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Strategies for surgical remediation of the multi-fundoplication failure patient

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Abstract

Background Outcomes are not well studied in patients undergoing remediation for multi-fundoplication failure, that is, two or more prior failed fundoplications. Re-operation must balance reflux control and restoration of the ability to eat with the challenge of reconstructing a distorted hiatus and GE junction. The purpose of this study is to present our experience with surgical remediation for multi-fundoplication failure.

Methods Medical records were retrospectively reviewed of 91 patients who underwent third time or more esophagogastric operation for fundoplication failure at a single institution from 2007 to 2016. Dysphagia was present in 56% and heartburn in 51%. Median number of prior operations was 2 with range up to 6. Anatomic failure consisted of slipped wrap in 26 cases, wrap herniation in 23, hiatal stenosis in 24, hiatal mesh complication in 8, and wrap dehiscence in 10. Operative approaches generally followed an institutional algorithm and consisted of hiatal hernia repair with: re-do fundoplication in 55%, takedown of fundoplication alone in 24%, Roux-en-Y gastrojejunostomy in 14%, and GE junction resection in 7%. Laparoscopic approach was successful in 81%.

Results Mean duration of operations was 217 min and median length of stay was 3 days. The complication rate was 13%, with 7% undergoing unplanned early re-operation. Patients were followed for mean 11 months, and recurrent hiatal hernia was detected in 13%. Late re-operation was performed in 6% for recurrent hiatal hernia. Recurrent reflux symptomatology resolved in 93%. Dysphagia resolved in 84%. There were no significant differences in outcomes with regard to number of prior operations, operative approach, BMI, or age.

Conclusions There is no single best approach to remediation in the multi-fundoplication failure patient. Re-do fundoplication is appropriate in over half of patients. Reoperation for multi-fundoplication failure can be performed via minimally invasive approach with excellent remediation of symptoms, low morbidity, and low recurrence rates.

Keywords Fundoplication failure · Laparoscopy · Outcomes

Fundoplication is the surgical treatment of choice for gastroesophageal reflux disease refractory to medical management or in the setting of GERD-related complications. Satisfactory symptom control is attained in up to 90% of patients at 5 years post-operatively [1]. Laparoscopic approach, first applied in the 1990s, is generally considered standard of care, with advantages including decreased operative times, length of stay, morbidity, and overall costs [2, 3]. However, the rate of failure of fundoplication for GERD has variably been reported in the 2–30% range. Fundoplication failure results when reflux symptomatology recurs or new foregut symptoms arise, with an anatomical etiology based on objective testing. Classification of fundoplication failure has been previously described but invariably includes categorization of a combination of disrupted, misplaced, and/or herniated fundoplication [4].

Remediation for fundoplication failure remains a heavily contested topic with regard to optimal approach. There is an even greater paucity of data to guide management of patients who have undergone two or more prior failed antireflux operations, which we term multi-fundoplication failure. In one of

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the largest series examining results of reoperation for fundoplication failure, Smith and colleagues found that the rate of anatomic failure was 33%, while the rate of symptom failure was 7% [5]. In a systematic review of 4509 patients over 81 studies (with 5% undergoing revision for multi-fundoplication failure), Furnée and colleagues found that the symptomatic indication for revision was recurrent reflux in 42% and dysphagia in 17%, with intra-operative findings of fundoplication herniation in 28% and fundoplication disruption in 23%. Gastric or esophageal resection was performed in 7% of cases. Symptom resolution success rate was 81%, similar to findings in another systematic review [6, 7]. Little and colleagues found that patients who had undergone three or more re-operations had significantly more dysphagia and suffered more complications. This group advocated consideration of resection at second re-operation [8]. Other groups have advocated conversion to Roux-en-Y reconstruction. Makris and colleagues noted significant improvement in reflux symptom scores and reduction in BMI to the non-obese range in their patients undergoing Roux-en-Y reconstruction for failed antireflux surgery, 38% of whom had two or more prior anti-reflux operations [9]. Control of reflux symptoms is attainable in patients with morbid obesity and multi-fundoplication failure [10]. Awais et al. reported results from a large series of patients undergoing Roux-en-Y near-esophagojejunostomy, nearly half of whom had undergone multiple prior antireflux operations [11]. These patients had similarly improved outcomes with normalization of BMI and resolution of reflux symptomatology. In contrast, in a series of patients with multi-fundoplication failure who were predominantly treated with Roux-en-Y gastrojejunostomy (68%), Mittal and colleagues reported a Clavien-Dindo grade ≥ 3 morbidity rate of 17%. They also observed higher rates of persistent severe symptoms and lower rates of satisfaction in comparison to patients who had undergone only one prior revisional antireflux operation [12].

