



Impedance planimetry (EndoFLIP™) after magnetic sphincter augmentation (LINX®) compared to fundoplication

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Abstract

Introduction Functional luminal imaging probe (FLIP) use during laparoscopic fundoplication (LF) for gastroesophageal reflux disease is well described. However, there is a lack of data on FLIP measurements during magnetic sphincter augmentation (MSA). This study aims to report our institutional experience in performing FLIP during MSA and to compare these measurements to those obtained during Nissen and Toupet fundoplication.

Methods and procedures A retrospective review of a prospectively maintained quality database was performed. Patients who underwent MSA or LF and had FLIP measurements between April 2018 and June 2021 were included. FLIP measurements at the gastroesophageal junction (GEJ) were recorded without pneumoperitoneum at 40 mL balloon fill after hernia reduction, cruroplasty, and MSA or fundoplication. Reflux symptom index (RSI), GERD-HRQL, and dysphagia score were collected up to 2 years. Group comparisons were made using two-tailed Wilcoxon rank-sum and χ^2 tests, with statistical significance of $p < 0.05$.

Results Twenty-seven patients underwent MSA and 100 patients underwent LF (66% Toupet, 34% Nissen). Type III hiatal hernia was present in 3.7% of MSA patients versus over 50% for fundoplication patients. Minimum diameter, cross-sectional area, and distensibility index (DI) were lower after MSA device placement compared to Nissen or Toupet fundoplication ($p < 0.05$). Postoperative follow-up showed no differences in RSI, GERD-HRQL, and dysphagia score between MSA and Nissen fundoplication ($p > 0.05$).

Conclusion Intraoperative impedance planimetry provided objective information regarding the geometry of the GEJ during MSA. The ring of magnetic beads restores the anti-reflux barrier and transiently opens with food bolus and belching. The magnetic force of the beads may explain why the DI after MSA is lower yet postoperative quality of life is no different than Nissen fundoplication.

Keywords EndoFLIP · LINX · Impedance planimetry · Nissen · Toupet · GERD

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Impedance planimetry with the functional luminal imaging probe (FLIP) can produce real time three-dimensional images of gastrointestinal sphincters of interest, particularly the gastroesophageal junction (GEJ). One unique feature of this technology includes the ability to quantify the tightness of a sphincter, known as the distensibility index (DI). FLIP has been used in the field of gastroenterology to describe the GEJ in patients with GERD being more distensible compared to patients without GERD [1]. Intraoperative impedance planimetry has gained traction due to the potential to tailor laparoscopic fundoplication (LF) and optimize patient outcomes. Recent studies have reported impedance planimetry measurements correlating to patient outcomes, quantitatively tighter values leading to worse outcomes [2, 3].

Magnetic sphincter augmentation (MSA) was developed due to the need for standardization of operative technique and consistent outcomes. There is wide variability in creating a fundoplication, and some patients suffer from dysphagia and gas–bloat syndrome [4–6]. In MSA, the mechanism to treat GERD includes biomechanical augmentation of the GEJ by implanting a ring of magnetic beads around the lower esophageal sphincter. The strength of the magnetic beads in the ring ideally is weak enough to allow for food bolus transit and belching while strong enough to stay closed at rest, resulting in increased GEJ pressure to decrease pathologic reflux [4]. MSA has been demonstrated to be a safe operation, and outcomes are equivalent if not better than Nissen fundoplication [7, 8].

FLIP measurements after MSA have been reported; however, outcomes have not been analyzed alongside LF [9]. We aim to report our institutional experience in performing FLIP during MSA and compare these measurements to those obtained during Nissen and Toupet fundoplication.

Methods

Data collection

Patients who underwent MSA or LF (Nissen or Toupet) and had FLIP measurements between April 2018 and June 2021 were included. Dedicated research fellows are present during each operation and acquire FLIP measurements. Patients are prospectively followed. Clinical data such as preoperative (e.g., demographics, symptomatology), perioperative (e.g., intraoperative complications, blood loss), and postoperative data (e.g., follow-up visits, readmission rates) is maintained in an institutional quality database. Institutional Review Board approval was obtained for this study.

