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# Outcomes of esophageal surgery, especially of the lower esophageal sphincter

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This paper includes commentaries on outcomes of esophageal surgery, including the mechanisms by which fundoduplication improves lower esophageal sphincter (LES) pressure; the efficacy of the Linx<sup>TM</sup> management system in improving LES function; the utility of radiologic characterization of antireflux valves following surgery; the correlation between endoscopic findings and reported symptoms following antireflux surgery; the links between laparoscopic sleeve gastrectomy and decreased LES pressure, endoscopic esophagitis, and gastroesophageal reflux disease (GERD); the less favorable outcomes following fundoduplication among obese patients; the application of bioprosthetic meshes to reinforce hiatal repair and decrease the incidence of paraesophageal hernia; the efficacy of endoluminal antireflux procedures, and the limited efficacy of revisional antireflux operations, underscoring the importance of good primary surgery and diligent work-up to prevent the necessity of revisional procedures.

**Keywords:** esophagogastric junction; lower esophageal sphincter; antireflux; manometry; obesity

## Concise summaries

- Improvement of the lower esophageal sphincter (LES) basal pressure has been initially suggested as the most relevant effect of fundoplication. However, length of the sphincter has a proved effect on the LES pressure (LESP) required to establish competence, and in addition, increased sphincter length decreases the effect of gastric wall tension in opening the sphincter, that is, more gastric distension can occur before an opening pressure is reached. Another mechanism of action of antireflux surgery is represented by the gastroesophageal flap, which tends to occlude the lumen of the distal esophagus as intragastric pressure rises. Restriction of the caliber of the distal esophagus is another mechanism that can explain the antireflux effect of an operation. In addition, fundoplication prevents complete relaxation of the LES upon swallowing and decreases the triggering of transient LES relaxations (TLESRs). The crural repair which is usually combined with the antireflux procedure has the potential to prevent mediastinal migration of the wrap and may add strength to the antireflux barrier.
- The Linx<sup>TM</sup> reflux management system is designed to provide a permanent solution to gastroesophageal reflux disease (GERD) by augmenting the physiologic function of the LES with a simple and reproducible laparoscopic procedure that does not alter gastric anatomy and, importantly, is easily reversible if necessary. In order for reflux to occur, gastric pressures must overcome both the patient's native LESP and the magnetic bonds of the device. This new reflux management system can interrupt distraction of the LES by gastric wall tension and therefore increase the intragastric pressure required to open the cardia. It is speculated that this effect may be sufficient to prevent unfolding of the LES and to provide physiological reflux control in patients with early disease and small hiatal hernia (HH).
- The modern barium swallow emphasizes motion recording (video), uses a tightly controlled examination protocol, and requires an understanding of esophageal physiology.

Normal postfundoplication findings on contrast material should be a tapered narrowing of the distal esophagus that extends for 2–3 cm. The valve should be located below the diaphragmatic hiatus and the wrap is seen as a smooth filling defect in the fundus, with the barium column passing through the center of an image that mimics a pseudotumor. Assessment of the anatomic outcome is essential and should be done systematically because symptomatic outcome may underestimate the true recurrence rate. Complications are generally diagnosed with barium swallow examination, and include too-tight fundoplication with delayed clearance, complete or partial fundoplication dehiscence, recurrent hernia, and slipped wrap.

- Correlation of the endoscopic aspect of the antireflux barrier with symptoms, manometry, and 24-h pH studies show that there is a very good correlation between a normal postoperative valve with symptoms and functional studies, but a poorer correlation when a defective value is present.
- Laparoscopic sleeve gastrectomy is recognized as an option for surgical treatment for obesity. Its consequences on the anatomy of the esophagogastric junction (EGJ) may lead to gastroesophageal dysmotility and decrease of LES, probably due to partial resection of the sling fibers during the operation.
- The outcomes and durability of fundoplication in the setting of severe obesity are not as favorable as those in not severely obese patients. Correlation between failures of antireflux procedures and increasing body mass index (BMI) is probably due to the relative increase in intra-abdominal pressure associated with obesity, thus predisposing to breakdown of the fundoplication but not necessarily to a wrap herniation.
- The use of prosthetic and bioprosthetic meshes as a reinforcement of the hiatal repair has gained the acceptance of different groups in order to decrease the incidence of recurrence after repair of paraesophageal hernia (PEH). To lower the risk of complications, new bioprosthetic meshes have been used to reinforce the hiatal closure. These biomaterials act as an extracellular matrix scaffold to augment the native tissue healing and regeneration: they are pliable and temporary, by nature, so they should not have the associated risks of the non-absorbable meshes. The use of these biomaterials appears to be safe, and it is an effective alternative to the use of synthetic mesh for repair of PEH.
- All endoluminal treatments for GERD result in a moderate improvement in symptom scores, some decrease in medication use, but no correction of objective acid exposure testing in 70% or so of patients, with controversy over what exactly the appropriate endpoint of GERD treatment should be—patient satisfaction or a normal objective measurement. Current endoluminal devices and procedures have many patient exclusions, are disliked by the medical insurance community, and do not normalize pH in the majority of patients. On the other hand, they do markedly improve patients' symptoms and may make them easier to control medically.
- The cause of failure of antireflux operations is, in the majority of patients, an anatomic abnormality such as recurrent HH with wrap migration or disruption/disconfiguration of the wrap. In approximately 2% of patients, failure is found to be due to a previously unknown motility disorder. Revisional operations have a higher mortality and morbidity than primary surgery, and their outcome is less favorable than after primary repair. Quality-of-life scores are however generally improved.

