



Minimal versus obligatory dissection of the diaphragmatic hiatus during magnetic sphincter augmentation surgery

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Abstract

Background The magnetic sphincter augmentation (MSA) device was initially implanted with minimal hiatal dissection (MHD) at the diaphragmatic hiatus. Due to concern of possible MSA device dysfunction if herniated into an occult or small hiatal hernia, and increased understanding to the role of defective crura in reflux disease, the operative procedure was changed to planned obligatory dissection (OD) of the hiatus at the time of all implantations.

Methods Between December 2012 and September 2016, 182 patients underwent MSA implant at a single medical center and have complete records available for review through September 2017. The MHD dissection period extended from December 2012 to September 2015, from September 2015 to 2016 all patients underwent OD.

Results MHD occurred 53% (96/182) versus OD in 47% (86/182), mean follow-up time in days for MHD and OD was 554 (SD 427) versus 374 (298) days. Intraoperative measurement of hernia size for the MHD versus OD was 0.77 (1.1) versus 3.95 (2.4) cm, $p < 0.001$. At first visit follow-up, there was no difference in any dysphagia ($p = 0.11$). Recurrent GERD (defined as resumption of PPI after successful initial post-operative wean) was less frequent after OD than after MHD, 3.6 versus 16.3%, $p = 0.006$. Delayed onset dysphagia was 1.2% in the OD group versus 8.6% in the MHD group, $p = 0.04$. Recurrent hiatal hernia of 2 cm or greater occurred in 0.0% of the OD and 11.5% of the MHD, $p = 0.03$. Repeat surgery for hiatal hernia repair has occurred in 0% of the OD and 6.6% of the MHD, $p = 0.02$.

Conclusion OD of the hiatus with crural closure resulted in less recurrence of reflux symptoms and hiatal hernia, despite an increased proportion of patients with larger hiatal hernia and more complex anatomic disease at the time of operation.

Keywords GERD · LINX · MSA · Magnetic sphincter augmentation · Hiatal hernia

Traditional antireflux surgery accomplished through gastric fundoplication mandates an obligatory dissection (OD) of the diaphragmatic hiatus to reduce any hiatal hernia, ensure adequate length of intra-abdominal esophagus and to provide an anatomic window to facilitate passage of the gastric fundus posterior to the esophagus. The Linx magnetic sphincter augmentation (MSA) device provides an alternate

to fundoplication in the treatment of reflux disease. Rather than relying on the bulk and external compression of a fundoplication wrap, the Linx augments the function of the lower esophageal sphincter (LES) by increasing the yield pressure of the LES [1–6]. The Linx was initially approved for use in patients with a small (<3 cm) or no hiatal hernia [6]. Initial thoughts were that patients with small or no hiatal hernia did not require hiatal dissection as the function of the Linx was independent of the status of the hiatus, and the necessity of a bulky wrap to decrease recurrent hiatal herniation was unnecessary in patients with no hiatal hernia. Initial experience with the device led us to hypothesize that this approach underestimated the importance of the contribution of the crura to the competence of the anatomic antireflux mechanism, that the crural diaphragm sphincter mechanism is defective in patients with reflux, and that the hiatus requires dissection and crural plication in all patients.

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Recent studies demonstrating the feasibility of efficacious device implantation in patients with even large hiatal hernia continues to support this hypothesis [7, 8].

Methods

Study population

All patients who underwent MSA with the LINX® Reflux Management System (Torax® Medical, Inc, Shoreview, MN) at Hoag Memorial Presbyterian (Newport Beach, CA USA) between December 2012 and November 2016 are included in this study with follow-up complete through November 2017. The institutional review board of the University of Southern California approved the study. Inclusion criteria were any patient undergoing implantation of the Linx device who had not undergone a previous antireflux or diaphragmatic surgery or procedure.

Pre-operative assessment

All patients underwent 48-h esophageal pH testing, video esophagography, and upper gastrointestinal endoscopy prior to operative intervention. A DeMeester score of > 14.72 diagnosed GERD. Screening for hiatal hernia or dysmotility pre-operatively was through review of videoesophagram (VEG) and esophagogastroduodenoscopy (EGD) findings; high-resolution manometry was performed in cases when the video esophagram or symptoms suggested dysmotility. Pre-operative characteristics recorded include the following: age, sex, duration of symptoms, DeMeester score, and body mass index (BMI).

Surgical procedure

Detailed operative procedure can be reviewed in previous publications [1–3]. All MSA device implantation and hiatal hernia repairs were performed by authors JCL or NB.