Operative protocol

All patients undergo a comprehensive esophageal workup before their operation. The workup includes an esophagram or CT scan, manometry, acid-reflux testing (impedance or BRAVO study, unless the patient had symptomatic paraesophageal hernia), and upper endoscopy. Patients who demonstrated objective evidence of GERD were offered anti-reflux surgery. This would include an abnormal acid monitoring test (DeMeester score > 14.72), esophagitis seen on endoscopy, or biopsy proven esophagitis or Barrett's disease. Work-up may also include a negative nuclear medicine test for delayed gastric emptying. A single surgeon performed the operations. Indications for MSA are normal esophageal motility, no allergy to titanium, stainless steel, nickel or ferrous material, no frequent MRI (MRI system up to 1.5 T), insurance approval, and patient preference.

Our practice utilizes manometry and FLIP to decide which fundoplication a patient will receive. A patient will receive a Nissen fundoplication after demonstrating normal motility (peristalsis > 80% along with no Ineffective Esophageal Motility, Diffuse Esophageal Spasm, or Jackhammer Esophagus based on Chicago Classification v3.0) and a DI of greater than 7.0 mm²/mmHg after hernia reduction, otherwise a Toupet fundoplication is performed.

For MSA, pneumoperitoneum was achieved through a Veress needle technique. If a hiatal hernia was present, mediastinal dissection continued until the stomach was completely reduced from the mediastinum, resulting in 3 cm of intra-abdominal esophagus. Both of the vagus nerves were visualized and left intact. The GEJ is localized utilizing anatomical landmarks and upper endoscopy. The crura were usually approximated with three permanent posterior sutures. A measuring device was then used to measure the esophagus after separating the posterior vagus nerve from the esophagus. Two separate measurements were taken with the sizing tool before placing the device around the esophagus. The implanted device used was two or three sizes up from the measured size. The sutures were cut after confirming that the device was in place and locked.

For fundoplication, pneumoperitoneum was achieved through a Veress needle technique as well. After hiatal dissection, reduction of hiatal hernia, and mobilization of 3 cm of intra-abdominal esophagus, the crura opening was typically closed with three permanent sutures. If a paraesophageal hernia was present, then biologic mesh in a rectangular configuration was posteriorly placed and incorporated into a horizontal mattress closure with three permanent sutures with pledgets. Before fundoplication begun, either the FLIP balloon or a bougie (52 to 60 French) was inserted through the GEJ under laparoscopic vision. The surgeon visually gauges the size of the esophagus and subsequently decides on the French size of the bougie. The study included a time period where a portion of patients who had their fundoplication created over the FLIP balloon at 30 mL fill, our practice was adopting a continuous method of monitoring the GEJ during anti-reflux surgery. For a Nissen fundoplication, the posterior fundus was sutured to the crus, and apical stitches were placed incorporating a portion of fundus, esophagus, and diaphragm bilaterally. The fundoplication was completed with three interrupted permanent sutures, each grasping a partial-thickness bite of the esophagus while preserving both vagus nerves resulting in a floppy fundoplication. A posterior gastropexy to the median arcuate ligament was done with a permanent suture for a Toupet fundoplication. Two coronal sutures incorporating fundus, crus, and the esophagus were placed bilaterally with permanent sutures. Four additional sutures, two on each side, were placed about a centimeter inferior to each other incorporating fundus and esophagus.