The optimal approach to revision of multi-fundoplication failure remains to be elucidated. While expert reconstruction of a previously mal-positioned fundoplication may achieve success in one patient, other patients may be more appropriately served with resection if prior operations have too greatly distorted the anatomy of the gastroesophageal junction (GEJ), or Roux-en-Y reconstruction if morbid obesity is present. Herein we describe our experience with remedial operative intervention for multi-fundoplication failure, and present our institution's algorithm to optimize patient satisfaction and minimize further re-operation.

Table 1 Demographics of patients with multi-fundoplication failure

Median age (years)	59 (IQR 50–67, range 15–79)
Mean BMI (kg/m^2)	26.8 (SD $\pm$ 5.3)
Gender distribution	21 (23%) male/70 (77%) female
Personal history of other hernias	16 (18%)
Airway disease	21 (23%)
Barrett esophagus	14 (15%)

Table 2 Symptoms of patients with multi-fundoplication failure

Dysphagia	51 (56%)
Pyrosis	46 (50%)
Regurgitation	32 (35%)
Chest/abdominal pain	24 (26%)
Weight loss	24 (26%)
Airway complaints/respiratory problems	14 (15%)

Methods

Patients and pre-operative evaluation

From 2007 to 2016, 91 patients underwent second time or more revisional fundoplication and/or hiatal hernia repair at a single tertiary-referral center. Mayo School of Graduate Medical Education Institutional Review Board approval was obtained for this research protocol (#11-007575). Prospectively collected data were maintained in a computerized database (Excel, Microsoft, Redmond, WA) and were retrospectively reviewed. Demographics are presented in Table 1 and include gender distribution, age, and BMI. Pertinent co-morbidities were history of abdominal wall hernia in 16 patients, airway disease in 21 patients, and Barrett esophagus in 14 patients. Presenting symptoms were dysphagia and/or pyrosis in over half, and a third or less complained of regurgitation, chest/abdominal pain, weight loss, and/or airway complaints (Table 2). All patients had undergone two or more prior operations: 74 had two prior operations, 14 had three prior operations, and one each had four, five, and six prior operations (Table 3). All patients were studied with UGI and flexible upper endoscopy prior to operation, and selectively underwent manometry, pH testing, and/or nuclear gastric emptying study. Primary indications for operation based on objective findings in order of decreasing frequency were most commonly slipped fundoplication, herniated fundoplication, and hiatal stenosis (roughly a quarter each). The remaining patients were offered remedial operation because of mesh complications or disrupted fundoplication (Table 4).

Table 3 Details of prior operations in patients with multi-fundoplication failure stratified by operative approach

	Re-do fundoplication ($n=50$)	GEJ resection ($n=6$)	Roux-en-Y GJ ($n=13$)	Takedown alone ($n=22$)	Total ($n=91$)
Prior open operation	15 (30%)	6 (100%)	3 (23%)	6 (27%)	30 (33%)
Prior hiatal mesh	10 (20%)	4 (67%)	4 (31%)	4 (18%)	22 (24%)
Prior collis gastroplasty	1 (2%)	0	0	2 (9%)	3 (3%)
Number of prior operations					
2	46 (92%)	3 (50%)	8 (61%)	17 (77%)	74 (81%)
3	3 (6%)	3 (50%)	3 (23%)	5 (23%)	14 (15%)
4	1 (2%)	0	0	0	1 (1%)
5	0	0	1 (8%)	0	1 (1%)
6	0	0	1 (8%)	0	1 (1%)

Table 4 Indications for revisional operation in patients with multi-fundoplication failure

Slipped fundoplication	26 (29%)
Hiatal stenosis	24 (26%)
Herniated fundoplication	23 (25%)
Disrupted fundoplication	10 (11%)
Mesh complication	8 (9%)

Operative technique

Selection of operative technique generally proceeds according to the algorithm is presented in Fig. 1. Patients with deformity of the distal esophagus and proximal stomach that is non-reconstructible due to non-viability undergo segmental resection with Roux-en-Y esophagojejunostomy or gastric pull-up. Patients in which co-morbid obesity was felt to be complicit in causing fundoplication failure were offered fundoplication takedown with conversion to Roux-en-Y gastrojejunostomy. Patients with severe dysphagia and GEJ stenosis on pre-operative imaging or endoscopy and resultant anatomy not amenable to repeat fundoplication undergo fundoplication takedown alone. Patients with amenable anatomy and primary complaint of recurrent regurgitation and/or pyrosis undergo re-do fundoplication.

