Dissection should take place below the insertion of the phrenoesophageal ligament above the junction of the hepatic branch of the vagus nerve. The lateral surface of the left crus is dissected off of the fundus while avoiding injury to the short gastric vessels. The gastrohepatic ligament is opened above and below the hepatic branch of the vagus nerve. Posterior dissection is performed from the right side to form a retroesophageal window. The posterior vagus nerve should be identified, and a small opening between this nerve and the esophageal body is created. A Penrose drain is then passed through this tunnel from right to left. Fibrous and fatty tissue overlying the esophageal musculature is cleaned off. A custom sizing instrument with a numerical indicator corresponding to the size range of the Linx is used for device selection.[1,35] The device should fit snugly around the esophagus without indenting the tissue. After selection of an appropriately sized device, the Linx is passed in a right to left direction through the tunnel. The ends are manipulated so that both ends of the Linx device come together on the anterior surface of the esophagus.[19] The device should be placed at the bottom of the LES just above the peritoneal reflection. Higher placement permits persistent damage and shortening of the distal-most esophagus.[36] The ends of the newest version of the device have a latch mechanism that, once properly aligned, allows the implant to be permanently secured in place around the GE junction. Endoscopy is often performed intraoperatively to confirm that a camera can be easily passed through the GE junction after the device is secured.[3]

Posterior crural repair may also be performed during the procedure depending on the size of the observed hiatal defect. Defects up to 3 cm in size may be repaired by approximation of the crura with interrupted sutures.[1] In the case of a hiatal hernia >3 cm with LES incompetence, hiatal herniorrhaphy should be performed. A 2016 study revealed that patients with concomitant repair of large hiatal hernias at the time of Linx placement had a more significant decrease in their GERD Health-Related Quality-of-Life (HRQL) scores than those with small hernias or none at all (20.5 down to 3.6 and 18.6 to 5.6, respectively).[24] This suggests that much of the benefit of the procedure comes from reestablishing normal crural anatomy.

Reported hospital stays are relatively short, with discharge on postoperative day one or even on the day of surgery at some institutions.[37] After the procedure, the patients are started on a diet early in the postoperative course with many authors suggesting initiation on the day of surgery.[37,38] It is thought that early introduction of food boluses to open the Linx device may reduce formation of a constrictive scar capsule around the device, which ultimately is thought to lead to reduced dysphagia.[37] Patients should be made aware the Linx device may affect their ability to undergo MRI.[3,39] As per the Linx implant card, those with the device placed prior to May 22, 2015, may only be exposed to MR of 0.7 Tesla, while those with the device placed after may be exposed to MR of 1.5 Tesla.[9]

Efficacy

Since its conception in the early 2000s, numerous studies have been performed to assess the efficacy of the Linx device in the management of GERD. End points of such studies have included esophageal acid exposure, changes in PPI use, and changes in symptoms based on GERD-HRQL responses. The GERD-HRQL is a validated questionnaire including six heartburn-related questions, two swallow-related questions, one gas bloating question, and one question related to medication use. Each question is scored 0–5 (5 corresponding to most severe symptoms) to obtain a maximum total score of 50.[19]

Prior to FDA approval in 2012, several feasibility trails were carried out. One of the earliest was performed by Bonavina et al in 2008.[18] In this study of 41 patients (38 underwent MSA), the median GERD-HRQL score decreased from 26 to 1 and 2.5 at 3 and 6 months, respectively. Eighty nine percent of patients no longer used anti-reflux medications, and 79% of patients had a normal 24-hour pH. No device migrations or erosions occurred during this study period.

