# Revisional Foregut Surgery

Frank J. Borao
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*Editors*

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*I would like to dedicate this book to my wife, children and parents. Without their support this publication would not have been possible.*

*Thank you.*
*Frank J. Borao*

*For my loving parents, Larry and Tanya.*
*Steven Julian Binenbaum*

*I would like to dedicate this book to my parents, wife, and children. Without their collective and unwavering support, this would not have been possible. Thank you.*
*Gurdeep S. Matharoo*

# Foreword

The concept of a textbook detailing re-operative upper gastrointestinal surgery is meant to stimulate thinking about re-operative dilemmas. These problems are shared by experienced surgeons who have tackled challenges, usually with laparoscopic approaches. The hostile abdomen is factored into all situations. The success of any approach is tempered by the occasional conversion to open surgery. A safe approach and a good outcome are usually correlated with the skill set of the surgeon.

Most procedures have learning curves, but the variants described in this text are sometimes unique in a surgeon's practice. Occasionally, surgeons seek opinions from other surgeons, and even intraoperative consultation is not rare. The availability of another surgeon for advice is one of the strengths of a robust department of surgery but unavailable in many hospitals.

New laparoscopic operations have spawned new complications. These complications have compelled surgeons to reverse, modify, adjust, or abandon certain procedures. No operation is without complication but some complications are devastating and deadly. The progress in preoperative assessment of the patient, tailoring the proper operation, and assessing patient compliance does not guarantee the operative course. The ability of a surgeon to deal with operative complications is a skill set that requires extensive experience and judgment.

The cases detailed in the book are meant to help surgeons show the "way." The authors have common dominators that they have contributed to their approaches. One approach they agree to is that if a result is "bad," a review of technique often prevents future mishaps, and if the result is "good," the approach is worth documenting and explaining to other surgeons.

The chapter authors are surgeons with integrity and innovative, curious natures. They represent a collegial group who often speak to each other about difficult cases. One of the greatest joys I have had in my career is the honor of being asked to write this foreword by former residents I have helped train. All of the authors feel privileged to share their efforts with the reader and welcome feedback.

Sincerely,

Michael A. Goldfarb, MD, FACS
Department of Surgery, Monmouth Medical Center,
Long Branch, NJ, USA

# Special Acknowledgment

The reason this textbook of revisional surgery came to fruition was because of our mentor, Dr. Michael A. Goldfarb. He was instrumental in recognizing that revisional surgeries are in a class of their own. Over the years, he constantly encouraged us to perfect this craft, through surgical critique, investigation, and collaboration. Now, as revisional surgery is becoming more common, he was able to campaign our attention into sharing our experience through writing this text.

Dr. Goldfarb graduated at New York University School of Medicine and then completed a general surgical residency at Beth Israel Medical Center, New York City. He then served as a Major in the United States Army, where he was Surgical Director of Wound Ballistics, at Edgewood Arsenal, Maryland. In this role, Dr. Goldfarb helped direct the development and testing of Kevlar body armor. His research established the standard for military grade bulletproof body armor, saving countless lives.

Dr. Goldfarb then entered private practice at Monmouth Medical Center (MMC) in Long Branch, New Jersey, in 1976. He became immersed in resident and medical student education. He was appointed Professor of Surgery at Drexel University School of Medicine. He served as Chairman and Residency Program Director of the Department of Surgery at MMC from July 2000 until July 2014. Over his career, he has helped train over 700 surgeons, concentrating on compassionate interactions and meticulous surgical techniques to facilitate excellent clinical results.

Throughout his career, Dr. Goldfarb has numerous publications in peer-reviewed journals and books. He was a Member of multiple surgical societies and hospital committees, including the Board of Trustees at Monmouth Medical Center. He recently was a Governor of the American College of Surgeons. He currently edits the column on New Innovations in Surgery, in *General Surgery News*. He is on the Advisory Boards of Carespan International and Prescient Surgical.

Dr. Goldfarb has developed inventions and holds patents including a laparoscopic tissue dissector, soft tissue anchor, camera light link, and an inguinal hernia model. His clinical interests have led to establishing one of the first hospital day-stay centers. He introduced the clinical use of laparoscopic ultrasound and laparoscopic cholecystectomy in April of 1990, the first in New Jersey. He was also appointed as Surgical Coordinator of the J. M. Wilentz Comprehensive Breast Center in 1998 and introduced sentinel lymph node detection to New Jersey surgeons. His latest research has gravitated

toward outcome studies of surgical morbidity and mortality. He has developed a surgical complication analysis program that has improved patients' safety and reduced costs. He has also established tele-video intraoperative consultation and credentialing programs in surgery.