FLIP system and protocol

The EndoFLIP unit 1.0 and 8 cm catheter (EF-325) was used for this study. After the pre-check process, the catheter is placed transorally through the oropharynx into the esophagus then under laparoscopic visualization as it straddles the GEJ. The balloon is inflated to 30 mL, then position of the catheter is adjusted until an hourglass shape is visualized on the monitor, identifying the location of the GEJ. After balloon pressure equilibrates, measurements are recorded after hiatal dissection, crural closure, and sphincter augmentation. The measurements are minimum diameter (D_{\min}), cross-sectional area (CSA), intra-balloon pressure, and DI. The DI is calculated by dividing the minimum CSA over the peak intra-balloon pressure. Measurements are recorded at 30 and 40 mL balloon fill, with and without pneumoperitoneum, and patient in reverse Trendelenburg position. We followed recent published intraoperative FLIP protocol and analyzed the 40 mL balloon fill values without pneumoperitoneum measurement [10, 11].

Clinical follow-up

All patients are seen for postoperative follow-up within 3 weeks. Quality of Life (QOL) questionnaires are distributed at 3 weeks, 6 months, 1 year, and 2 years. The questionnaires include the reflux symptom index (RSI), gastroesophageal reflux disease-health related quality of life questionnaire (GERD-HRQL), and dysphagia score. RSI assesses for “atypical” symptoms of reflux, a score > 13 represents severe reflux [12]. The GERD-HRQL evaluates for “typical” reflux symptoms [13]. A higher QOL score indicates worse symptomatic disease. The gas–bloat score is extrapolated from the GERD-HRQL question #7, the response range from a score of 0 (no symptoms) to 5 (symptoms are incapacitating). Dysphagia score measures the severity of dysphagia on a five-point scale from 1 (I am able to eat a normal diet/no dysphagia) to 5 (I am unable to swallow anything/total dysphagia).

Statistical analysis

Patient and clinical characteristics were summarized using mean with standard deviation, median with interquartile range or frequency with percentage. Differences between groups and measurements at different time points were made using two-tailed Wilcoxon rank-sum and χ^2 tests. All statistical tests were two-tailed and performed using SAS 9.4 (SAS Institute, Cary, NC). Statistical significance was set at $p < 0.05$.

Results

Patient demographics

From August 2018 to June 2021, 27 patients had MSA and intraoperative FLIP evaluations. One hundred patients had fundoplication (66 Toupet and 34 Nissen) and intraoperative FLIP within the same timeframe. MSA patients were younger, the operation was completed in less time, had less estimated blood loss, and a shorter length of stay when compared to Nissen or Toupet fundoplication. Patients who underwent MSA had a significantly lower rate of type III hiatal hernia compared to Toupet or Nissen fundoplication (3.7 versus 65.2 or 50%, $p < 0.001$). Fundoplication was created over the FLIP balloon catheter in 39.4% (26/66) Nissen and 44.1% (15/34) Toupet patients. Patient characteristics are displayed in Table 1 and perioperative/postoperative data in Table 2.

Impedance planimetry measurement differences between magnetic sphincter augmentation and fundoplication

MSA patients’ FLIP measurements were compared to the patients who underwent Nissen or Toupet fundoplication (Table 3). The DI of the GEJ was lower after MSA compared to Toupet or Nissen (1.9 ± 0.8 versus 3.5 ± 1.4 or 3.5 ± 1.3 mm²/mmHg, $p < 0.001$, respectively). The CSA was significantly lower after MSA versus Toupet or Nissen (66 ± 26 mm² versus 113 ± 43 or 119 ± 43 mm², respectively, $p < 0.001$).

The change in DI from hernia reduction to sphincter augmentation varied between operations. At hernia reduction, patients who had MSA or Toupet fundoplication did not have a significantly different DI, even though 65% of Toupet patients had paraesophageal hernias. MSA had a larger reduction in DI after sphincter augmentation (DI reduction of 3.8 ± 2.4 versus 2.1 ± 2.7 mm²/mmHg, $p < 0.001$) due to a lower DI. When compared to Nissen fundoplication, MSA had a smaller reduction in DI after sphincter augmentation (DI reduction of 3.8 ± 2.4 versus 5.3 ± 2.2 mm²/mmHg, $p < 0.001$, Fig. 1) due to Nissen patients having a higher DI after hernia reduction (8.6 ± 2.7 versus 5.6 ± 2.8 mm²/mmHg, $p < 0.001$). Paraesophageal hernia was present in 50% of Nissen patients.