In a follow-up feasibility study in 2010, Bonavina et al found that 77% and 90% of the 44 patients that underwent MSA had normal esophageal acid exposure at 1 and 2 years, respectively. Average GERD-HRQL symptoms score improved by 90% at 2 years (P <0.0001), and complete cessation of PPI use was reported by 90% of patients at 2 years.[19]

These early studies made way for a pivotal trial designed with the FDA reviewing the outcomes of 100 patients undergoing MSA. Early results from this study were published

by Ganz et al in 2013. At 1 year, it was found that 64% of patients had normalization of pH or a reduction of at least 50%, 93% of patients had a 50% or greater reduction in PPI use, and 92% of patients had a 50% or greater improvement in GERD-HRQL score compared to PPI-free baseline.[20] In 2012, during the execution of this pivotal trial, the Linx device was approved for use in the management of GERD by the FDA. The FDA's Summary of Safety and Effectiveness Data stated that the data from the pivotal trial supported a reasonable assurance that the device was both safe and effective with a side effect profile comparable to Nissen fundoplication and a significant reduction in esophageal pH and PPI use.

The same year that the FDA approved the Linx device, Lipham et al published long-term data regarding the 44 patients previously discussed in Bonivina et al's 2010 feasibility study. At 4 years, 23 subjects were able to be followed up and 20 subjects completed esophageal pH testing. Mean percentage of time with esophageal pH <4 decreased from 11.9% to 3.8% (P<0.001). Mean GERD-HRQL scores decreased from 25.7 to 3.3 (P<0.001). Complete cessation of PPI use was achieved in 80% of subjects. No patients had erosion or migration of the Linx device.[40]

The following year, a 2013 single-center study of 66 patients who underwent MSA found that most patients were satisfied or neutral with their condition at median follow-up of 5.8 months. Median GERD-HRQL score dropped from 26 preoperatively to 6, and 83% of patients no longer required PPIs.[41]

Bonavina et al published a case series in 2013 evaluating the first 100 patients who underwent MSA at a single institution over 6 years. It was found that the median percentage of time with esophageal pH <4 decreased from 8.0% to 3.2% after MSA (P<0.001). Median GERD-HRQL score improved from 24 off PPIs (16 on PPIs) to 2 (P<0.001) and 85% of patients ceased daily use of PPIs.[38]

Another single institution case series published in 2014 by Scwameis et al reported the short-term (4-week follow-up) effect of MSA on GERD symptoms. In this study of 23 patients, significant improvement in GERD symptoms was found with a reduction in reported heartburn (from 96% to 22% of patients, P> 0.001), bloating (from 70% to 30% of patients, P=0.006), and sleep disturbance (from 65% to 4% of patients, P>0.001). Eighty percent of patients had a 50% or greater reduction in PPI dose.[42]

Also in 2014, Reynolds et al reported the results of a larger multi-institutional study of 67 patients who underwent MSA. The median GERD-HRQL score was 4 with a median follow-up of 5 months, and 76.9% of patients ceased PPI use. The mean operative time was 60 min, and the mean length of stay was 11 h.[43]

In 2015, Saino et al published the 5-year follow-up outcomes of the feasibility trail first reported in 2010. Thirty-three of 44 subjects were available for follow-up and 20 subjects completed esophageal pH testing. Total percentage of time with pH <4 was found to be 4.6%, still down from 11.9% (P<0.001). Seventy percent (14/20 subjects) achieved normalization of esophageal pH. The mean GERD-HRQL scores at 5 years improved further down to 2.9 from 25.7 (P<0.001). Complete cessation of PPI use was achieved by 87.8%. No patients had erosion or migration of the Linx device.[44]

Ganz et al went on to publish the 5-year results of their pivotal trail of 100 patients in 2016. At 5 years, 85 patients were available for follow-up. The median GERD-HRQL score for these subjects dropped from 27 (off PPIs) to 4. PPIs were used by 100% of patients prior to the procedure and 15.3% of patients at 5 years. Fifty-seven percent of patients reported moderate-to-severe regurgitation preoperatively, while only 1.2% of patients have this complaint at 5 years. Bothersome dysphagia did increase with 5% reporting this symptom at baseline and 6% reporting it at follow-up. No patients lost the ability to belch or vomit when needed and no device erosions, migrations, or malfunctions occurred.[45]