Laparoscopic re-operation is initiated with patients in the split-leg position. Adhesions of the prior fundoplication and stomach to the hiatus and inferior surface of the liver are meticulously lysed. Previously placed hiatal mesh is excised. Short gastric arteries are transected to fully mobilize the fundus if not done previously. If herniated, the wrap is reduced into the abdomen. The prior fundoplication is completely taken apart to re-establish normal anatomy. High mediastinal dissection is performed to obtain adequate intra-abdominal esophageal length. Attempts are made to preserve the vagi in all cases, but if inadvertent vagotomy is felt to have occurred, then this influences conservative decision making to place a gastrostomy tube to ameliorate post-operative gastric distention. Pyloroplasty is concomitantly performed when gastroparesis has been diagnosed pre-operatively. Stapled wedge Collis gastroplasty as described by Terry et al. is performed when inadequate length is obtained [13]. Stapled fundectomy is performed when takedown of the wrap results in ischemia or injury to this part of the stomach. The hiatus is closed with non-absorbable interrupted sutures. Pledgets of Teflon or acellular fetal bovine dermis matrix are used selectively per surgeon preference when the crural pillars subjectively appear attenuated or a large amount of tension is created with re-approximation. Re-do fundoplication is calibrated around a 50–60 Fr bougie across the GEJ. If distal esophageal/proximal gastric anatomy is too severely distorted to permit fundoplication but is otherwise viable and non-ischemic, then no wrap is performed. Gastrostomy tube placement is performed at surgeon discretion based on manipulation of the stomach and concern for post-operative delayed gastric emptying, or desire for additional gastropexy. Conversion to Roux-en-Y gastrojejunostomy is the preferred approach when obesity is felt to be contributory to fundoplication failure. The five non-obese patients who underwent Roux-en-Y gastrojejunostomy were felt pre-operatively to possess a salvageable GEJ. However, it was anticipated that they would likely not have anatomy amenable to re-do fundoplication, yet still require a definitive operation to separate acid-producing stomach from esophagus. Roux-en-Y reconstruction generally is performed with 40-cm biliopancreatic limb and 60–80 cm alimentary limb. The Roux limb is routed in a retro-colic, retro-gastric fashion. Esophagojejunostomy is performed with a circular EEA stapler. Gastrojejunostomy is performed in double-layered hand-sewn fashion. The pouch and anastomosis are sized for weight loss. Enteroenterostomy is performed with double linear stapled technique. Mesenteric defects are routinely closed to prevent internal hernia.