Quality of life after MSA, Toupet, and Nissen fundoplication

The MSA and Nissen fundoplication patients’ QOL questionnaire responses, RSI, GERD-HRQL, and dysphagia score, did not differ upon 1- or 2-year follow-up (Table 4).

Table 1 Patient characteristics

	MSA	Toupet	Nissen	<i>p</i> -value
Total patients, <i>N</i>	27	66	34	
Age (years) [mean ± SD]	56 ± 11	66 ± 13	67 ± 9	< 0.001 ^{b,c}
Body mass index [mean ± SD]	29.4 ± 4.6	30.1 ± 0.2	29.3 ± 3.8	0.578
Male [<i>N</i> (%)]	11 (40.7)	21 (31.8)	11 (32.4)	0.695
Smoking status [<i>N</i> (%)]				0.511
Never	20 (74.1)	41 (62.1)	18 (52.9)	
Former	7 (25.9)	24 (36.4)	15 (44.1)	
Current	0 (0.0)	1 (1.5)	1 (2.9)	
Prior medical history [<i>N</i> (%)]				
Myocardial infarction/coronary artery disease	0 (0.0)	5 (7.6)	5 (14.7)	0.105
Hypertension requiring medication	7 (25.9)	29 (43.9)	16 (47.1)	0.193
Pneumonia	2 (7.4)	5 (7.6)	4 (11.8)	0.754
Chronic obstructive pulmonary disease	0 (0.0)	1 (1.5)	0 (0.0)	0.628
Diabetes	1 (3.7)	6 (9.1)	5 (14.7)	0.341
Preoperative symptoms [<i>N</i> (%)]				
Reflux	19 (70.4)	51 (77.3)	32 (94.1)	0.046 ^c
Heartburn	19 (70.4)	50 (75.8)	27 (79.4)	0.716
Regurgitation	17 (63.0)	43 (65.2)	22 (64.7)	0.980
Dysphagia	10 (37.0)	24 (36.4)	11 (32.4)	0.907
Cough	9 (33.3)	18 (27.3)	12 (35.3)	0.674
Epigastric chest pain	9 (33.3)	22 (33.3)	7 (20.6)	0.381
Preoperative proton pump inhibitor use [<i>N</i> (%)]	24 (88.9)	58 (87.9)	29 (85.3)	0.903
Preoperative DeMeester score [median (Q1–Q3)]	34 (29–46)	39 (28–55)	31 (25–40)	0.455

MSA magnetic sphincter augmentation, SD standard deviation, Q1 first quartile, Q3 third quartile

^bMSA vs. Toupet *p* < 0.05

^cMSA vs. Nissen *p* < 0.05

So there were no differences in patient-reported atypical or typical GERD symptoms after MSA or Nissen fundoplication. However, when compared to Toupet fundoplication, MSA had a worse GERD-HRQL score at 1-year follow-up (8.5 ± 6.1 versus 3.1 ± 4.0 , $p = 0.005$) along with worse RSI (14.6 ± 11.0 versus 3.3 ± 4.1 , $p = 0.016$) and GERD-HRQL score at 2-year follow-up (7.9 ± 5.7 versus 1.3 ± 1.5 , $p = 0.010$). Toupet fundoplication patients also had a better GERD-HRQL score than Nissen fundoplication patients (1.3 ± 1.5 versus 6.3 ± 7.9 , $p = 0.01$).