Measure of hiatal hernia

For the purposes of this study, hiatal hernia is defined based on the measurement of long-axial distraction of the gastroesophageal junction (GEJ) cephalad an imaginary horizontal plane spanning the diaphragmatic crura prior to initiation of crural dissection. All operative measurements were obtained at routine insufflation pressures using a laparoscopic tool marked for measurement. Measurement occurred prior to hernia reduction and after exposure of the crus through the opening of the pars flaccida regardless of surgical dissection intention.

Hiatal dissection and crural closure

Early in our experience with the Linx device, patients with hiatal hernia larger than 3 cm were excluded for consideration of surgery. If a hiatal hernia of significant size, or one that impacted the placement of the Linx was found during surgery, the hiatal hernia was completely dissected, reduced and posterior stitch cruroplasty was performed. In the second study phase, hiatal dissection and cruroplasty were performed on all patients regardless of whether there was an apparent hiatal hernia. Patients during the initial phase of the study that underwent hiatal hernia repair at the time of operation were included in the OD group for analysis.

When performing a hiatal hernia repair, we perform a complete hiatal dissection with reduction and resection of the hernia sac from the mediastinum, mobilization of the thoracic esophagus to provide a minimum of 2–3 cm of intra-abdominal esophageal length, and primary posterior cruroplasty. No patient underwent Collis gastroplasty or mesh placement. The crura are approximated with 2–3 synthetic non-absorbable sutures in a figure-of-eight fashion. A bougie is not used during crural closure, rather the crura are approximated such that only one closed laparoscopic grasper can easily pass through the hiatus along the side of the esophagus through the hiatus (Fig. 1). We do not use mesh or adhesives at the diaphragmatic hiatus during MSA. Once the hiatal repair was complete, the external circumference of the GEJ was measured and an appropriately sized LINX® device placed around the esophagus secured by passing between the posterior vagus and the esophageal wall.

Post-operative assessment

Subjective post-operative outcomes were evaluated at routine post-operative visits at 1 week, 1, 3 months and then yearly after the date of surgery. Post-operative visits included assessment of PPI use, dysphagia, and recurrence or resolution of symptoms at each visit. Patients with persistent dysphagia or reflux were seen more frequently on an as needed basis. Symptom resolution or improvement was based on patient response to verbal inquiry. In this study, “early” is defined as the period up to the 1-month post-operative clinic visit, and “delayed” is defined as symptoms recurring, after their initial resolution in the early period, in the period extending from or beyond 1-month post-operative visit. Routine 1-year post-operative surveillance includes VEG and/or EGD to assess for hiatal hernia recurrence, irrespective of patient symptoms. Studies ordered on an as needed basis for symptoms are

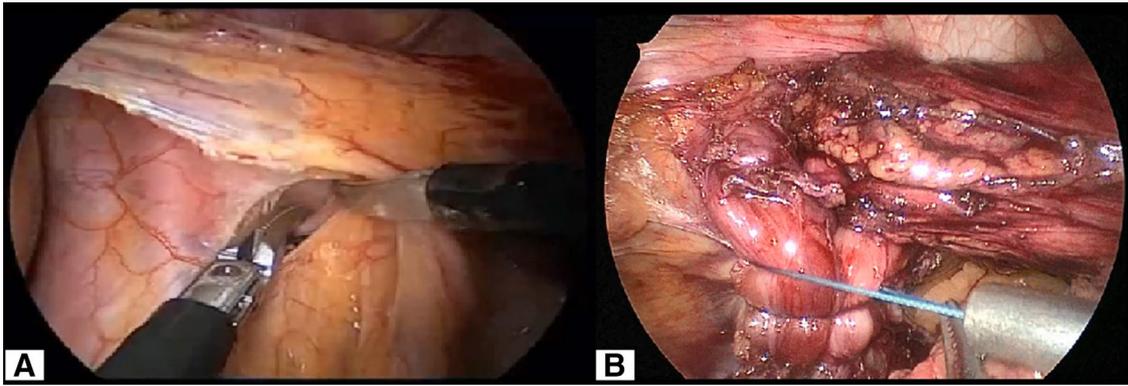


Fig. 1 **A** Illustrates minimal dissection at the diaphragmatic hiatus prior to Linx placement around the esophagus. **B** illustrates the OD of the hiatus with posterior stitch cruroplasty prior to Linx placement

also included in analysis. A recurrent or persistent hiatal hernia is defined as an excursion of the stomach above the level of the diaphragm equal to or > 2 cm by either EGD or VEG.