We are extremely grateful in having had the opportunity to develop and progress our surgical careers with such a great man. He always emphasized on upholding the highest standards of quality and never blaming the patient for a bad outcome. He provided valuable advice and engrained upon us to always do the right thing. As a mentor, colleague, and, most importantly, a friend, we would like to thank him for what he has done for us and his accomplishments in the advancement of surgery.

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# Acknowledgment

We would like to thank Dr. Richard Ruchman for providing radiological images for this text. Dr. Ruchman is our constant ally in the reading room. His detailed eye and experience have provided us with the opportunity to care for countless patients. Thank you.

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# Part I

# Revisional Bariatric Surgery

# Revision of the Laparoscopic Gastric Band

1

Jeffrey D. Sohn, James C. Botta, and Gurdeep S. Matharoo

## History of the Gastric Band

The former popularity of laparoscopic adjustable gastric banding can be appreciated by understanding the evolution of bariatric surgical techniques and the culmination of events which lead to its discovery as a seemingly safe and effective weight loss solution for the morbidly obese. Looking at the genealogy of bariatric surgery, malabsorptive procedures were first performed in the 1950s, followed by combined malabsorptive/restrictive types of procedures in the 1960s [1]. However, these procedures were fraught with both short- and long-term complications. For the jejunoileal bypass, a purely malabsorptive operation, patients experienced effective weight reduction at the expense of significant morbidity including acute liver failure, renal failure, steatorrhea, nephrolithiasis, cirrhosis, electrolyte abnormalities, fat-soluble vitamin deficiencies, and bypass-associated encephalopathy and dermatitis [2]. Gastric bypass, a combined malabsorptive/restrictive procedure, has the potential to cause dumping syndrome, marginal ulcers, iron deficiency anemia, and vitamin B12 deficiency. These long-term consequences prompted a need to find an alternative bariatric procedure. Thus, during the 1970s–1980s, restrictive gastric surgery techniques were developed to fulfill the need for a safer weight loss alternative [1, 3].

In 1971, Mason and Printen performed the first gastric restrictive procedure, the horizontal gastroplasty. This technique involved creating a horizontal partial transection of the stomach (from the lesser curvature to the greater curvatures), leaving a small conduit along the greater curvature which regulated passage of food from a small gastric pouch (Fig. 1.1). This procedure offered inferior weight loss results when compared to gastric bypass. It was also found that overeating would stretch the conduit, reducing the procedure's weight loss effectiveness. Additionally, the staple line could break down which rendered the partition ineffective [1, 4, 5].

The vertical band gastroplasty (VBG) was described in 1982 by Mason [6]. The procedure involved forming a 50 cc gastric pouch via creation of a window through the anterior and posterior walls of the stomach just above the crow's foot, applications of vertical staples to the angle of His, and banding of the neo-gastric outlet using a polypropylene mesh (Fig. 1.2) [5, 6]. Unfortunately, as time progressed, this staple line also had a propensity to disrupt, resulting in weight gain. As a result, weight loss was found to be inferior with VBG when compared to gastric bypass [5, 8]. Additionally, another drawback to the procedure was the significant inflammatory

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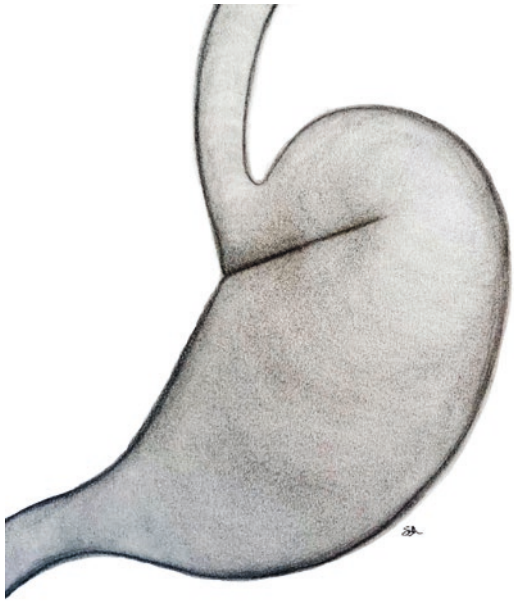