Discussion

GERD is a multifactorial disease that can lead to the deterioration of the GEJ. Surgical management aims to tighten the GEJ and prevent pathologic acid reflux. Nissen fundoplication is the most effective treatment for GERD, although patients contemplating surgery are often wary of postoperative dysphagia and gas-bloat. The short and floppy fundoplication has been shown to combat these side effects [5]. A partial fundoplication such as the Toupet is just as effective in managing GERD symptoms with a lower rate of

dysphagia and gas-bloat [14–18]. The advantages of MSA include having a standard operating technique, no permanent alteration of gastric anatomy, and being reversible. The MSA device consists of a ring of magnetic beads with intrinsic forces that are strong enough to keep the ring close; however, weak enough to open and accommodate food bolus transit and belching with ease. There MSA is an attractive operation due to the ability of the magnetic ring to partially open for belching and allow for gastric decompression in contrast to Nissen fundoplication [19].

Our study describes impedance planimetry values after MSA in an attempt to understand how MSA affects the GEJ. After the MSA device is implanted, we see that the minimum diameter, CSA, and DI are significantly lower than Nissen or Toupet fundoplication. Without the passage of a food bolus being propagated by a peristaltic wave or belching through increased gastric pressure, the MSA device remains in its firm closed configuration, preventing pathologic reflux. This configuration may explain why the FLIP balloon pressure is also higher after MSA, resulting in a lower calculated DI, a quantitative representation of a tighter GEJ. MSA patients in our study had a mean DI 1.9 ± 0.8 mm²/mmHg, which would cause concern for postoperative dysphagia. Especially

Table 2 Perioperative and postoperative data

	MSA	Toupet	Nissen	<i>p</i> -value
Total patients, <i>N</i>	27	66	34	
ASA Class 3 or 4 [<i>N</i> (%)]	6 (22.2)	24 (36.4)	14 (41.2)	0.277
Hernia type [<i>N</i> (%)]				<0.001 ^{b,c}
None	13 (48.1)	15 (22.7)	6 (17.6)	
I	13 (48.1)	8 (12.1)	11 (32.4)	
III	1 (3.7)	43 (65.2)	17 (50.0)	
Operating room time (min, mean ± SD)	87 ± 27	126 ± 38	131 ± 33	<0.001 ^{b,c}
Estimated blood loss [mL, median (Q1–Q3)]	2 (1–5)	5 (5–10)	10 (5–15)	<0.001 ^{b,c}
Redo surgery [<i>N</i> (%)]	1 (3.7)	2 (3.0)	0 (0.0)	0.560
MSA size/number of beads (mean ± SD)	15 ± 1	–	–	–
Mesh use [<i>N</i> (%)]	2 (7.4)	56 (84.8)	24 (70.6)	<0.001 ^{b,c}
Intraoperative complication [<i>N</i> (%)]	0 (0.0)	2 (3.0)	0 (0.0)	0.391
Length of stay [h, median (Q1–Q3)]	7 (7–8)	24 (24–32)	24 (11–29)	<0.001 ^{b,c}
Pain at discharge, VAS [median (Q1–Q3)]	3 (1–4)	2 (0–4)	3 (2–3)	0.966
Medication stopped [days, median (Q1–Q3)]	2 (1–3)	2 (1–3)	1 (0–4)	0.347
Return to ADL [days, median (Q1–Q3)]	4 (2–7)	4 (2–7)	3 (1–7)	0.924
30-Day mortality [<i>N</i> (%)]	0 (0.0)	0 (0.0)	0 (0.0)	–
30-Day complication [<i>N</i> (%)]	4 (14.8)	5 (7.6)	1 (2.9)	0.230
30-Day ED visit [<i>N</i> (%)]	1 (3.7)	10 (15.2)	4 (11.8)	0.300
30-Day readmission [<i>N</i> (%)]	1 (3.7)	6 (9.1)	3 (8.8)	0.662
All symptoms resolved [<i>N</i> (%)]	12 (44.4)	38 (57.6)	17 (50.0)	0.480
Off proton pump inhibitor [<i>N</i> (%)]	21 (91.3)	59 (93.7)	25 (86.2)	0.500
Follow-up [months, median (Q1–Q3)]	11 (3–18)	8 (2–13)	14 (3–18)	0.049 ^a