## 1. How does antireflux surgery correct lower esophageal sphincter dysfunction?

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Antireflux surgery has developed on an empirical basis without full understanding of the pathophysiological determinants of antireflux competence. Rudolf Nissen serendipitously discovered that wrapping the gastric fundus around the

anastomosis to protect from anastomotic leakage after esophagectomy was also effective to prevent gastroesophageal reflux (GER). By 1960, the Nissen fundoplication was used in patients with HH and reflux esophagitis, and has then become the gold standard of surgical therapy. However, the mechanical behavior of the gastroesophageal junction (GEJ) after antireflux surgery remains controversial.

The main factors involved in the surgical control of reflux are (1) the pressure, length, and location of the LES; (2) the GER valve as defined by the angle of His and the mucosal flap valve; and (3) the caliber of the cardia and the length–tension properties of the gastric sling fibers. The pinchcock action of the diaphragmatic crura and the reduction in the gastric capacity of the gastric fundus may also be indirectly involved in the control of reflux.

Improvement of the LES basal pressure has been initially suggested as the most relevant effect of fundoplication. It has been shown that this effect is independent of the presence of a native LES, emphasizing the role of the tone of the gastric muscle in the surgical restoration of LES competence.<sup>1</sup> However, LESP is not the sole determinant of competence. The interaction of LESP and length of the sphincter has been extensively studied in an *in vitro* model and it was suggested that the longer the LES, the lower the LESP required to establish competence.<sup>2</sup> In addition, increasing sphincter length decreases the effect of gastric wall tension in opening the sphincter, that is, more gastric distension can occur before an opening pressure is reached.<sup>3</sup>

Another mechanism of action of antireflux surgery is represented by the gastroesophageal flap or flutter valve, which tends to occlude the lumen of the distal esophagus as intragastric pressure rises. The effect of augmentation of the gastroesophageal mucosal valve can be reached by reducing the angle of His, that results in a more oblique entry of the esophagus into the stomach, by anchoring the GEJ to the median arcuate ligament (Hill operation) or by remodeling the GEJ with a total (Nissen), partial anterior (Dor), or partial posterior (Toupet) fundoplication.

Restriction of the caliber of the distal esophagus is another mechanism that can explain the antireflux effect of an operation. According to the law of Laplace, the smaller the radius of a tube, the greater the pressure required to distend it. Therefore, the intragastric pressure required to open the cardia and the

LES is increased by the restriction in esophageal diameter provided by the fundoplication.<sup>4</sup> Calibration of the cardia provided by fundoplication results in improving the mucosal seal and the length–tension properties of the gastric sling fibers that prevent effacement of the distal esophagus.<sup>5,6</sup>

In addition, it has been shown that fundoplication prevents complete relaxation of the LES upon swallowing and decreases by 50% the triggering of TLESRs.<sup>7</sup> This effect may be the result of reduced distensibility of the cardia buttressed by the gastric fundus wall.<sup>8</sup>

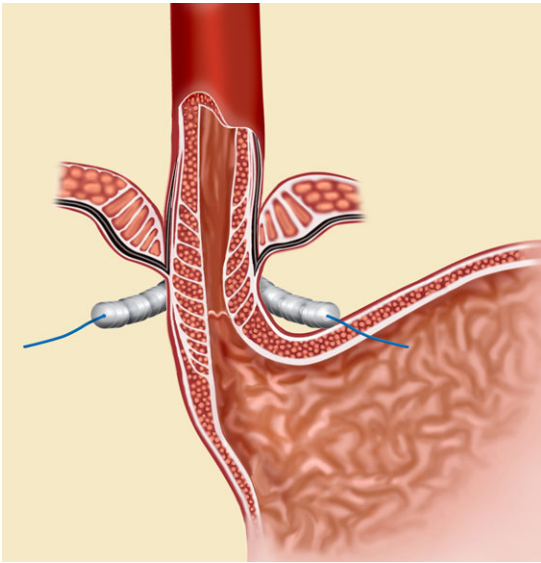
The crural repair which is usually combined with the antireflux procedure following reduction of a HH has the potential to prevent mediastinal migration of the wrap and may add strength to the antireflux barrier.<sup>9</sup> Improvement of the gastric emptying rate is an additional physiological effect of the fundoplication that may help in the control of GER. It is conceivable that a reduction in size of the gastric reservoir contributes to this effect.<sup>10</sup>

In summary, the fundoplication restores tone and length of the LES by extrinsic squeezing, by calibrating the cardia, and by optimizing geometry and biomechanics of the EGJ. It is likely that the new Linx reflux management system can interrupt distraction of the LES by gastric wall tension and therefore increase the intragastric pressure required to open the cardia.<sup>11,12</sup> It is speculated that this effect may be sufficient to prevent unfolding of the LES and to provide physiological reflux control in patients with early disease and small HH.