**Fig. 1.1** Horizontal gastroplasty anatomy

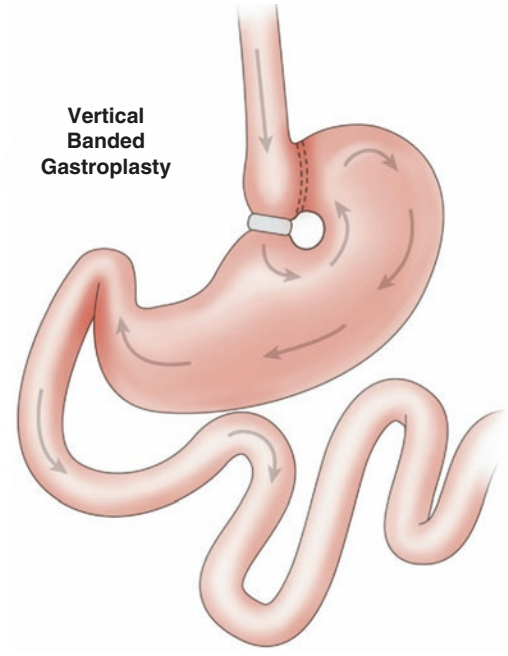


**Fig. 1.2** VBG anatomy [7]

reaction and subsequent scarring caused by the polypropylene mesh. This led patients to experience food intolerance, reflux esophagitis, and even outlet obstruction. A modification to the VBG was performed by placing a fixed silastic band in place of the Marlex® mesh. This resulted in far less adhesions and inflammatory reaction and was thus easier to remove if patients experienced difficulties with the band [1]. Nonetheless, overall weight loss was found to be inferior when compared to malabsorptive options, and other techniques were sought.

Concerned with the sequelae of bypass procedures, Wilkinson began experimentation on animals in an effort to produce a procedure that could reduce gastric reservoir capacity in humans. In 1976, Wilkinson performed the first gastric banding on a human using a polypropylene mesh [5, 9]. This was modified in 1983 by using a silicone band [10]. Initially, there was no way to adjust the silicone band once it was placed. It wasn't until in 1986 that Kuzmak introduced an inflatable and thus adjustable silicone band with a subcutaneous injectable port that could be used to modify the caliber of the gastric band and thus the diameter of the stoma [1, 10].

With the emergence of laparoscopic surgery in the 1990s, the next natural step in evolving and improving the technique of gastric banding was to adopt a minimally invasive approach. The prospect of providing a less-invasive means of gastric restriction to the already high-risk morbidly obese patient was attractive. Belachew from Belgium spearheaded efforts to make laparoscopic gastric banding a reality. He approached Kuzmak from the USA and expressed his interest of using laparoscopy to perform adjustable silicone gastric banding. Adopting techniques for operating in the technically challenging abdomen of the overweight proved to be a challenge. Initially tested in pigs, laparoscopic techniques were refined. Finally, in 1993, the first human laparoscopic adjustable silicone gastric banding (LAGB) was performed in Belgium by Belachew and colleagues (Fig. 1.3). Initial preliminary results by Belachew proved that LAP-BAND® placement was a safe procedure and that weight loss was comparable to open ASGB and open VBG. The first clinical trials and workshops were held in Europe. In July 1994 the LAP-BAND® became available to market [11, 12].

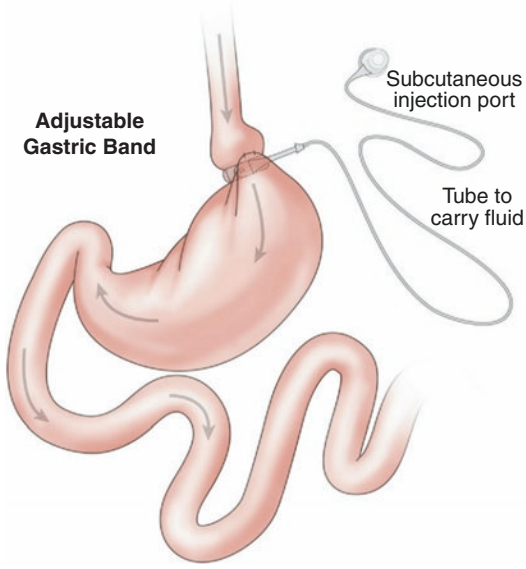


**Fig. 1.3** Lap-band anatomy [7]

Initial studies conducted in Europe and Australia concluded that the LAGB was an effective procedure for obtaining acceptable weight loss results. In 1998, a study of 350 patients by Belachew demonstrated 60% excess weight loss (EWL) in 80% of patients at 1 year and that weight loss had been retained for up to 3 years [13]. One prospective study by O'Brien from Australia followed 277 patients and demonstrated 51% EWL at 1 year [14]. Similar results were reproduced by multiple studies from other European centers [15–17].