MSA magnetic sphincter augmentation, ASA American Society of Anesthesiologists, SD standard deviation, ADL activities of daily living, ED emergency department

^aNissen vs. Toupet *p* < 0.05

^bMSA vs. Toupet *p* < 0.05

^cMSA vs. Nissen *p* < 0.05

when previous work showed that a DI < 2.0 mm²/mmHg was associated with more gas–bloat and dysphagia [3]. However, when comparing our MSA and Nissen patients, similar in the degree of wrapping around the esophagus, their QOL scores did not differ. Another reason for the lower DI after MSA may be related to our operative technique. In Nissen and Toupet fundoplication, the wrap is created over a bougie, resulting in a minor dilation of the GEJ. The bougie is removed after fundoplication. Only the FLIP catheter is in the GEJ for measurements at the end of the operation. MSA is sized without a bougie, so there is nothing in the GEJ to withstand the initial tightening from the magnetic beads. We have to consider that the magnetic beads may affect the sensors within the FLIP catheter; however, to what degree remains to be studied.

Interestingly, our analysis revealed that Toupet fundoplication patients had the best QOL scores, even though their final intraoperative DIs were no different from Nissen fundoplication, mean DI of 3.5 mm²/mmHg. However, there is a divide between the best anti-reflux treatments within the surgical community. Impedance planimetry may remedy this

issue as we learn more about how each operation affects the GEJ. When performing a fundoplication, our target DI is between 2 and 3.5 mm²/mmHg, since previous work in our lab reported better patient-reported outcomes in this range [3]. As FLIP and outcomes data after MSA accumulates, we anticipate an analysis of DI thresholds or ranges associated with postoperative side effects such as dysphagia or gas–bloat. For example, if a patient demonstrated a normal distensibility, a larger magnetic ring size, such as three sizes over where the measuring device “pops,” may provide symptomatic control of GERD along with decreased dysphagia.

We postulate that the difference in QOL between Nissen and Toupet may be due to each operation's different anatomical configurations. A Toupet fundoplication accentuates the angle of His recreating a flap valve with the ability for anterior radial expansion, which allows the ability to vent air. The 360-degree wrap in a Nissen fundoplication leads to a tight nipple valve, seemingly a one-way valve, seen on postoperative endoscopy [20]. In addition, a total fundoplication results in a neo-high pressure zone at the GEJ that cannot relax compared to a

Table 3 Intraoperative FLIP measurements

Time point	Measurement	MSA <i>N</i>	Toupet <i>N</i>	Nissen <i>N</i>	<i>p</i> -value
		Mean ± SD	Mean ± SD	Mean ± SD	–
Hernia reduction	<i>N</i>	<i>N</i> =24	<i>N</i> =59	<i>N</i> =24	
	D_{\min} (mm)	12.8 ± 2.8	13.1 ± 2.5	15.6 ± 2.2	<0.001 ^{a,c}
	Pressure (mmHg)	26 ± 6	27 ± 9	24 ± 6	0.410
	CSA (mm ²)	135 ± 57	143 ± 59	197 ± 56	<0.001 ^{a,c}
	DI (mm ² /mmHg)	5.6 ± 2.8	5.7 ± 2.7	8.6 ± 2.7	<0.001 ^{a,c}
Crural closure	<i>N</i>	<i>N</i> =26	<i>N</i> =59	<i>N</i> =30	
	D_{\min} (mm)	9.9 ± 2.1	9.8 ± 2.0	10.7 ± 2.1	0.124
	Pressure (mmHg)	32 ± 7	32 ± 8	28 ± 6	0.047 ^a
	CSA (mm ²)	79 ± 33	79 ± 32	93 ± 35	0.117
	DI (mm ² /mmHg)	2.6 ± 1.4	2.5 ± 1.2	3.5 ± 1.5	0.009 ^a
Final MSA/fundoplication	<i>N</i>	<i>N</i> =27	<i>N</i> =65	<i>N</i> =34	
	D_{\min} (mm)	9.0 ± 1.8	11.9 ± 2.2	12.2 ± 2.3	<0.001 ^{b,c}
	Pressure (mmHg)	36 ± 7	33 ± 9	35 ± 7	0.137
	CSA (mm ²)	66 ± 26	113 ± 43	119 ± 43	<0.001 ^{b,c}
	DI (mm ² /mmHg)	1.9 ± 0.8	3.5 ± 1.3	3.5 ± 1.4	<0.001 ^{b,c}
Change from hernia reduction to final*	<i>N</i>	<i>N</i> =24	<i>N</i> =59	<i>N</i> =24	
	D_{\min} (mm)	−3.9 ± 2.4	−1.1 ± 2.9	−3.7 ± 2.4	<0.001 ^{a,b}
	Pressure (mmHg)	12 ± 7	8 ± 7	12 ± 7	0.012 ^a
	CSA (mm ²)	−70 ± 49	−27 ± 68	−81 ± 54	<0.001 ^{a,b}
	DI (mm ² /mmHg)	−3.8 ± 2.4	−2.1 ± 2.7	−5.3 ± 2.2	<0.001 ^{a,c}