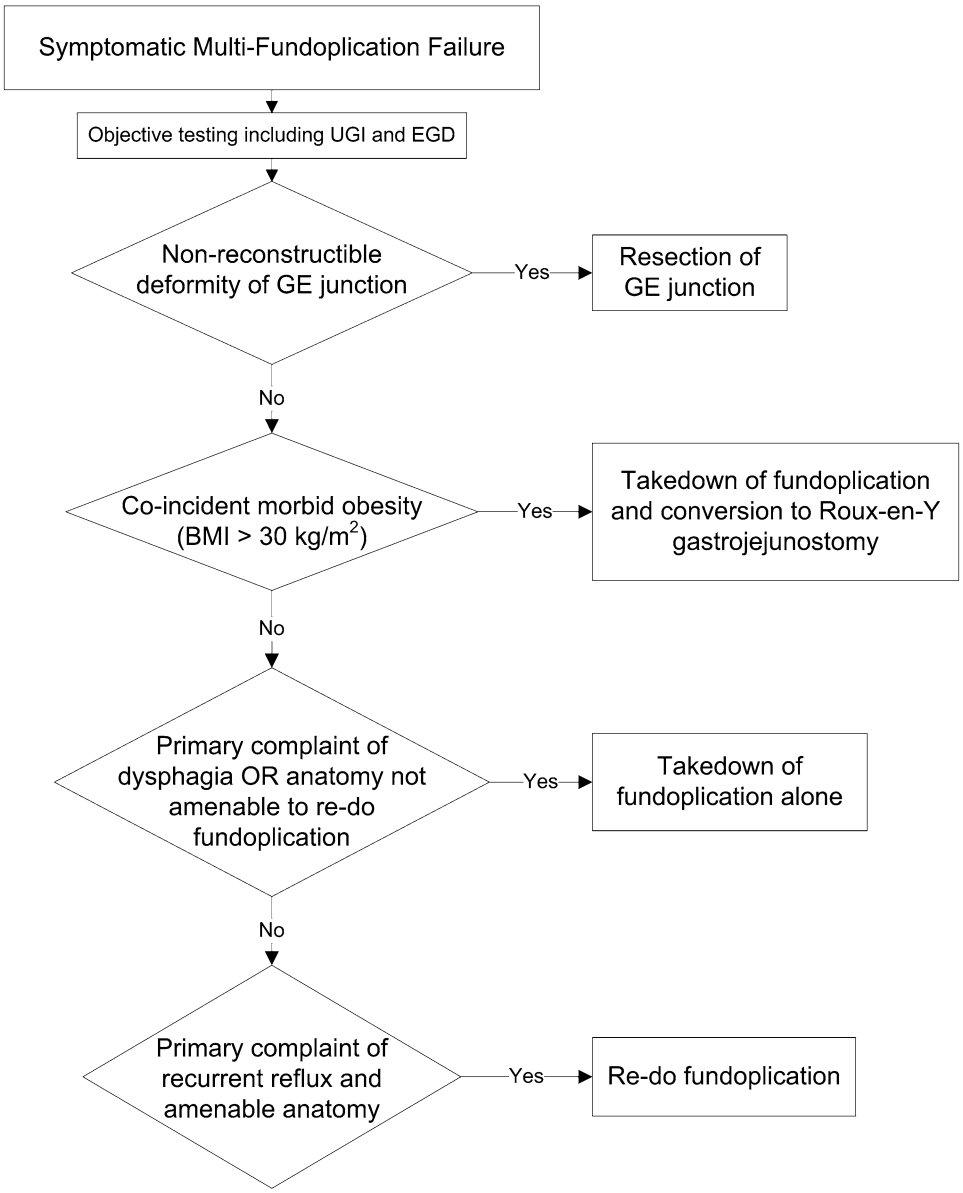

Fig. 1 Algorithm for selection of optimal surgical remediation for symptomatic multi-fundoplication failure

Post-operative care and follow-up

Routine post-operative care is provided and patients are studied with UGI prior to initiation of oral intake. Patients are discharged when they are able to tolerate a liquid diet. They are seen again in clinic with reassessment of symptoms at 2 weeks and 6 months post-operatively, and then on as-needed basis thereafter.

Statistical analysis

Data are expressed as median with interquartile range or mean with standard deviation, and overall range. Univariate statistical analysis was performed with ANOVA for continuous variables, and Chi-square or Fisher exact test for categorical variables. Statistical significance was considered as probability of type I error of $<5\%$, or p value of <0.05.

Results

Intra-operative outcomes

Operative approach was takedown and re-do fundoplication in 50 patients (55%), takedown of fundoplication alone in 22 patients (24%), takedown of fundoplication and conversion to Roux-en-Y gastrojejunostomy in 13 patients (14%), and GEJ resection with Roux-en-Y esophagojejunostomy or gastric pull-up in 6 patients (7%). The majority of patients undergoing re-do fundoplication underwent

Nissen fundoplication (60%), but when fundic tissue would not permit creation of an appropriately floppy complete wrap, then either Toupet (32%) or Dor (8%) fundoplication was performed depending on the compliance of gastric tissue. Patients who had two prior operations most commonly underwent re-do fundoplication (62%), whereas patients with three or more prior operations did not undergo one operative approach significantly more often than the alternatives (Table 3). The operative plan changed in 16 patients based on intra-operative findings: two patients underwent GEJ resection due to non-viable tissue after fundoplication takedown, and 14 patients underwent takedown of fundoplication alone due to insufficient fundus for re-do fundoplication. For those remaining eight out of 22 patients who underwent takedown of fundoplication alone, the decision had been made pre-operatively to not attempt re-do fundoplication because of a primary complaint of dysphagia and as part of informed and shared decision making with patients who wished to avoid major resection or reconstruction with Roux-en-Y gastrojejunostomy. Non-reconstructible deformities of the GE junction that required resection were in one case due to mesh erosion, in two cases due to major GEJ injury as a consequence of dissecting a severely scarred hiatus, and in another two cases due to severe non-dilatable GEJ stricture with hiatal stenosis. The sixth patient who was treated with resection underwent gastrectomy for both severe GERD refractory to two prior Nissen fundoplications and severe gastroparesis refractory to prior pyloroplasty. Patients undergoing takedown of fundoplication and conversion to Roux-en-Y gastrojejunostomy had a higher mean BMI compared to others in the series (32.7 kg/m^2 vs. 25.8 kg/m^2, $p<0.05$). Finally, there was no statistically significant increased risk of undergoing GEJ resection if patients had undergone three or more prior operations versus two prior operations (17.6% vs 6.4%, $p=0.39$). This was similarly true for patients undergoing takedown alone (29.4% vs 23%, $p=0.55$).