In June 1995 the Food and Drug Administration (FDA) approved clinical trials for the LAP-BAND® system to be conducted in the USA [18]. After implanting a total of 292 LAP-BAND® devices, patients were found to have a mean EWL of 35% at 12 months and a mean EWL of 36% at 36 months; a mean overall weight loss of 18% was achieved. The LAP-BAND® was approved by the FDA in June 2001 [19]. Though initially these results seemed to be less promising than what was observed internationally, additional studies were conducted in the USA which demonstrated comparable results when compared to their European colleagues [20].

When inquiring why patients opted for LAGB over other bariatric procedures, the choice was made based on the characteristics of gastric banding itself. Specifically, patients were attracted to the idea that the gastric band is both reversible and removable. Most importantly, however, patients perceived the procedure to be less invasive than other available procedures and thus more attractive [21]. Not only were patients attracted to the idea of the gastric band, but the relative simplicity of the technical aspects of LAGB and the low rate of perioperative morbidity and mortality contributed to its rising popularity among surgeons. It is not surprising then that in the USA, the LAGB gained increasing popularity once it was approved. In 2003, about 9,000 gastric bands were placed in the USA/Canada, and by 2008, 96,800 patients had received gastric bands annually [22].

Unfortunately, the LAGB, which was initially thought to be a seemingly safe and effective weight loss procedure, was in fact shown to be otherwise. Emerging studies had demonstrated that the LAGB was less effective at both producing long-term weight loss and reducing obesity-related comorbidities when compared to the gastric bypass and sleeve gastrectomy [23–25]. It was also found to result in a multitude of complications, including gastric pouch dilation and band slippage, erosion and migration [26, 27]. As a result, the LAGB dramatically decreased in popularity in the USA. By 2017, only 2.77% of all bariatric surgeries were gastric banding, per the American Society for Metabolic and Bariatric Surgery (ASMBS) [28]. The inferiority of the gastric band to provide effective and lasting weight loss and the band's potential to create serious complications resulted in a need and demand for bariatric surgeons to become proficient at revisional surgery.

## Gastric Banding – Outcomes, Complications, and Reasons for Revision

The international trend for placement of LAGB saw a dramatic decline in popularity from 2008 to 2011 (42% to 18%). One major contributing factor to this trend was emerging evidence that

questioned the long-term safety of the band. Some studies have demonstrated complication rates to be as high as 40–50%, with reoperation rates as high as 30%. Additionally, failure to maintain weight loss was also demonstrated in some studies. Thus, the primary indications for reoperation and revisional surgery include both long-term weight loss failure and complications of the band itself [29–31].

The decline in the USA when compared to international trends has similarly been significant. Since 2013, the number of surgeries for gastric band explantation overtook the rate of surgeries for placement. Unsurprisingly, explantation and revisional procedures are associated with increased morbidity, postoperative ICU admissions, and longer hospital length of stay when compared with implantation [32].

## Weight Loss Failure

The goal of bariatric surgery is to reduce the incidence of weight-related comorbid conditions. This often results in cosmetic and psychological benefits to the patients. Thus, in order to produce long-lasting outcomes in patients undergoing bariatric surgery, the procedure must effectively produce weight loss that is not only impactful in its initial quantitative reduction of BMI but must also result in long-term weight reduction.

As long-term data became available, studies began to show failure of the LAGB to maintain acceptable long-term excess weight loss (EWL). In 2006, Suter in Switzerland published prospective data from up to 8 years of follow-up that demonstrated an approximate 40% 7-year success rate (defined as EWL >50%); and in patients without major complications, only approximately 60% of patients were able to maintain an acceptable EWL long-term. With the aforementioned findings in conjunction with data showing unacceptably high rates of major complications and reoperation, they concluded that the gastric band should not be considered the treatment of choice for morbid obesity [29].

A study trending EWL over a mean of 14 years after patients had undergone LAGB (with bands still in place) demonstrated a mean EWL of 49% after 5 years, 41% after 10 years, and 21% after 15 years [33]. Additionally, another long-term study was able to show a weight loss failure rate of 42% at 15 years (defined as EWL <25%) [34].

A systematic review comparing medium-term weight loss results showed that LAGB had worse weight loss outcomes when looking at the first 2 years when compared to LRYGB, but that there was no difference in mean EWL from 3 to 7 years after [31, 35].

It should be noted that some studies were able to demonstrate successfully maintained long-term weight loss, albeit at the risk and expense of overall long-term patient safety. A study published by Himpens et al. in 2011 demonstrated a mean EWL of 48% after 12 years in individuals who still had their bands in place; however, 50% of the studied cohort required band removal mostly due to serious complications. Approximately 12% of patients that underwent reoperation had their band removed for weight gain [36]. Similarly, Victorzon et al. were able to demonstrate an acceptable mean EWL of 49% juxtaposed to a disappointingly high reoperation rate of 60%, and a band removal rate of about 50% [37].