## 2. The magnetic sphincter

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Up to 40% of patients with GERD have incomplete relief of symptoms that cannot be addressed by increasing the daily dose of proton pump inhibitors (PPIs).<sup>13</sup> The laparoscopic Nissen fundoplication is an effective and durable therapy when performed in specialized centers, but the level of technical difficulty and the risk profile have limited its use to fewer than 30,000 procedures annually in the United States, corresponding to less than 1% of the GERD population.<sup>14</sup> These factors have contributed to the propensity of patients to persist with medical therapy, even when it is inadequate to control symptoms and complications of the disease such as



**Figure 1.** Magnetic sphincter augmentation device (Linx) implanted around the gastroesophageal junction.

aspiration, esophagitis, and Barrett's esophagus (BE).<sup>15</sup> As a consequence, a significant gap in the treatment continuum for GERD remains evident in current clinical practice.

The Linx reflux management system is designed to provide a permanent solution to GERD by augmenting the physiologic function of the LES with a simple and reproducible laparoscopic procedure that does not alter gastric anatomy and, importantly, is easily reversible if necessary. The Linx consists of a series of titanium beads with magnetic cores sealed inside. In order for reflux to occur, gastric pressures must overcome both the patient's native LES and the magnetic bonds of the device.<sup>16</sup> The device also allows for expansion to accommodate a swallowed bolus or the escape of elevated gastric pressure associated with belching or vomiting (Fig. 1).

The Linx is implanted laparoscopically under general anesthesia. By preserving the phrenoesophageal ligament, a tunnel is formed between the posterior esophageal wall and the posterior vagus nerve to accommodate the device. A small HH (<3 cm) can be repaired at the discretion of the surgeon. The outer diameter of the esophagus is measured with a sizing tool and the appropriate Linx device is implanted and secured. Patients are discharged on the day of surgery or on the first postoperative day; they are on a free diet, discontinue the use of PPIs, and typically return to normal physical

activity in less than a week. The most common complaints following the Linx procedure are dysphagia and chest pain, which are usually well tolerated and require only temporary diet adjustments.

A prospective controlled and multicenter study evaluated 44 patients implanted with the Linx between February 2007 and October 2008.<sup>17</sup> Data from this study were submitted for CE certification and were determined to have a positive risk-to-benefit ratio. Subsequent publications reported the 2- and the 4-year clinical results.<sup>11,12,18</sup> The FDA Gastroenterology and Urology advisory panel voted unanimously in March 2012 that there was reasonable assurance of safety and effectiveness with the use of the Linx.

On upper gastrointestinal endoscopy, the impression of the device was observed in the region of the GEJ in all patients. There was no increased resistance to passage of a standard endoscope. A consistent improvement of quality of life, normalization of reflux, and a dramatic reduction in PPI use were recorded in these patients. Thirty-two patients had both baseline and 1-year postoperative manometric testing. The LES resting pressure increased from 6.5 to 14.6 mmHg ( $P < 0.005$ ) in the nine patients with a hypotensive LES. There were no statistically significant changes in the length of the LES nor in the amplitude of esophageal contractions.

Esophageal pH monitoring was obtained in 20 patients at 1–2 and 3 years after surgery. The mean total% time pH was <4 decreased from a preoperative baseline of 11.9–3.8% ( $P < 0.001$ ). All of the other components of the 24-h pH test and the DeMeester composite score were significantly reduced compared to baseline. The esophageal acid exposure was normalized in 80% of patients.

The mean total GERD–HRQL (health-related quality of life) score at 4 years or more decreased to 3.3 compared to the baseline score of 25.7 ( $P < 0.0001$ ); all patients had at least a 50% reduction in the total GERD–HRQL score. Interestingly, 87.5% of patients were satisfied with their present condition, and 80% of patients were free from daily dependence on PPIs.

To date, no mucosal or transmural erosions of the device have been reported. Forty-three percent of patients complained of mild dysphagia during the postoperative period; in all individuals the symptom resolved by 90 days without treatment. Three

patients were explanted without operative complications: one because of persistent dysphagia, one because of the need to undergo an MRI study, and the last one who elected to have a Nissen fundoplication for persisting GERD symptoms. Inability to belch or vomit was reported by less than 5% of patients.

Based upon the clinical experience to date, magnetic sphincter augmentation with the Linx reflux management system provides patients with a permanent, easily reversible, and more physiologic solution to their reflux. To date, the device has demonstrated a high level of efficacy and has met patient expectations, with few side effects or serious adverse events.

### 3. The radiologic characteristics of antireflux valves following surgery

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Barium upper gastrointestinal studies provide an enormous amount of information on the structure and function of the esophagus and stomach, especially when the entire examination is recorded on video rather than as a series of still films. This subject was opportunely pointed out in a paper by Jeffery H. Peters, “Modern imaging for the assessment of GERD begins with the barium esophagogram.”<sup>19</sup>

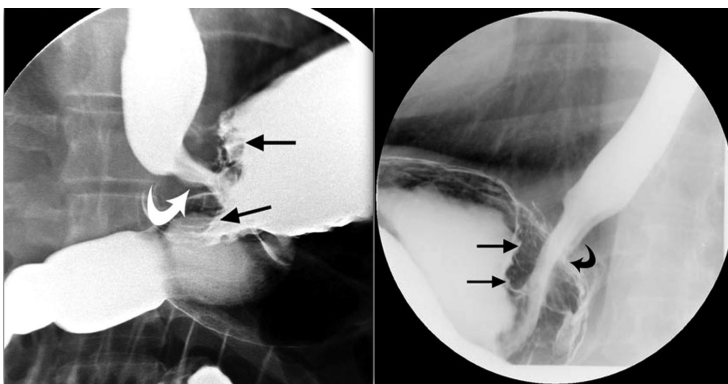
The modern barium swallow emphasizes motion recording (video), uses a tightly controlled examination protocol, and requires an understanding of esophageal physiology. The quality of these imaging results is closely related to careful attention to the patient’s body position and the technique used in the examination.<sup>19</sup>

An HH is observed in 80% of patients with GERD, and is best demonstrated in the prone position. This position increases abdominal pressure and promotes distention of the hernia above the diaphragm. The finding of a large hernia (>5 cm) or an irreducible hernia in the upper position is relevant, since this may suggest the possibility of an esophageal shortening.