Statistical analysis

Demographic data, perioperative characteristics, and post-operative outcomes were recorded into a centralized database and summarized and compared between OD and minimal hiatal dissection (MHD) groups. Analysis of outcomes between groups was accomplished through the use of χ^2 of Fisher's exact test for analysis of categorical variables, continuous variables were analyzed using two-tailed Student's *t* test. Statistical analyses were performed using SPSS® Statistics v. 25 (IBM®). Statistical significance was set at $p \leq 0.05$.

Results

Patient and pre-operative characteristics

A total of 182 patients were included in the analysis (Table 1) with 96 in the MHD arm and 86 in the OD arm. The average age was 63.1 (SD 12.0) in the MHD and 55.3 (16.1) in the OD arm, $p < 0.01$. Mean follow-up time in days for MHD and OD was 554 (427) versus 374 (298) days. Pre-operative assessment of hiatal hernia size by endoscopy was significantly different between the MHD and OD arms, 0.64 (0.9) versus 2.0 (2.3) cm, $p < 0.001$. Other patient characteristics compared without significant differences include, sex, BMI, duration of symptoms, proportion with dysphagia pre-operatively.

Intraoperative

There are several significant differences in the intraoperative characteristics between the MHD and OD arms of the study. The size of hiatal hernia was significantly smaller in the MHD versus the OD group 0.77 (1.1) versus 3.95 (2.4) cm,

Table 1 Patient characteristics

Patient characteristics	Minimal hiatal dissection <i>N</i> =96	Obligatory hiatal dissection <i>N</i> =86	<i>p</i>
Age (years) (SD)	55.3 (16.1)	63.1 (12.0)	0.01
Gender male (%)	50.0%	52.0%	0.75
BMI (kg/m ²) (SD)	26.8 (4.3)	27.8 (4.4)	0.75
GERD duration (years) (SD)	13.4 (11.1)	15.3 (12.9)	0.17
DeMeester score (SD)	39.9 (31.2)	79.3 (19.9)	0.003
Pre-operative dysphagia, % of patients	32.0%	24.0%	0.17
Endoscopic hiatal hernia size (cm) (SD)	0.64 (0.9)	2.0 (2.3)	<0.001

BMI body mass index, *SD* standard deviation, *GERD* gastroesophageal reflux disease

Table 2 Operative characteristics

Patient characteristics	Minimal hiatal dissection N=96	Obligatory hiatal dissection N=86	<i>p</i>
Operative pre-dissection hernia size (cm) (SD)	0.77 (1.1)	3.95 (2.4)	<0.001
Linx size, # beads	13.5 (0.9)	14.8 (1.1)	0.22
Operative time (min) (SD)	56.4 (32.0)	69.3 (27.5)	0.91

SD standard deviation

$p < 0.001$. This is expected due to progressively more liberal approach to the placement of the device in patients with known hiatal hernia (Table 2). Operative time was not significantly different between the MHD and OD arms of the study, 56.4 (32.0) versus 69.3 (27.5) min, $p = 0.91$.

Post-operative

In the early post-operative period (< 1 month from surgery), the incidence of any dysphagia was not significantly different between MHD versus OD group, 67.0 versus 55.3%, $p = 0.11$. The incidence of severe dysphagia impacting the ability to take adequate hydration or nutrition by mouth for a period of ≥ 24 h was low and not significantly different between groups as 1.1% in the MHD and 3.5% in the OD, $p = 0.28$. Delayed onset GERD or dysphagia are defined as a recurrence of pre-operative symptoms recurring in patients after initial resolution, after the early post-operative period is depicted in Table 3. Recurrent GERD occurred during the follow-up period in 16.3% of MHD patients versus 3.6% of OD patients, $p < 0.01$. Delayed onset dysphagia occurred

in 8.6% of MHD and 1.2% of OD patients, $p = 0.04$ —all of whom had either recurrent hiatal hernia and/or significant recurrence of reflux symptoms. At date of last follow-up 23.4% of MHD and 17.8% of OD patients reported any (including even occasional) PPI use, $p = 0.48$. Recurrent or persistent hiatal hernia were observed with higher frequency in the MHD versus OD groups, 11.5 versus 0.0%, $p = 0.03$.

Late complications examined include the need for balloon dilatation, device removal or recurrent hiatal hernia. No statistically significant differences were observed in the incidence of any of these complications between the MHD and OD groups, except the incidence of recurrent hiatal hernia. Repeat surgery to repair an untreated hiatal hernia occurred in 6.6% of MHD and 0.0% of OD patients, $p = 0.02$.