In a systematic review, the mean EWL of compiled cohorts was found to be 49% (range 30–82%) at 10-years follow-up [31]. While studies to date can demonstrate both successes and failures of effective long-term weight loss in LAGB, the literature regarding the significant morbidity caused by gastric banding is well established.

## Long-Term Complications of Laparoscopic Gastric Band

Though the initial intent of LAGB was to provide effective weight loss with safe outcomes, an overwhelming amount of evidence has made it clear that the procedure carries with it a significant rate of morbidity. Common complications include port- or catheter-related problems, band leakage, band infection, gastroesophageal reflux disease and resulting esophagitis, esophageal dilation, and esophageal dysmotility. Psychological intolerance and dysphagia can also occur. Some of the most concerning complications are band slippage,

pouch dilation, and band erosion and/or migration, [31, 38]. A review conducted by Shen et al. in 2015 analyzed 17 studies (15 observational studies, 2 randomized controlled trials) and found a median long-term complication rate of 43% and reoperation rate of 37%. Of these patients, 23% of patients underwent band explantation. Common reasons for band removal were complications (66%), unsatisfactory weight loss (17%), and psychological intolerance without complication (8%) [31]. Table 1.1 highlights common long-term complications as studied by Shen et al., with reported median incidence. Note that the range of incidence is widely variable depending on the study. This is likely due to inherent differences in the studied cohort and differences in both surgeon and surgical technique utilized.

The true incidence of gastric erosion generally ranges from 1% to 10% depending on the studied cohort [39]. Erosion is a serious complication and is a major indication for explantation [27, 40]. The pathogenesis of gastric band erosion has been a topic of contention. Though the exact etiology is still debated, some have speculated that tension created by placement of gastro-gastric fundic sutures used to secure the band may result in erosion [41]. Others have postulated, based on inferring from histologic analysis of periprosthetic tissue, that erosion is caused by unrecognized intraoperative damage to the stomach wall by either direct mechanical manipulation or thermal injury from electrocautery (Lattuada 2006). Difference in band type has also been discussed, with certain bands demonstrating a higher predilection for erosion (*see Addressing Type of Band*)

**Table 1.1** Common long-term complications (extracted from Shen et al. [31])

| Long-term complications | Median incidence % (range) |
|---|---|
| Pouch dilation or slippage | 15.3% (1.1–39.9%) |
| Catheter or port-related problems | 11.1% (0.9–24.2%) |
| Band leakage | 6.5% (1.6–20.5%) |
| Esophagitis (reflux) | 5.0% (0.9–28.8%) |
| Gastric band erosion (and migration) | 3.9% (0.8–28.0%) |
| Esophageal dilation | 3.6% (0.5–24.0%) |
| Psychological intolerance | 2.7% (0.3–7.1%) |
| Band infection | 1.2% (0.3–3.2%) |

[41, 42]. Some have demonstrated that band over-distention is more likely associated with erosion, though it is unclear if this finding establishes causation or if this correlation is a consequence or symptom [42, 43]. Contradictory to this, gastric erosion occurring in an unfilled band has also been described [44]. Infection at the band site has also been proposed [43].

As surgeons became more experienced, decreasing rates of erosion could be appreciated with time. In one study, the erosion rate decreased from 9.4% for the first 500 patients, to 2.8% in the second 500 patients, to about 1.6% thereafter. Change in technique could also improve erosion rates. In the same study, the perigastric approach had an erosion rate of 6.8%, while the pars flaccida approach was associated with a reduction in erosion rate of 1.1%. Though both increased experience and change in approach reduced the rate of erosion, erosion was never completely eliminated [41]. Once erosion is recognized in the patient, it is always managed operatively.

The average time from band placement to diagnosis of erosion is about 32 months [27]. Common presenting symptoms at the time of diagnosis are failure of weight loss, loss of satiety, abdominal pain (usually epigastric), dysphagia, nausea and/or vomiting, and port-site-related problems including infection or pain [27, 40, 41]. After eroding through the stomach, the band may migrate distally intraluminally resulting in a mechanical bowel obstruction [45]. Other less common acute presentations include hemorrhage, perforation, peritonitis, and sepsis [41, 45].