The significance of radiologic GER varies depending on whether the reflux is spontaneous or induced by various maneuvers. Spontaneous reflux is defined when it happens with the patient in upright position. It is observed by the radiologist in only 40% of patients with classic symptoms of reflux. When the radiologist tries to provoke reflux with maneuvers, like Valsalva, the idea is to reproduce the rises of the intra-abdominal pressure that occurs when the patient makes an abdominal effort, coughs, or sneezes.<sup>19,20</sup>

Another important point to stress is that up to 50% of GERD patients have dysmotility,<sup>21</sup> expressed by slowing or weakening of primary esophageal peristalsis, representing a nonspecific motility disorder or an ineffective peristalsis. It is important to be aware that in these patients a retrograde transport of barium may be mistaken for spontaneous reflux.

Nissen fundoplication is the most common operation for reflux disease worldwide. The esophagogram is a simple, cheap, and well-tolerated study that allows for a functional and anatomic evaluation of the fundoplication (Fig. 2). Radiologists should be familiar with normal postfundoplication findings on contrast material-enhanced studies. There should be a tapered narrowing of the distal esophagus that extends for 2–3 cm. The valve should



**Figure 2.** Radiologic image of Nissen fundoplication.



be located below the diaphragmatic hiatus,<sup>22,23</sup> and the wrap is seen as a sharply margined and smooth filling defect in the fundus, with the barium column passing through the center of an image that mimic a pseudotumor.<sup>24</sup>

It is not always possible to differentiate between a Nissen and a modified Toupet fundoplication by esophagogram. Instead, a Collis gastroplasty plus Nissen is clearly identified by the image of the wrap encircling a tube with gastric folds. The postoperative symptoms that usually require radiographic evaluation include dysphagia, gas bloat syndrome, and recurrent heartburn. But the assessment of anatomic outcome is essential and should be done systematically because symptomatic outcome may underestimate the true recurrence rate. Complications are generally diagnosed with barium swallow examination, and include too-tight fundoplication with delayed clearance, complete or partial fundoplication dehiscence, recurrent hernia, and slipped wrap.

Haniaux defines the term *intrathoracic migration* of the wrap as a herniation of an intact fundoplication through the hiatus. He emphasizes that it is an underreported recurrence rate because postoperative follow-up does not include a systematic esophagogram.<sup>23</sup> He performed radiologic follow-up yearly in 148 patients after laparoscopic Nissen, and diagnosed 30% of intrathoracic migrations at 5 years follow-up.

Donkevoort also reported a high rate of anatomic recurrences. He prospectively investigated 57 patients after Nissen fundoplication at 2 years follow-up and with strict radiologic criteria he found that 55% of patients had some degree of anatomic failure. Curiously, he could not find correlation between anatomic failure and symptomatic subjective outcome.<sup>24</sup> On the other hand, Italo Braghetto found a strong association between postoperative symptoms and different abnormal anatomic deformities in the evaluation with barium swallow.<sup>25</sup>

In a personal follow-up of 250 consecutive laparoscopic Nissen fundoplications for sliding HH, even when the follow-up was short (4 years) the symptomatic outcome was excellent (94% of patients without symptoms), but a very strict protocol of radiologic follow-up demonstrated 16.4% of anatomic recurrences, and there was a significant association between anatomic failure and symptoms.<sup>26</sup>

In conclusion, barium esophagogram enhanced with motion video recording is a very useful diagnostic tool to evaluate the morphology and function of the esophagus, and provides valuable information for the evaluation of antireflux surgery. The esophagogram offers precise information about the position of the fundoplication and the transit of the barium through the wrap. The assessment of anatomic outcome with an esophagogram is simple and should be done systematically because symptomatic outcome may underestimate the true recurrence rate.

#### **4. Is there any correlation between symptoms and endoscopic findings following antireflux surgery?**

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After antireflux surgery in patients with GERD, recurrence of symptoms can occur in near 15–25% of the patients late after surgery.<sup>27–29</sup> The majority of studies only consider the presence of symptoms, without performing objective evaluations of the real antireflux capacity of the surgical procedure. In the present report we analyze the correlation with the endoscopic aspect of the antireflux barrier correlated to symptoms and to manometry and 24-h pH studies.