Sub-group analysis of patients with 0–2 cm hiatal hernia on pre-operative videoesophagography

Patient who on pre-operative videoesophagography who had evidence of a small, or no hiatal hernia only were examined based on the performance of MHD of OD. Patient characteristics (Table 4) reveal no clinically relevant differences between these two groups of patients. Table 5 shows that patients undergoing MHD had smaller-sized hiatal hernia diagnosed or measured during the procedure 0.79 (1.1) versus 3.36 (2.2) cm, $p \leq 0.001$, had smaller LINX devices implanted 13.5 (1.0) versus 14.5 (1.0), $p \leq 0.001$ and had slightly shorter operative times 55.2 (27.5) versus 68.1 (24.5) min, $p \leq 0.01$.

Outcomes among patients with absent to small hiatal hernia based on performance of MHD versus OD are shown in Table 6. Notable outcomes include the lack of significant differences in early or late dysphagia or

Table 3 Post-operative characteristics

Patient characteristics	Minimal hiatal dissection N=96 (%)	Obligatory hiatal dissection N=86 (%)	<i>p</i>
Early post-operative period (< 1 month from surgery)			
Early post-operative dysphagia (any)	67.0	55.3	0.11
Early severe post-operative dysphagia	1.1	3.5	0.28
Late post-operative period (> 3 months from surgery)			
Delayed onset GERD	16.3	3.6	0.006
Delayed onset dysphagia	8.6	1.2	0.04
PPI use at last follow-up	23.4	19.0	0.48
Late complications			
Required post-operative balloon dilation	16.3	15.5	0.88
Any recurrent/persistent hiatal hernia	17.1	6.3	0.41
EGD recurrent/persistent hiatal hernia > 2 cm	11.5	0.0	0.03
Device removed	8.3	3.7	0.24
Repeat hiatal hernia repair +/- Linx removal	6.6	0.0	0.02

GERD gastroesophageal reflux disease, PPI proton-pump inhibitor, EGD esophagogastroduodenoscopy

Table 4 Patient characteristics 0–2 cm hiatal hernia

Patient characteristics	Minimal hiatal dissection N=90	Obligatory hiatal dissection N=45	<i>p</i>
Age (years) (SD)	54.9 (16.5)	62.9 (12.0)	<0.01
Gender male (%)	57.8%	47.8%	0.2
BMI (kg/m ²) (SD)	26.8 (4.3)	26.4 (3.9)	0.62
GERD duration (years) (SD)	13.7 (11.2)	16.5 (15.4)	0.26
DeMeester score (SD)	40.4 (32)	65.2 (169.4)	0.23
Pre-operative dysphagia, % of patients	33.70%	22.2%	0.17

BMI body mass index, SD standard deviation, GERD gastroesophageal reflux disease

Table 5 Operative characteristics 0–2 cm hiatal hernia

Patient characteristics	Minimal hiatal dissection N=90	Obligatory hiatal dissection N=45	<i>p</i>
Operative Pre-dissection hernia size (cm) (SD)	0.79 (1.1)	3.36 (2.2)	<0.001
Linx size, # beads	13.5 (1.0)	14.5 (1.0)	<0.001
Operative time (min) (SD)	55.2 (27.5)	68.1 (24.5)	<0.01

SD standard deviation

delayed onset GERD, dysphagia or PPI use at last follow-up. There was a significant difference in the rates of recurrent hiatal hernia between MHD and OD 19.0 versus 2.4%, $p = 0.01$ as well as the need for reoperation for hiatal hernia repair between those initially undergoing MHD versus OD, 6.6 versus 0%, $p = 0.08$.

Table 6 Post-operative characteristics 0–2 cm hiatal hernia

Patient characteristics	Minimal hiatal dissection N=90 (%)	Obligatory hiatal dissection N=45 (%)	<i>p</i>
Early post-operative period (< 1 month from surgery)			
Early post-operative dysphagia (any)	66.3	62.2	0.64
Early severe post-operative dysphagia	1.1	6.6	0.80
Late post-operative period (> 3 months from surgery)			
Delayed onset GERD	17.1	2.3	0.14
Delayed onset dysphagia	7.1	0	0.69
PPI use at last follow-up	22.5	18.1	0.57
Late complications			
Required post-operative balloon dilation	16.3	20.0	0.60
Any recurrent/persistent hiatal hernia	19.0	2.4	0.01
Device removed	8.8	6.8	0.68
Repeat hiatal hernia repair +/- linx removal	6.6	0.0	0.08

GERD gastroesophageal reflux disease, PPI proton-pump inhibitor

Discussion

The traditional and most simplistic understanding of pathologic reflux is that it results from low LES pressure. Studies over the past two decades have deepened our understanding of the complex physiology contributing to a competent LES and we now understand that it is more likely that a two-sphincter system is present, one sphincter being the LES and one being a crural diaphragm [9]. The crural valve is of particular importance during periods of increased intra-abdominal pressure as well as functioning as a physiologic one-way valve during alterations in pressure during a swallow as LES pressure decreases with esophageal ampulla filling in anticipation of bolus transit [10–12].