MSA magnetic sphincter augmentation, D_{\min} minimum diameter, CSA cross-sectional area, DI distensibility index, SD standard deviation

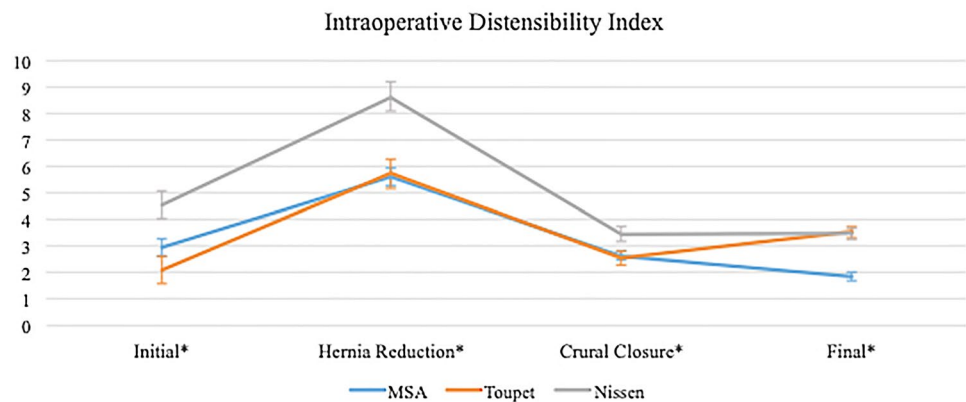
*All changes in measurements from hernia reduction to final are $p < 0.05$

^aNissen vs. Toupet $p < 0.05$

^bMSA vs. Toupet $p < 0.05$

^cMSA vs. Nissen $p < 0.05$

Fig. 1 Intraoperative distensibility during different time points in the operation. *Statistically significant difference between groups, $p < 0.05$



partial fundoplication, which would have a lower GEJ resting pressure and ability to vent [18, 21, 22]. This leads us to believe that the DI provided by impedance planimetry may not be a sole predictor of patient outcomes; however, a supplement in learning how postoperative side effects develop after fundoplication.

Limitations in this study include a small sample of patients for comparison. In addition, our practice selectively performs Nissen fundoplication, leading to a majority of Toupet fundoplication. Around 5 to 10 MSA operations are performed per year. After a comprehensive esophageal workup demonstrating GERD, if the patient has normal