In a 2017 retrospective study of 170 patients who underwent MSA with the Linx device, excellent outcomes (GERD-HRQL <5) were reported by 47% of patients, good (GERD-HRQL 6–15) by 28%, fair (GERD-HRQL 16–25) by 22%, and poor (GERD-HRQL >25) by 3% of patients at median follow-up of 48 months. Review of patient characteristics revealed that a BMI >35 kg/m^2, a structurally defective sphincter, and elevated residual LES pressure were frequently present in patients with less favorable outcomes of MSA.[46]

Complications

In Bonavina et al's 2010 feasibility study of the Linx device, early dysphagia was the most common complaint, occurring in 43% of the patients. In most cases, this condition self-resolved by 90 days. During the 2-year period of the study, one device was laparoscopically explanted for persistent dysphagia. There were no reported device migrations, erosions, or related mucosal injuries.[19] In a follow-up of that report, three subjects ultimately had the Linx device removed in the 4-year study period. One patient had persistent dysphagia that resolved after removal, and two patients had the device

electively removed for reasons other than implant-related adverse events.[40] At the 5-year follow-up, there were still no device migrations or erosions reported.[45]

In the 2013 pivotal study of 100 patients who underwent laparoscopic insertion of the Linx device, dysphagia was found to be the most frequent complication occurring in 68% of patients immediately postoperatively, in 11% at 1 year and in 4% at 3 years.[20] In a single-center study also published in 2013, Smith et al reported that four of 66 patients who underwent insertion of the Linx required dilation for persistent dysphagia.[41]

In Reynolds et al's 2014 publication, the most common complication was also dysphagia. This was seen in 82.7% of the 67 subjects, but resolved in 79% of these patients in a median time of 8 weeks. Eight of the patients experienced persistent dysphagia, which required balloon dilation. This led to improvement in symptoms in all patients. The second most common side effect was painful esophageal spasm, which was reported by 5.7% of patients.[43]

In 2015, following Lipham et al's study regarding MSA outcomes at 4 years, this team published a safety review of the first 1000 Linx implantations. They reported that 5.6% underwent endoscopic dilation for dysphagia, 3.4% underwent reoperation for device removal, and 1.3% had hospital readmission for minor complaints including pain, dysphagia, nausea, and vomiting. No device migrations or malfunctions were reported. In this study, one case of device erosion was reported. This device was removed endoscopically.[47]

A review of the FDA's Manufacturer and User Facility Device Experience (MAUDE) data repository was performed in 2016. One hundred thirty-three reports mentioning the Linx device since its approval were identified. Of the 133 events deemed serious enough for report, there were 11 cases of endoscopically confirmed device erosion. Dysphagia remained the most common complication with 60 cases submitted.[48]

Given the increasing awareness of complications that may warrant removal of the device, Asti et al published a review of this topic in 2017. At a median follow-up of 48 months, 11 of the 164 patients who underwent MSA had their Linx device explanted, usually between 12 and 24 months after surgery. Two devices were removed due to endoluminal erosion, while the rest were removed for dysphagia or recurrence of heartburn and chest pain.[49]

Esophageal erosion appears to be the most significant complication of the Linx procedure. While rare, in the few case reports discussing erosion, the device was found to compromise the lumen of the esophagus and cause severe dysphagia. In discussions of eroding devices, the Linx device has been successfully removed without producing esophageal leaks or other long-term sequela. Of the literature reviewed, one case was identified in which the device was removed in a two-stage procedure: endoscopically using an Olympus Endoloop cutter to extract the eroding beads and later laparoscopically to remove the remainder.[47] In the other cases, the device was able to be completely removed in one procedure either endoscopically or laparoscopically with no further intervention. [49–51]

Comparison to laparoscopic Nissen fundoplication

Since its FDA approval in 2012, numerous studies have been carried out to compare MSA to LNF in the management of GERD. In 2014, Louie et al published a retrospective case–control study of surgical management for GERD patients with hiatal hernias <3 cm. Thirty-four subjects underwent MSA and 32 subjects underwent LNF. The mean operative time for MSA was 73 min compared to 118 min for LNF (P=0.001). The percentage of time with esophageal pH <4 normalized in both MSA and LNF groups, but was only statistically significant for the LNF group (4.6% vs 1.1%, P=0.0001). At 6 months, scores on the GERD-HRQL scale improved from 20.6 to 5.0 for MSA vs 22.8 to 5.1 for LNF. The MSA group had a significant improvement in symptoms of bloating compared with LNF subjects, and MSA permitted 67% of subjects to belch versus 0% of the LNF group.[52]