These theoretical concepts are born out in a study by Souza et al. demonstrating that among patients without hiatal hernia, pressures at the GEJ are lower and inadequate in patients with esophagitis compared to controls, suggesting pathology secondary to a defective crural mechanism [13]. While it seems obvious that a hiatal herniation and the resulting anatomic dissociation of the LES from the crural

diaphragm contributes reflux, there is increasing evidence to suggest that even with intact anatomy, there may be underlying pathology of the diaphragmatic crura in reflux disease. Fei et al. used electron microscopy to examine and compare phrenoesophageal membrane and diaphragmatic crural muscle samples from 33 patients with GERD and hiatal hernia and 60 patients without disease. They found that ultrastructural abnormalities of the muscle fibers were present in 94% patients with GERD and hiatal hernia, 75% of them severe alterations versus no ultrastructural crural abnormalities in controls [14]. We know that the crural diaphragm in a healthy individual has a resting tone that decreases with swallowing and increases with post swallow gastric distension. This phenomenon has been documented with pressure transduction in conjunction with electromyography by Shafik et al., this provides even more definitive evidence of not only a crural diaphragmatic valve—but one reflexively involved in GEJ competence during the execution of a swallow [10].

In this study, we document the outcomes after a change in surgical strategy at the hiatus during Linx implantation. We have embraced the idea of a two-sphincter antireflux mechanism contrived of not only the pressure at the GEJ exerted by the LES and augmented in these patients by the Linx device, but also of an equally important anatomic diaphragmatic hiatal sphincter, holding the GEJ with some external compression subject to reflexive relaxation and constriction, as well as securing the GEJ both in the abdomen and in the appropriate anatomic proximity to the crural diaphragm [15–19]. Early in our Linx experience, we performed only minimal dissection in the absence of inadequate length of intra-abdominal esophagus or an obvious anatomically significant hiatal hernia which would impact our ability to place the Linx at the prescribed anatomic location. What we observed in the follow-up period was an anecdotally high rate of recurrent or progression of the hiatal hernias in conjunction with recurrent or persistent reflux symptoms.

We have become convinced that the reduction of any hiatal hernia in conjunction with crural tightening (even in the absence of any hiatal hernia) improves reflux symptoms and reduces their recurrence or progression to larger hernias over time [20]. The risk of this strategy was that by increasing the complexity and extent of the surgery we would increase operative times or the incidence of post-operative dysphagia. Our results here support our hypothesis—patients have more durable reflux control after OD with no increase in operative time, equal early and reduced delayed onset dysphagia. There is a clinically significant difference in observed rates of device removal with lower rates in the OD dissection group as well as recurrent/persistent hiatal hernia of any size. There are statistically significant lower rates of recurrence of hiatal hernia > 2 cm in size. We also observed a statistically significant reduced need for repeat

surgery to repair a recurrent or persistent hiatal hernia in the OD group, (6.6% in the MHD versus 0% in the OD group, $p=0.02$). While crural closure increases the efficacy of the LINX procedure, it should be noted that in the event of symptomatic hiatal hernia recurrence the need for re-operative surgery at the hiatus would be in a re-operative field.

Sub-group analysis of patients who based on pre-operative studies is included in “Results” section. These results are difficult to interpret given the fact that we believe in order to diagnose a small hiatal hernia a crural dissection must be performed, suggesting that we do not know the true rate of small hiatal hernia among patient in whom MHD was performed. The results of this sub-group analysis are however consistent with the observations across our entire sample which shows that the performance of MHD reduces both recurrence (or progression) of hiatal hernia and reduces the need for re-operative surgery without increasing rates of dysphagia, early or late post-operative complications.

Hopefully, these results will continue to be born out as the follow-up periods equal equivalency in these two groups of patients, an area of further study for our group and others.

Limitations

This study is limited by its retrospective nature, unequal follow-up times between arms and changes in practice over the study period not independent of the study variable—extent of dissection. While these limitations are multiple, they reflect an evolving practice with a novel device and we believe differences in outcomes of decreased recurrence of reflux symptoms primarily reflect a change in the extent of dissection at the hiatus and the repair or reinforcement of the diaphragmatic crural sphincter.

Compliance with ethical standards

Disclosures Nikolai Bildzukewicz and John C. Lipham are both paid consultants for Johnson and Johnson Inc. James M. Tatum, Evan Alicuben, Kamran Samakar and Caitlin C. Houghton have no conflicts of interest.

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