Table 4 Quality of life scores

	MSA Mean ± SD	Toupet Mean ± SD	Nissen Mean ± SD	<i>p</i> -value
Preop	<i>N</i> =18	<i>N</i> =36	<i>N</i> =17	
RSI	19.7±10.5	17.3±9.0	19.5±10.7	0.699
GERD-HRQL	18.8±9.6	13.3±9.3	20.7±12.2	0.041 ^a
Dysphagia	1.3±0.5	1.3±0.6	1.3±0.7	0.722
Gas/bloat	1.8±1.4	2.0±1.3	2.1±1.6	0.863
3WPO	<i>N</i> =8	<i>N</i> =21	<i>N</i> =11	
RSI	11.0±3.3	12.8±9.6	8.9±6.3	0.548
GERD-HRQL	6.7±5.9	6.7±5.0	3.5±3.4	0.230
Dysphagia	2.0±0.5	2.5±1.1	1.8±0.4	0.155
Gas/bloat	1.1±1.5	2.3±1.4	1.4±0.8	0.0701
6MPO	<i>N</i> =6	<i>N</i> =15	<i>N</i> =4	
RSI	6.3±6.1	7.1±7.7	7.7±11.6	0.896
GERD-HRQL	4.5±4.3	5.4±8.4	1.0±0.8	0.318
Dysphagia	1.2±0.4	1.3±0.9	1.0±0.0	0.730
Gas/bloat	0.8±1.2	1.8±1.6	1.3±0.6	0.362
1YPO	<i>N</i> =11	<i>N</i> =34	<i>N</i> =12	
RSI	11.1±5.8	6.8±7.9	6.2±5.2	0.061
GERD-HRQL	8.5±6.1	3.1±4.0	5.5±5.4	0.005 ^b
Dysphagia	1.3±0.5	1.1±0.4	1.3±0.5	0.382
Gas/bloat	1.7±1.3	1.8±1.4	1.9±1.2	0.875
2YPO	<i>N</i> =8	<i>N</i> =11	<i>N</i> =18	
RSI	14.6±11.0	3.3±4.1	11.1±11.2	0.016 ^b
GERD-HRQL	7.9±5.7	1.3±1.5	6.3±7.9	0.010 ^{a,b}
Dysphagia	1.3±0.5	1.0±0.0	1.2±0.4	0.259
Gas/bloat	1.8±1.6	1.3±1.3	1.9±1.3	0.453

MSA magnetic sphincter augmentation, RSI reflux symptom index, GERD-HRQL gastroesophageal reflux disease-health related quality of life, SD standard deviation, YPO years postoperatively

^aNissen vs. Toupet *p*<0.05

^bMSA vs. Toupet *p*<0.05

^cMSA vs. Nissen *p*<0.05

esophageal motility, no allergy to titanium, stainless steel, nickel or ferrous material, no need for frequent MRI (MRI system up to 1.5 T), and insurance approval, then their surgical options would include MSA. These patients are provided with information about LF and MSA. The younger patients seem to gravitate toward an operation that is considered reversible. In our cohort there was a significant difference in the presence of type III hiatal hernia between patients who had MSA, one patient, compared to over 50% of patients in each fundoplication group. The paraesophageal hernias require extensive dissection compared to patients without hiatal hernia, so it may be difficult to compare outcomes. Therefore, a profound impact on the analysis and interpretation of our data has to be considered. Continued collection of FLIP data in MSA patients will further our understanding of optimizing MSA for patients suffering from GERD.

A comparison of FLIP in the subset of patients with GERD and minimal to no hiatal hernia would be ideal, however, there were not enough patients in our database for a meaningful analysis. Therefore, this will be an important question we aim to answer. QOL surveys are sent to patients electronically regularly. However, responses vary due to patient time constraints, access to a computer, or patient symptoms. Finally, there is a lack of objective data in GERD resolution, such as postoperative acid monitoring or endoscopy, unless clinically indicated.

Conclusion

Intraoperative impedance planimetry showed that GEJ CSA and DI are lower after MSA than Nissen and Toupet fundoplication. The lower FLIP values may be due to the magnetic forces of the MSA device that keep the GEJ firmly closed, preventing acid reflux while able to open during food bolus transit and belching transiently. Even though the GEJ DI after MSA is lower than Nissen, representing a tighter sphincter, QOL scores are no different. Further research is required to fully understand how to utilize impedance planimetry in the setting of MSA.

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