Laparoscopic approach was successful in 74 cases (81%). Out of the remaining 17 cases, 14 were executed via laparotomy, and three were initiated laparoscopically but were converted to open procedures (one laparotomy, two thoracolaparotomy). Pyloroplasty was performed in six patients undergoing takedown and re-do fundoplication, and had been previously performed in four patients who underwent alternate operative approaches. Partial stapled fundectomy was necessary in 13 cases (14%) due to either devascularization of a segment of the fundus or gastrotomy during dissection. Gastrostomy for anterior gastropexy or drainage in anticipation of delayed gastric emptying was performed in 58 cases (64%). Biomaterial buttress of the hiatus was used in 11 cases (12%). Diaphragmatic relaxing incisions to enable crural closure were necessary in only two cases. Collis gastroplasty to address esophageal foreshortening was necessary in only one case. Esophagotomy and/or gastrotomy were identified intraoperatively and immediately repaired in four cases with no further deleterious sequelae. Average length of case was 217 min.

Peri-operative outcomes

Peri-operative outcomes stratified by operative approach are presented in Table 5. Median patient length of stay was 3 days. The complication rate (including all grades of morbidity by Clavien-Dindo classification) was 12.1% and consisted of one gastrostomy leak requiring laparoscopic washout, one leak at site of longitudinal esophageal stricturoplasty requiring return to the operating room and GEJ resection, and one instance of leakage from an esophagotomy that had been recognized and repaired at the index operation but required return to the operating room for washout and repeat closure. There were two instances of hemorrhage successfully managed non-operatively, one chylothorax requiring thoracic duct ligation, one gastric outlet obstruction, one retching-related immediate post-op fundoplication herniation, one wound infection, and two episodes of pneumonia. The single mortality in this series was due to necrotizing pneumonia that occurred after discharge. Unplanned re-operation was necessary in six cases. When comparing instances of morbidity by operative approach, there was no statistically significant difference in occurrences ($p=0.65$). When comparing instances of morbidity by stratifying patients by two prior esophagogastric

Table 5 Peri-operative outcomes stratified by operative approach

	Re-do fundoplication ($n=50$)	GEJ Resection ($n=6$)	Roux-en-Y GJ ($n=13$)	Takedown alone ($n=22$)	Total ($n=91$)	p value
Mean length of surgery (min)	201 (SD ± 87.3)	272 (SD ± 110)	266 (SD ± 49)	206 (SD ± 61)	217 (SD ± 83)	**< 0.05**
Median length of stay (days)	3 (IQR 2–4)	11 (IQR 8–17)	5 (IQR 3–6)	3 (IQR 2–6)	3 (IQR 2–5)	**< 0.05**
Morbidity	8 (16%)	0 (0%)	2 (15%)	2 (9%)	12 (13%)	0.65
30-day mortality	0 (0%)	0 (0%)	1 (8%)	0 (0%)	1 (1%)	0.11

Statistical significant values are given in bold

operations versus third time or more operation, there was no statistically significant difference in occurrences ($p=0.69$).

Follow-up

Patients were followed for mean 11 months. Symptom resolution was determined by direct patient questioning during post-operative clinic encounters. Resolution of heartburn was realized in 89% of cases. Resolution of regurgitation was realized in 84% of cases. Dysphagia resolved in 82% of cases. Of the patients who had persistent/new foregut symptoms, 12 (13%) of these were found to have objective evidence of recurrent hiatal hernia. Less than half of these required repeat revisional operation (Table 6). The four patients who underwent repeat revisional operation include the following: one in the re-do group that had retching-related immediate post-op fundoplication herniation, and underwent takedown alone; one in the GE junction resection group who had been reconstructed with gastric conduit that later underwent re-operation Roux-en-Y hepaticojejunostomy for severe refractory bile reflux; one in the takedown alone group that later underwent GEJ resection; and one more in the takedown alone group that required re-do hiatal hernia repair. When comparing resolution of heartburn, regurgitation, and dysphagia by operative approach, there were no statistically significant differences (Table 6). New onset symptoms of heartburn (9%), regurgitation (12%), and dysphagia 3% were not significantly different between operative approaches. When comparing rates of recurrent hiatal hernia and need for repeat revisional operation by operative approach, again there were no statistically significant differences (Table 6). Biomaterial buttress of the hiatus was used in seven instances during re-do fundoplication and in follow-up there were no hiatal hernia recurrences, but this was not statistically significant and mean follow-up in this group was shorter at 4 months. Analysis of rates of symptom resolution, recurrent hiatal hernia, and need for repeat revisional operation with stratification by second revisional operation versus third-time or more revisional operation, again, showed no statistically significant differences as illustrated in Table 7.