In a prospective study, we evaluated 120 consecutive patients with GERD, excluding patients with long-segment BE. The objective evaluations were performed 3–5 years after surgery. Besides clinical questionnaire, manometric and 24-h pH studies were performed in each patient. They were divided by endoscopy according to the presence of a normal or a defective fundoplication after surgery according to the classification of Seltman and Jobe.<sup>30,31</sup>

The presence of a normal fundoplication by endoscopic evaluation was present in 97 patients (81%). Among them, symptoms of recurrent reflux were present in 6%, endoscopic esophagitis in 6%, hypotensive LES in 2%, and abnormal acid reflux in 10%. On the contrary, 23 patients (19%) showed a defective wrap. Among them, recurrent reflux symptoms were present in 48%, endoscopic esophagitis in 48%, hypotensive LES in 63%, and an abnormal acid reflux in 87% (Table 1).

In conclusion, the presence of a normal fundoplication late after surgery is associated with 95%

**Table 1.** Postoperative radiologic and endoscopic evaluation of anatomic characteristics of cardia and defective antireflux barrier correlated to postoperative manometry, endoscopic esophagitis, and postoperative reflux symptoms

|                            | Abnormal acid reflux | Hypotensive sphincter (<12 mmHg) | Endoscopic esophagitis  | Reflux symptoms         |
|----------------------------|----------------------|----------------------------------|-------------------------|-------------------------|
| Defective fundoplication   |                      |                                  |                         |                         |
| Radiology ( <i>n</i> = 22) | 20 (90.9%)           | 11 (50%)                         | 11 (50%) <sup>a</sup>   | 9 (40.1%) <sup>a</sup>  |
| Endoscopy ( <i>n</i> = 23) | 20 (86.9%)           | 15 (62.5%)                       | 11 (47.8%) <sup>b</sup> | 11 (47.8%) <sup>b</sup> |
| Normal fundoplication      |                      |                                  |                         |                         |
| Radiology ( <i>n</i> = 98) | 10 (11.3%)           | 6 (6.1%)                         | 6 (6.1%) <sup>a</sup>   | 6 (6.1%) <sup>a</sup>   |
| Endoscopy ( <i>n</i> = 97) | 10 (10.3%)           | 2 (2.1%)                         | 5 (5.1%) <sup>b</sup>   | 5 (5.1%) <sup>b</sup>   |

<sup>a</sup>*P* < 0.001, <sup>b</sup>*P* < 0.001.

of good clinical outcome and 90% of normal acid reflux studies.<sup>25,32</sup> On the contrary, when a defective antireflux wrap is detected, clinical recurrence is present in only 52% of the patients, but 87% have an abnormal acid reflux. This means that there is a very good correlation of a normal postoperative valve with symptoms and functional studies, but a poorer correlation if a defective value is present.

## 5. Lower esophageal sphincter after sleeve gastrectomy for obese patients

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Obesity is associated with a statistically significant increase in the risk of GERD symptoms; erosive esophagitis, BE, and esophageal carcinoma progressively increase with increasing weight.<sup>32–36</sup> Laparoscopic sleeve gastrectomy has been accepted as an option for surgical treatment for obesity. After surgery and this procedure modify the anatomy of the EGJ, consequently some patients present reflux symptoms associated with endoscopic esophagitis, therefore PPI treatment must be indicated. We

have studied the manometric changes and GER after sleeve gastrectomy. Preoperative mean LESP was  $14.2 \pm 5.8$  mmHg. After the operation, LESP decreased significantly to a mean value of  $10.5 \pm 6.06$  mmHg (*P* = 0.01). Three patients (15%) presented normal LESP ( $23.1 \pm 3.7$  mmHg) and 17 patients (85%) presented hypotensive LES with a mean LESP of  $8.3 \pm 2.6$  mmHg: six of them (30%) presented LESP < 6.0 mmHg ( $5.45 \pm 0.5$  mmHg) and 11 patients (55%) presented LESP more than 6.1 mmHg ( $9.9 \pm 1.7$  mmHg). All patients had normal total and abdominal length before the operation. After sleeve gastrectomy, the abdominal length and total length of the high-pressure zone at the EGJ were also affected. Six patients had normal total and abdominal length of the LES (total length >3.5 cm and abdominal length >1 cm). Of the other 14 patients, five patients had total length = 3.5 cm but abdominal length <1 cm and nine patients had total <3.5 cm and abdominal length = 0.5 cm (Table 2).<sup>37</sup>

In addition, associated with these findings we observed the presence of increased GER with scintigraphic assessment, endoscopic erosive esophagitis,

**Table 2.** Lower esophageal sphincter length before and after sleeve gastrectomy

|   | Before              | After                                   |
|---|---------------------|---|
| LES pressure                              | $14.2 \pm 5.8$ mmHg | $10.5 \pm 6.06$ mmHg ( <i>P</i> = 0.01) |
| Incompetent LES                           | –                   | 17 (85%)                                |
| Normal length <sup>a</sup>                | 20                  | 6                                       |
| Incompetent                               | 0                   | 14                                      |
| Total length >3.5; abdominal length <1 cm |                     | 5                                       |
| Total length <3.5; abdominal length <1 cm |                     | 9                                       |

<sup>a</sup>Total length >3.5; abdominal length >1 cm.

and cardia dilatation.<sup>38</sup> Some authors have suggested that sleeve can be associated with severe postoperative gastroesophageal dysmotility and reflux, but others have suggested that reflux esophagitis improves after sleeve.<sup>39,40</sup> Himpens<sup>40</sup> published GERD appearance *de novo* in 21.8% of patients after 1 year, but 3 years later only 3.1% of patients presented GERD. Petersen<sup>41</sup> observed significantly increased LESP after sleeve gastrectomy, however in the same paper it is described that gastroscopy demonstrated cardiac insufficiency, esophagitis, and HH in most patients. That appears incomprehensible.