In a case–control study of 24 subjects published in 2015, Shue et al compared 12 patients who underwent MSA to 12 patients who underwent LNF. Patients were matched for age, gender, and hiatal hernia size. At a mean follow-up of 7 months, MSA and LNF were both found to be effective treatments for reflux with resolution of GERD symptoms in 75% and 83% of patients, respectively. While both groups reported dysphagia postoperatively (83% of MSA subjects and 58% of LNF subjects), severe dysphagia requiring endoscopic dilation was more frequent after MSA (50% of MSA vs 0% of LNF subjects, P=0.01). Symptoms of bloating, flatulence, and diarrhea were less common after MSA compared to LNF (0% vs 33%, respectively). From a technical standpoint, MSA was found to be quicker with a mean operative time of 64 min vs 90 min for LNF (P<0.01).[53]

In 2015, Riegler et al published a multicenter prospective study comparing 1-year outcomes for 202 patients who underwent MSA and 47 who underwent LNF. GERD-HRQL scores significantly improved in both groups decreasing from 20.0 to 3.0 after MSA and 23.0 to 3.5 after LNF. Severe

reflux symptoms decreased from 58.2% to 3.1% after MSA implantation and from 60.0% to 13.0% after LNF (P=0.014). Gas and bloating were found in 10.0% of subjects after MSA compared to 31.9% of subjects after LNF (P<0.001). While 91.3% of MSA subjects were able to vomit if needed after MSA, only 44.4% of LNF subjects retained that function.[54]

Reynolds et al published two studies comparing the outcomes of MSA and LNF in 2015 and 2016. [35,55] In the 2015 retrospective analysis of 100 propensity-matched patients who underwent MSA (50 patients) or LNF (50 patients) from 2007 to 2013, it was found that both groups had similar GERD-HRQL scores (4.2 MSA vs 4.3 LNF, P=0.897) and PPI use (17% of MSA vs 8.5% of LNF, P=0.355) at 1 year. While mild gas and bloating occurred at similar rates in both groups (27.6% of MSA and 27.6% of LNF, P=1.000), severe gas and bloating occurred in 0% of MSA patients compared to 10.6% of LNF patients (P=0.022). Only 8.5% of MSA subjects were unable to belch, while 25.5% LNF subjects were unable to belch (P=0.028). Similarly, only 4.3% of MSA subjects were unable to vomit when needed, while 21.3% of LNF subjects were unable to vomit (P=0.0040).[35]

The second study published by Reynolds et al examined the same group of patients without the use of the best-fit model (52 Linx and 67 LNF). Hospital charges, operating time, length of stay, and complications were reviewed. Hospital charges between the two groups were similar (US$48,491 MSA vs US$50,111 Linx, P=0.506). MSA had a shorter operating time (66 min MSA vs 82 min LNF, P>0.01) and shorter hospital length of stay (17 h MSA vs 38 h LNF, P>0.01) when compared to LNF. Again, fewer symptoms of severe gas bloat and a retained ability to belch or vomit were more frequent in the MSA subject group versus the LNF subject group.[55]

Warren et al's 2016 multi-institutional retrospective study reported 1-year outcomes in 201 MSA subjects and 214 LNF subjects. At 1 year, 169 MSA subjects and 185 LNF subjects had significant improvement in their GERD-HRQL scores (21 down to 3 for MSA and 19 down to 4 for NLF). Ninety-six percent and 95% of MSA subjects retained the ability to belch and vomit, respectively, whereas 69% and 43% of LNF subjects were able to voluntarily belch and vomit, respectively. Gas bloat was experienced less frequently after MSA implantation (47% vs 59% after LNF). However, 44% of MSA subjects still experienced dysphagia at 1 year, compared to 32% of LNF subjects. Resumption of daily PPI use was also higher for MSA in this study (24% vs 12% for LNF).[56]