Diagnosis can be obtained with endoscopy via visualization of an intraluminal band. Retroflexion during endoscopy is essential as this may be the only method of visualizing the eroded band. Barium swallow and contrast CT are used as adjuncts, though are not sensitive enough to clench the diagnosis [41]. Emergent cases can be managed with laparotomy or laparoscopy, depending on surgeon preference and patient characteristics. However, most cases present non-urgently and are thus treated as such. Both laparoscopic and endoscopic techniques have been utilized for explantation, as well as hybrid approaches by simultaneously combining both

endoscopy and laparoscopy [40]. For patients who are presenting electively for removal of the gastric band, we routinely perform an upper GI series to evaluate the phi angle of the band and locate the band to ensure it has not herniated into the posterior mediastinum.

Pouch enlargement and band slippage are the most common late complications of LAGB, but these entities are not the same. Gastric band slippage or prolapse occurs when the anterior or posterior distal stomach herniates through the proximal band. It is the most common complication of LAGB [46]. Prolapse leads to symptoms of heartburn, reflux, and vomiting. Diagnosis is obtained via barium swallow. As band prolapse can cause a complete obstruction of the stoma, it is treated as a surgical emergency. Prior to taking the patient to the operating room, it is imperative that the band is accessed and completely deflated. A nasogastric tube may be placed to decompress the stomach at the surgeon's discretion. Patients are then taken to the operating room for reduction of the prolapsed stomach [47]. In our practice, any patient that presents with prolapse is recommended to have the band removed as we do not advocate for band repositioning.

When comparing the operative techniques utilized today versus the procedural steps at its inception, placement of the LAGB has seen significant revision in an attempt to reduce complications like prolapse. For example, band placement was modified such that it is now positioned at the apex of the stomach to reduce the size of the pouch above the band. Anterolateral fundal fixation was additionally emphasized. Further reduction in prolapse rates were obtained by revising the technique from a perigastric approach to a pars flaccida approach. Years of technical revision sought to improve complication rates. As proven by a prospective randomized trial, the pars flaccida approach dramatically decreased the incidence of band prolapse, particularly posterior prolapse, when compared to the earlier perigastric approach [46, 48]. Despite reported decreases in slippage rate, other complications remain pervasive and are central to justifying revisional surgery.

An abdominal plain film and an upper GI should be obtained as they can aid in identifying abnormal band positioning (Table 1.2, Fig. 1.4) [46]. Specifically, the phi angle is measured and identified. It is the angle created between the band's long axis and its orientation relative to the vertical midline of the thoracic spine. The phi angle has a normal range of 4–58 degrees [49]. Additionally, the classic O sign may also be identified during gastric band slippage. This phenomenon is observed when superior herniation of the stomach causes the band to tilt along its horizontal axis so that a circle is visualized, as the anterior and posterior sides are no longer superimposed [50].

Proximal luminal dilatation (PLD) is a significant intermediate- to long-term complication of LAGB. It is defined as enlargement of the gastric pouch or esophagus occurring proximal to the band. Multiple variations of anatomical dilatation have been described. The CORE (Centre for Obesity Research Education) classification takes into account changes to both anatomy and esophageal motility (Fig. 1.5) [51]. The anatomic classification includes the following: symmetrical gastric enlargement, gastric prolapse, transhiatal gastric enlargement, transhiatal esophageal enlargement, pan-esophageal dilatation, and deficiency in esophageal motility [51, 52].

**Table 1.2** Band pathology and associated radiographic findings [46]

| | |
|---|---|
| Normal band positioning | Band lies obliquely; 1–2 cm of gastric mucosa above band (virtual pouch); contrast through the band and not around |
| Posterior prolapse | Band lies vertically; pouch often seen best on oblique view; pooling of contrast above the band; poor emptying of pouch; intraesophageal reflux |
| Anterior prolapse | Band lies horizontally; pouch often seen pooling laterally; pooling of contrast above the band; poor emptying of pouch; intraesophageal reflux |
| Symmetrical gastric enlargement | Band lies obliquely; symmetrical pouch above the band; pooling of contrast above the band; poor emptying of pouch; intraesophageal reflux |