In conclusion, sleeve gastrectomy produces important decrease of LESP, probably due to partial resection of the sling fibers during the operation.

## 6. Are outcomes of fundoduplication in the obese patient population equivalent to those in the nonobese?

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Many studies have supported the association of GERD with an increasing BMI reporting that 52% of obese patients present GERD, 53% have symptoms of GERD, 31% endoscopic esophagitis, 51% positive acid reflux (24-h pH monitoring), associated with abnormal esophageal acid exposure in 61% of cases. Erosive esophagitis is 1.25 times more frequent in obese patients and esophagitis plus BE is threefold more common. The odds ratio (OR) for GERD in obese patients is 2.6–6.3 with BMI > 35 compared to normal subjects, for LS-BEs the OR is 4.3, and for adenocarcinoma it is 16.2. Definitively, GERD is reported to be more prevalent among the morbidly obese (MO) than in the general population.<sup>33,42</sup> Although some authors disagree with these reports, increasing evidence has suggested that obesity predisposes individuals to GERD. The evidence that obese patients who have GERD are at risk of failure of antireflux procedures is also suggestive but not conclusive. Most of the available studies have had low patient numbers and subsequent low statistical power, or have examined patient populations that are not selective of the bariatric population (e.g., BMI < 35 kg/m<sup>2</sup>).<sup>43–45</sup>

Regarding the question: Are outcomes of fundoduplication in the obese patient population equivalent to those in the nonobese? The answer is also a con-

troversial point. In several large series, the outcomes and durability of fundoplication in the setting of severe obesity are not as good as those in patients who are not severely obese.<sup>45</sup> In another study performed in 224 consecutive patients (3 years follow-up) who underwent laparoscopic fundoplication, Perez *et al.* suggested that obesity adversely affects the outcome of antireflux operations: overall symptomatic recurrence was 31.3% in obese patients compared to 4.5% in normal-weight (NW) individuals.<sup>46</sup> Morgenthal demonstrated that obesity is one of the factors predisposing to failure of antireflux procedures, reporting 57% failure after fundoplication.<sup>47</sup>

On the contrary, according to several authors there are no differences concerning the postoperative outcome comparing normal to obese subjects (Table 3). Campos,<sup>48</sup> studying the predictor factors for failure after fundoplication, concluded that BMI is not predictive for failure. Anvari<sup>49</sup> suggested that obesity is not a contraindication for antireflux procedures, without deleterious effects on the postoperative reflux and with very successful results after fundoplication, reporting significant augmentation of the LESP in MO patients from 5.96 ± 0.6 to 15.76 ± 1.10 mmHg, and in NW patients found a similar increase in LESP from 10.80 ± 0.84 to 19.21 ± 0.82 mmHg after surgery. (*P* < 0.0001 in both cases). However, the MO patients reported significantly higher reflux symptoms scores 6 months postoperatively as compared to the NW patients (MO 12.41 ± 1.46 versus NW 4.87 ± 0.69 at 6 months

**Table 3.** BMI is not predictive for failure postoperative outcome comparing normal to obese subjects

|            | Failure (%) |
|------------|-------------|
| BMI < 35   |             |
| Anvari     | 4.8         |
| Campos     | 13          |
| Morgenthal | 22          |
| Perez      | 4.5         |
| Mean ± SD  | 11.07 ± 8.4 |
| BMI > 35   |             |
| Anvari     | 12.1        |
| Campos     | 14          |
| Morgentahl | 57          |
| Perez      | 31.3        |
| Mean ± SD  | 28.6 ± 20.8 |



postoperative,  $P < 0.0001$ ). There is no clear explanation for these findings.

Therefore, the question is still open because many studies have demonstrated a correlation between failures of antireflux procedures and increasing BMI, probably because the relative increase in intra-abdominal pressure associated with obesity may predispose to fundoplication breakdown but not necessarily to wrap herniation. Alternatively, fundoplication breakdown could be related to technical difficulties in performing laparoscopic antireflux surgery because of the obesity.

More studies are needed to reach a final conclusion.