A modification of the LNF, the laparoscopic Toupet fundoplication (LTF), which is a posterior 270° wrap, was also compared to MSA in 2016 by Asti et al. GERD-HRQL scores, gas-related symptoms, dysphagia, and rate of reoperation were all found to be similar.[57]

In a meta-analysis published in 2017, Skubleny et al identified 688 patients treated surgically for GERD, 273 who underwent Nissen fundoplication and 415 who underwent MSA. They again found that the ability to belch and vomit were preserved more frequently with MSA (95.2% vs 65.9%, P>0.00001 for belching and 95.2% vs 65.9%, P>0.00001 for vomiting). No significant difference was found between MSA and LNF with respect to bloating (26.7% vs 53.4%, P=0.06) or postoperative dysphagia (33.9% vs 47.1%, P=0.43). Rates of PPI elimination were also similar (81.4 vs 81.5%, P=0.68).[58]

Overall, when compared to LNF, implantation of the Linx device results in similar control of GERD symptoms with respect to QoL measurements. PPI use may be lower with LNF in the long term. Of note, the LNF can effectively treat GERD symptoms due to a large hiatal hernia, which the Linx device by itself cannot.[59] However, as discussed earlier, a hiatal hernia repair is often performed in conjunction with the insertion of the Linx device. MSA is unique as it allows for belching and vomiting, which LNF significantly limits. Both procedures appear to have similar rates of complications such as dysphagia and gas bloating.

Comparison to endoscopic treatment

In addition to laparoscopic techniques, several endoscopic devices exist for GERD management such as the Esophyx® (EndoGastric Solutions, Inc.) and Stretta® (Mederi Therapeutics, Greenwich, CT, USA). Studies of these techniques have suggested that their use is less likely to produce dysphagia sometimes experienced after insertion of Linx.[60,61] However, the overall efficacy of these therapies has been found to be mild to modest compared to sham procedures. Thus, it is questionable whether their benefits clearly outweigh their risks.[62] A direct comparison between these devices and the Linx would be necessary to definitively claim superiority or inferiority.

Conclusion

GERD may be the result of numerous underlying pathologies including acid hyperproduction with reflux, reflux without acid hyperproduction, visceral hypersensitivity to acid, and underlying esophageal motility disorders.[63] In light of the multitude of possible etiologies, it is not surprising that some patients do not respond to pharmacotherapy. Surgical methods to mechanically augment the lower esophagus have proven to be effective in this setting.

Since its creation in the early 2000s, numerous studies have been carried out to analyze the efficacy and safety of the Linx device in GERD management. With some studies approaching 5- and 6-year follow-up, most patients have been found to have persistent resolution of their GERD symptoms with 5-year PPI cessation rates of >80%.[44,45]

The most common complication reported after MSA in all of the studies reviewed was dysphagia with immediate post-op incidence ranging from 33.9% to 83%.[53,58] Less frequent unfavorable side effects include a decreased ability to belch, bloating, and chest pain. While not identified in earlier publications, recent studies with longer follow-up have found endoluminal erosion to be a rare, but noteworthy complication as well. An appreciation of these possible outcomes permits proper patient education prior to surgery. The Linx procedure is unique in that it is easily reversible if such complications do occur. Since the implanted device becomes encapsulated in fibrous tissue without incorporation into the esophageal wall,[1] it may be removed while leaving esophago-gastric anatomy intact. This allows for other surgical techniques to be carried out if needed in the future.

Based on the studies reviewed herein, MSA with the Linx device appears to have similar efficacy compared to the gold standard surgical treatment, laparoscopic Nissen fundoplication. Both procedures have their own risks, with dysphagia requiring intervention occurring more often with MSA and inability to belch or vomit being more frequent with LNF. An appreciation of these findings allows for better patient education and surgical decision making. While outcomes thus far have generally been favorable, further evaluation of the long-term safety and efficacy of MSA is important as this device if often used in patients with decades of life ahead of them.

Disclosure

The authors report no conflicts of interest in this work.

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