Discussion

Over half of our patients underwent successful takedown and re-do fundoplication with excellent rates of symptom resolution, and low rates of recurrent fundoplication failure (13% recurrent hiatal hernia) or need for repeat revisional operation (6%). Our multiply re-do outcomes are comparable to first-time re-do fundoplication. We found that those patients having two versus three or more prior fundoplications had no significant differences with regard to recurrent failure, need for repeat revisional operation, symptom resolution, or morbidity. Additionally, we did not find that increased

Table 6 Post-operative outcomes stratified by operative approach

	Re-do fundoplication ($n=50$)	GEJ resection ($n=6$)	Roux-en-Y GJ ($n=13$)	Takedown alone ($n=22$)	Total ($n=91$)	p value
Mean duration follow-up (mo)	11 (range 1–76)	16 (range 1–84)	14 (range 1–69)	5 (range 1–56)	11 (range 1–84)	0.81
Resolution of heartburn	20/23 (87%)	2/3 (67%)	8/8 (100%)	11/12 (92%)	41/46 (89%)	0.44
Resolution of regurgitation	11/15 (73%)	2/2 (100%)	7/8 (88%)	7/7 (100%)	27/32 (84%)	0.32
Resolution of dysphagia	22/27 (82%)	3/3 (100%)	4/4 (100%)	13/17 (76%)	42/51 (82%)	0.56
Recurrent hiatal hernia	6 (12%)	1 (17%)	1 (8%)	4 (19%)	12 (13%)	0.81
Repeat surgical remediation	1 (2%)	1 (17%)	0 (0%)	2 (10%)	4 (4%)	0.20

Table 7 Peri-operative and post-operative outcomes stratified by number of prior failed fundoplication operations

	2 prior operations ($n=74$)	3 or more prior operations ($n=17$)	Total ($n=91$)	p value
Morbidity	9 (12.2%)	3 (17.6%)	12 (13%)	0.69
30-day mortality	0 (0%)	1 (5.1%)	1 (1%)	0.19
Resolution of heartburn	34/39 (87%)	7/7 (100%)	41/46 (89%)	1.0
Resolution of regurgitation	23/28 (82%)	4/4 (100%)	27/32 (84%)	1.0
Resolution of dysphagia	35/44 (80%)	7/7 (100%)	42/51 (82%)	0.33
Recurrent hiatal hernia	8 (11%)	4 (24%)	12 (13%)	0.23
Repeat surgical remediation	3 (4%)	1 (6%)	4 (4%)	0.57

number of prior operations prevented re-do fundoplication. The authors do not feel that there is a particular number of operations beyond which fundoplication revision should be contraindicated. The absolute number of prior operations is not as important as the quality of gastric and esophageal tissue after complete dissection and mobilization. The decision to leave a wrap undone versus proceeding with major resection is not made lightly, and all attempts are made at esophageal preservation, but the revisional foregut surgeon must be prepared for this when contemplating surgical re-intervention for the multiply failed fundoplication patient. Regarding the eight patients who underwent fundoplication takedown alone with pre-operative intent to do so, these patients had a primary complaint of dysphagia and their most important goal was relief of this symptom, accepting a high likelihood of recurrent GERD. Even though alternatives of resection or Roux-en-Y reconstruction are discussed during pre-operative counseling, decision making is shared and it is ultimately the final decision of the patient who may want to avoid the added risk of a more complex operation.

Our strategy of aiming for revisional fundoplication did result in a change in operative plan in 16 patients. This was typically due to dense scar tissue or a non-reconstructible GE junction. Notably, resolution of heartburn, regurgitation, and/or dysphagia was still achieved in a high percentage of these patients. Resolution of the non-dysphagia symptoms would in these cases have to be attributable to strict adherence to anti-secretory therapy post-operatively, demonstrating the adjunctive importance of medical management in achieving success in this complicated patient population.