## 7. Paraesophageal hernia repair: is the use of a biologic mesh superior to a nonabsorbable mesh?

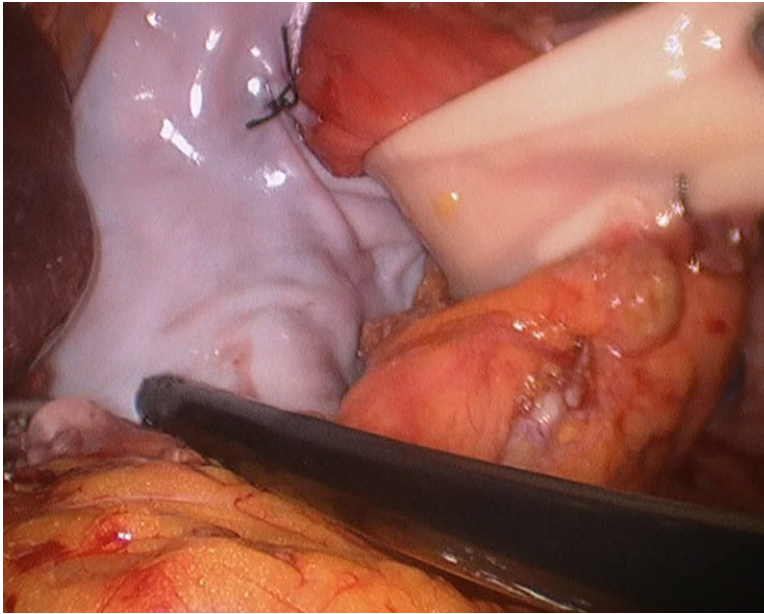
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The main principles to obtain an adequate PEH repair are complete tension-free reduction of the herniated contents into the abdomen, obtaining an adequate intra-abdominal esophageal length, complete circumferential excision of the hernia sac, closure of the hiatus defect, and fixation of the stomach in the subdiaphragmatic position; in addition, many surgeons advocate the addition of an antireflux procedure.<sup>50</sup> The closure of the hiatus defect is a critical step in the PEH repair, and if not performed is a major cause of recurrence. Several factors can affect the integrity of the closure. First, the diaphragm and the crurae undergo significant tension. Second, the muscular pillars of the crurae may be attenuated due to the constant stretch created by the hernia sac. Third, the size of the hiatal defect ensures significant tension if only sutures are used to reapproximate the crurae.<sup>51</sup>

More recently, the use of prosthetic and bioprosthetic meshes as a reinforcement of the hiatal repair has gained the acceptance of different groups in order to decrease the incidence of recurrence. Frantzides *et al.*<sup>52</sup> compared the incidence of recurrence of PEH in 72 patients with a hiatal defect greater than 8 cm in diameter, when simple hiatal closure was used versus polytetrafluoroethylene (PTFE) reinforcement. The study showed eight recurrences (22%) in the nonmesh group within 6 months, and none in the mesh group. Granderath

*et al.*<sup>53</sup> demonstrated a lower incidence of recurrence at 1 year in 50 patients using a mesh compared to 50 patients with primary repair (8% vs. 28%), and reported the same incidence of dysphagia at 1 year in both groups. Both studies did not report complications related to the mesh. There have been several reports of adverse outcomes associated with the use of PTFE mesh, and although uncommon, these complications, such as esophageal, stomach, or GEJ erosions of the mesh, can severely affect the patients needing significant surgical interventions.<sup>54</sup> Soricelli *et al.*<sup>55</sup> showed that the use of polypropylene mesh in laparoscopic Nissen for patients with GERD was overall safe in 204 patients, with only one erosion of the mesh (0.49%); the hernia sac was used to cover the mesh.

Due to the prosthetic mesh complications, new bioprosthetic meshes have been used to reinforce the hiatal closure. These biomaterials act as an extracellular matrix scaffold to augment the native tissue healing and regeneration; they are pliable and temporary, by nature, so they should not have the associated risks of the nonabsorbable meshes. The use of these biomaterials appears to be safe, and it is an effective alternative to the use of synthetic mesh for PEH repair. Lee *et al.*<sup>56</sup> showed acceptable recurrence rates (12%) in a group of patients in whom the hiatal defect was closed with acellular human dermal matrix mesh, after an average follow-up of 14.4 months. A prospective randomized trial comparing a U-shaped porcine small intestine submucosa (SIS) mesh reinforcement to primary hiatal closure, in 106 patients, showed a significantly lower recurrence rate in the mesh group (9% vs. 24%) at 6 months, assessed by UGI series.<sup>57a</sup> However, a follow-up study at 5 years failed to show a difference,<sup>57b</sup> but it showed no associated strictures, erosions, or higher incidence of dysphagia in the mesh group. The same group published a paper where 71 patients received a PEH repair with SIS mesh reinforcement with an average follow-up of 45 months, showing 14 patients with complications at 30 days, none of them related to the mesh use, and six patients with dysphagia, also none related to the mesh. The recommendations for the use of the biologic mesh are (1) use a U-shape mesh, never circumferentially placed; (2) cover the posterior hiatus, avoiding the sling effect on the esophagus; and (3) leave a space between the mesh edge and the esophagus, to avoid excessive contact<sup>58</sup> (Fig. 3).



**Figure 3.** U-shaped biologic mesh (SIS), placed to reinforce a hiatal closure in a paraesophageal hernia repair.

In conclusion, the use of a biologic mesh can be safe, and the complications associated with its use are uncommon. The use of nonabsorbable mesh might be safe, and although the mesh complications are not common, they can be very serious. The use of biologic mesh as reinforcement in a PEH repair compared with a primary repair, does not have any difference at 5 years in terms of radiologic recurrence, but is associated with improvement of the initial symptoms in patients who underwent a PEH repair. For these reasons, our group recommends the use of a biologic mesh.