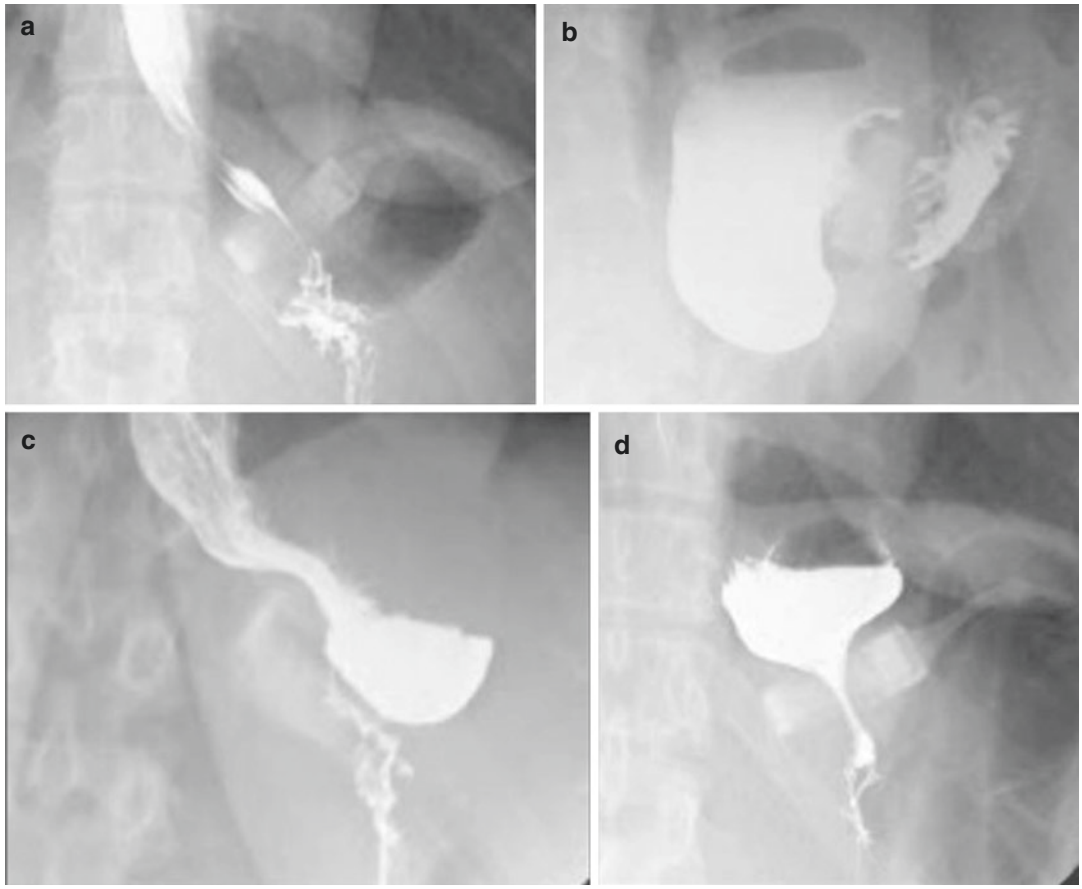


**Fig. 1.4** (**a**) Normally positioned LAGB; (**b**) posterior prolapse; (**c**) Anterior prolapse; (**d**) SPD (part of Table 1.2) – [46]

Symmetrical gastric enlargement, aka symmetrical pouch dilatation (SPD), or simply pouch enlargement, is caused by excessive pressure on the proximal gastric pouch secondary to (1) eating too fast or too much volume of food, or (2) excessive volume within the band itself which translates to a tight band. Excessive and repeated dilatation results in loss of tonicity of the proximal pouch, a decrease in effective motility, increase in food accumulation, regurgitation, and resulting symptoms of GERD. Less likely is that SPD may be representative of an unrecognized hiatal hernia. Patients commonly present with the following symptoms: reflux, nocturnal reflux, vomiting, dysphagia, and/or abdominal pain. Prevention involves educating patients to alter eating habits. Patients should be instructed to consume small volume meals (less than 4 oz. at a time, no carbonated beverages) and to consume these meals very slowly [46, 47]. Diagnosis can be made with barium swallow. Conservative treatment can be attempted with band deflation and reinforcing that patients comply with dietary restrictions. Patients are reevaluated 4 weeks after band deflation; at this time, the band and its associated anatomy are interrogated via barium swallow which is used to confirm band positioning, pouch size, and stoma permeability. The band may then be readjusted if the dilation is noted to have decreased. Failure of the pouch to revert to its original confirmation over serial assessments is defined as a failure in conservative management. One reason for failed conservative management may be the