The distribution of anatomic causes of fundoplication failure in our population varied somewhat from that reported in systematic reviews of initial re-operation for fundoplication failure. In our series, approximately a quarter each of failures were due to wrap slippage, hiatal stenosis, and wrap herniation, with a low frequency of mesh-related complications and wrap disruption. Slipped fundoplication is due to failure to properly identify the GE junction and position the wrap appropriately. Wrap herniation may occur as a consequence of presence of foreshortened esophagus, insufficient mediastinal mobilization to enable adequate intra-abdominal esophageal length, inordinate tension with crural closure, or excessive abdominal pressure and diaphragm failure.

In the majority of our re-operative cases, we were able to dissect higher in the mediastinum than was apparently accomplished in prior operations, and achieve significantly greater esophageal mobilization. Thus, the need for esophageal lengthening procedures was quite low in our experience. Other series have reported rates as high as 49% [14]. Mesh complications arise from the use of permanent mesh at the hiatus, in which prior studies have shown to be associated with erosion [15], and even an increased risk of major resection at revisional operation as noted in a previously reported series from our institution [16]. In our experience, of the 22 patients with prior hiatal mesh, eight presented with mesh complications and six required major resection. The authors do appreciate a role for biomaterial buttress of the hiatus when tension or attenuation of the crural pillars is subjectively of concern, and in short-term follow-up we detected no hiatal hernia recurrences, though this was statistically non-significant. The durability of small intestinal submucosa biologic prosthesis for laparoscopic paraesophageal hernia repair was shown by Oelschlager et al. to be significantly diminished at long-term follow-up compared to short-term (59% vs. 9%) [17]. In a prior study analyzing factors associated with anatomic recurrence after laparoscopic repair of giant paraesophageal hernia, we found that use of biomaterial buttress consisting of acellular fetal bovine dermis was associated with a non-significant decrease in rate of recurrent hiatal hernia (27% vs. 37%) although with short median follow-up of 7 months [18]. The ideal material and configuration to minimize recurrent hiatal hernia have yet to be discovered. In selected cases, we implement a relaxing incision of the right crus with permanent mesh repair of the defect, but would caution against the use of permanent material against the esophagus.

Reconstruction with Roux-en-Y gastrojejunostomy is an approach to surgical remediation of the failed fundoplication that has been increasingly accepted [9–12]. Benefits include diversion from the esophagus of acidic gastric secretions as well as biliary refluxate, and surgical weight loss for the morbidly obese. In our current series, we were more restrictive with offering Roux-en-Y gastrojejunostomy (14% overall), though we identified no significant differences in outcome between those re-constructed with Roux-en-Y versus other approaches. Our selection of patients for Roux-en-Y gastrojejunostomy however is generally influenced by the goal of correcting a causative influence on fundoplication failure.

The vast majority of cases in this series were able to be completed laparoscopically, and our rate of conversion to open operation was low. Operative times for the multi-fundoplication failure patient were uniformly greater than 3 h, and still significantly greater for patients undergoing GEJ resection or Roux-en-Y gastrojejunostomy. Remedial operations for multi-fundoplication failure that must be performed meticulously to achieve the low rate of morbidity that we report.

The weaknesses of this study include the retrospective nature of chart review and non-randomization of surgical approaches. Ideally, we would be able to control for patient demographics such as morbid obesity, and number of prior operations and components of those such as prior use of mesh. Another weakness was relatively short follow-up in a number of patients. In order to ascertain the durability of our results, we would ideally be able to re-assess symptoms

and repeat objective studies to detect anatomical failure in a standardized fashion beyond several years. We hope that studies from other large foregut centers will allow greater comparison of reconstructive techniques in this challenging patient population.

In summary, we show that patients undergoing surgical remediation for multi-fundoplication failure can achieve high rates of symptom resolution with low rates of repeat revisional operation. We demonstrate that our institutional algorithm for remedial operation is appropriate to guide decision making for the multi-fundoplication failure patient.

Author contributions All listed authors made substantial contributions to the conception and design of this work as well as acquisition, analysis, and interpretation of data. All revised critically for important intellectual content. All gave final approval for publishing. All agree to be accountable for all aspects of the work to ensure questions related to accuracy/integrity of any part are appropriately investigated and resolved.

Compliance with ethical standards

Disclosures Drs. Michael Antiporda, C. Daniel Smith, Mathew Thomas, Enrique Elli, Steven P. Bowers, and Ms. Chloe Jackson have no relevant conflicts of interest or financial ties to disclose.