## 8. What are the results of endoluminal antireflux procedures?

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Multiple endoluminal treatments for GERD have been developed over the last 15 years—this points to the need for an intermediate approach to GERD between medication (which only works well for 85% of patients) and laparoscopic funduplications (which are expensive and have side effects). Most of the endoscopic procedures enjoyed a brief popularity but then failed in the marketplace and were withdrawn. Today only the transoral incision-less fundoduplication (TIF) procedure (Endogastric Solutions, Seat-

tle, WA) and the Stretta procedure are commercially available and in active use. Failure of the procedures was multifactorial and mainly due to reimbursement issues in the United States. The procedures also had generally mediocre efficacy, which led to lack of physician–user enthusiasm and championship.<sup>59</sup> In general, all procedures, including the TIF and Stretta, result in a moderate improvement in symptom scores, some decrease in medication use, but no correction of objective acid exposure testing in 70% or so of patients.<sup>60</sup> This has led to some controversy in the academic community over what exactly the appropriate endpoint of GERD treatment should be: patient satisfaction or a normal objective measurement. Another factor leading to poor acceptance has been the long list of relative contraindications to the procedures: obesity, HHs, strictures, and BE.<sup>61</sup> Since most patients have one or more of these, practitioners quickly develop fatigue in trying to sort out the few who would benefit from endoluminal treatment and give up on it.

The Stretta procedure uses radiofrequency burns to the LES to decrease compliance and perhaps ablate some aberrant neural pathways in the cardia region. Its greatest efficacy has been noted to be in patients with mild disease, an anatomically normal LES, and documented transient sphincter relaxation as the cause of the reflux. In these patients, Stretta is

**Table 4.** Comparison of TIF results with Nissen and Toupet results

|                                   | TIF    | PPIs   | Nissen  | Toupet               |
|-----------------------------------|--------|--------|---------|----------------------|
| GERD–HRQL improved by $\geq 50\%$ | 53–86% | 68–91% | 61–97%  | 61–97% (from Nissen) |
| Off daily PPIs                    | 79–85% | 0%     | 79–100% | 65–92%               |
| Normal acid exposure              | 37–67% | 50–92% | 88–97%  | 49–94%               |
| Esophagitis reduced               | 67–80% | 84–94% | 86–95%  | 82–89%               |
| Hiatal hernia reduced             | 60–89% | 0%     | 87–99%  | 95%                  |

more than 80% effective at correcting reflux. It is hypothesized that the radiofrequency ablation (RFA) may destroy some of the neural trigger that leads to abnormal untimed relaxation in these patents. Overall, patients do not see an elevation of LES or substantial normalization of pH studies, but note improved symptom scores and decreased medication use.<sup>62</sup>

The TIF procedure seeks to create a robust antireflux valve by drawing the gastric fundus up to the esophagus and fastening it with small plastic tags. Various investigators have found that the endoscopic appearance of the resulting valve correlates well with better symptomatic and physiologic results.<sup>63</sup> The procedure has undergone several refinements in technique which have improved the results—currently the TIF2 is recommended that seeks to wrap more of the fundus around the esophagus. Once again, the list of relative contraindications is long and includes obesity, HHs, strictures, BE, and previous gastric surgery, as well as neck or esophageal problems that would make it difficult to pass this rather stiff 60 French device. Complications are mainly insertion problems, with several perforations having been reported, or bleeding from the fastener placement.<sup>64</sup> Bleeding has been reported in 5–10% of patients. Overall results of the TIF2 show an improved ( $>50\%$ ) symptom score in 80–85% of patients, a reduction of medications in 75% (no medications in 40%), and a normalized pH in around 40% (Table 4).

### Conclusion

Physicians and patients continue to ask for a less invasive mechanical option for their GERD. Current endoluminal devices and procedures have many patient exclusions, are disliked by the medical insurance community, and do not normalize pH in the majority of patients. On the other hand, they do markedly improve patient symptoms and may make

them easier to control medically. Therefore their place in the GERD treatment repertory remains to be spelled out and the technologies need to continue to evolve.

### 9. Outcomes of revisional antireflux surgery; surgical and quality of life<sup>47,65–73</sup>

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Primary antireflux operations have excellent results with low failure rate. Ten-year follow-up results show that 85–90% of patients are free of significant reflux. Over long-term follow-up though, 1–4% of patients undergo a reoperation. The indication for reoperation in the majority of cases is recurrent reflux (64%). Other reasons are dysphagia (31%), gas bloating syndrome (3%), and chest pain (2%).

The cause of failure in the majority of patients is an anatomic abnormality such as recurrent HH with wrap migration or a problem with the wrap itself (disruption or disconfiguration). In approximately 2% of patients, failure is found to be due to a previously unknown motility disorder. These patients therefore probably should not have undergone the initial antireflux procedure.

Primary antireflux operations are safe with very low mortality (0.2–0.5%) and morbidity (3.8–7.7%). Length of stay (2–4 days) and conversion rates (2% or less) are also low. Revisional operations, as can be expected, have a higher mortality (0.9%) and morbidity (14–16%) and therefore should not be taken lightly. Length of stay (5.5 days) and conversion rates (9%) are also higher.

The outcome of revisional antireflux operations is nonetheless good, with patients reporting it a success in 81–84% of cases, which is lower than after primary repair. Quality-of-life scores are generally improved as well, although also less improved compared to after primary repair. When followed

diligently, up to 33% of patients develop a rerecurrent hernia and 5% undergo another operation.

To conclude: a revisional antireflux operation is feasible but leads to a higher risk of complications, fewer good results, and a higher risk of failure than a primary antireflux operation. Therefore it remains essential to perform a good primary operation after diligent work-up to try and prevent the necessity of performing a revisional procedure.

## Conflicts of interest

The authors declare no conflicts of interest.

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