References

1. Robinson B, Dunst CM, Cassera MA, Reavis KM, Sharata A, Swanstrom LL (2015) 20 years later: laparoscopic fundoplication durability. Surg Endosc 29(9):2520–2524
2. Heikkinen TJ, Haukipuro K, Koivukangas P, Sorasto A, Autio R, Södervik H, Mäkelä H, Hulkko A (1999) Comparison of costs between laparoscopic and open Nissen fundoplication: a prospective randomized study with a 3-month followup. J Am Coll Surg 188(4):368–376
3. Ruiz-Tovar J, Diez-Tabernilla M, Chames A, Morales V, Martinez-Molina E (2010) Clinical outcome at 10 years after laparoscopic versus open Nissen fundoplication. J Laparoendosc Adv Surg Tech A 20(1):21–23
4. Hinder RA, Klingler PJ, Perdikis G, Smith SL (1997) Management of the failed antireflux operation. Surg Clin North Am 77(5):1083–1098
5. Smith CD, McClusky DA, Rajad MA, Lederman AB, Hunter JG (2005) When fundoplication fails: redo? Ann Surg 241(6):861–869 (**discussion 869–871**)
6. Furnée EJ, Draaisma WA, Broeders IA, Gooszen HG (2009) Surgical reintervention after failed antireflux surgery: a systematic review of the literature. J Gastrointest Surg 13(8):1539–1549
7. Van Beek DB, Auyang ED, Soper NJ (2011) A comprehensive review of laparoscopic redo fundoplication. Surg Endosc 25(3):706–712
8. Little AG, Ferguson MK, Skinner DB (1986) Reoperation for failed antireflux operations. J Thorac Cardiovasc Surg 91(4):511–517
9. Makris KI, Panwar A, Willer BL, Ali A, Sramek KL, Lee TH, Mittal SK (2012) The role of short-limb Roux-en-Y reconstruction for failed antireflux surgery: a single-center 5-year experience. Surg Endosc 26(5):1279–1286
10. Mittal SK, Légner A, Tsuboi K, Juhasz A, Bathla L, Lee TH (2013) Roux-en-Y reconstruction is superior to redo fundoplication in a subset of patients with failed antireflux surgery. Surg Endosc 27(3):927–935
11. Awais O, Luketich JD, Reddy N, Bianco V, Levy RM, Schuchert MJ, Gooding WE, Crist LR, Landreneau RJ, Pennathur A (2014) Roux-en-Y near esophagojejunostomy for failed antireflux operations: outcomes in more than 100 patients. Ann Thorac Surg 98(6):1905–1911. (**discussion 1911–1913**)
12. Singhal S, Kirkpatrick DR, Masuda T, Gerhardt J, Mittal SK (2018) Primary and redo antireflux surgery: outcomes and lessons learned. J Gastrointest Surg 22:177–186
13. Terry ML, Vernon A, Hunter JG (2004) Stapled-wedge Collis gastroplasty for the shortened esophagus. Am J Surg 188(2):195–199
14. Makdisi G, Nichols F, Cassivi S, Wigle D, Shen R, Allen M, Deschamps C (2014) Laparoscopic repair for failed antireflux procedures. Ann Thorac Surg 98:1261–1266
15. Stadlhuber RJ, Sherif AE, Mittal SK, Fitzgibbons RJ Jr, Brunt LM, Hunter JG, Demeester TR, Swanstrom LL, Smith CD, Filipi CJ (2009) Mesh complications after prosthetic reinforcement of hiatal closure: a 28-case series. Surg Endosc 23(6):1219–1226
16. Parker M, Bowers SP, Bray JM, Harris AS, Belli EV, Pfluke JM, Preissler S, Asbun HJ, Smith CD (2010) Hiatal mesh is associated with major resection at revisional operation. Surg Endosc 24(12):3095–3101
17. Oelschlager BK, Pellegrini CA, Hunter JG, Brunt ML, Soper NJ, Sheppard BC, Polissar NL, Neradilek MB, Mitsumori LM, Rohrmann CA, Swanstrom LL (2011) Biologic prosthesis to prevent recurrence after laparoscopic paraesophageal hernia repair: long-term follow-up from a multicenter, prospective, randomized trial. J Am Coll Surg 213(4):461–468
18. Antiporda M, Veenstra B, Jackson C, Kandel P, Daniel Smith C, Bowers SP (2018) Laparoscopic repair of giant paraesophageal hernia: are there factors associated with anatomic recurrence? Surg Endosc 32(2):945–954