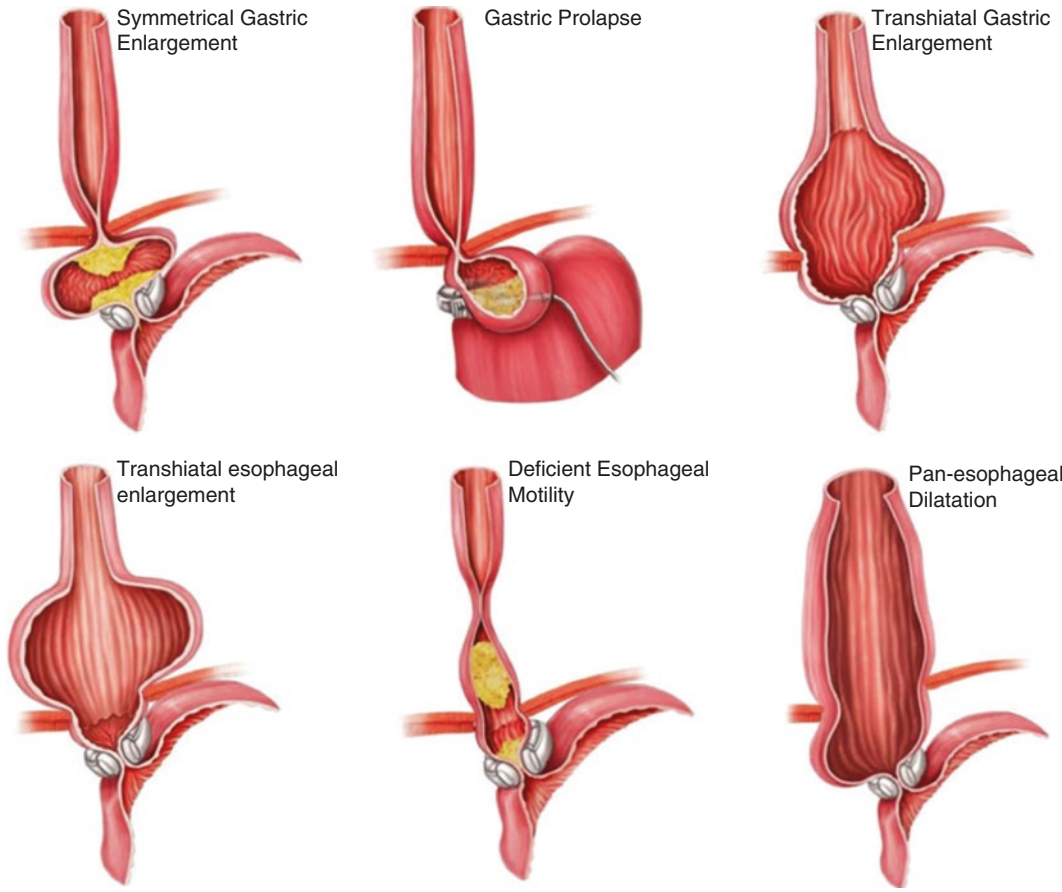


**Fig. 1.5** CORE classification [51]

formation of a cicatrix beneath the band which causes perpetual constriction of the gastric pouch [47]. At this point, patients should undergo explantation.

Esophageal-related complications may occur secondary to the band. It is still questioned if the gastric band acts as a refluxogenic device or if the band works to improve gastroesophageal reflux disease (GERD) [53]. Individuals with symptoms suggestive of GERD have been proven to demonstrate reflux physiology. Symptomatic patients after LAGB, when compared to asymptomatic individuals with LAGB, are found to have less contractility of the lower esophageal segment, decreased lower esophageal sphincter (LES) basal tone, a trend toward decreased LES length, and a larger gastric pouch (or effectively a higher-pressure zone length) on manometry. Additionally, 24-hour pH monitoring demonstrates increased total time of esophageal acidification, and an overall increase in the number of total reflux events [54]. The discrepancy in literature can likely be explained by band positioning, whereby a properly placed band acts to enhance the anti-reflux mechanism. However, improper placement of the band and thus its complications, particularly pouch dilation and esophageal motility deficiencies, can lead to reflux [53, 54]. Management of patients with GERD secondary to LAGB is variable, ranging from nonoperative treatment to revisional surgery with conversion to other bariatric procedures [54].

Esophageal dilation and erosion are additional complications and result in significant morbidity and resource utilization. Esophageal dilation can evolve into megaesophagus. As a result of chronic dilatation, patients may progress to esophageal

dysmotility. In fact, one study utilizing esophageal manometry formally evaluated patients for long-term esophageal dysmotility after laparoscopic adjustable gastric banding and found that even asymptomatic patients had severe esophageal dysmotility. It is thus recommended that preoperative manometry be performed in patients undergoing work up for revisional surgery [55].

## Addressing Band Type – Does It Matter?

Some studies were conducted to examine if a particular manufacturer produced a band that was superior to its competitors'. Ayloo et al. published data in 2014 that demonstrated no difference in terms of weight loss when comparing multiple bands available to market at the time of the study (LAP-BAND VG®, Allergan-LAGB®, LAP-BAND AP®, LAP-BAND AP Large®, Realize Band®, and Realize- C Band®); no discernable predilection was found when studying short- and long-term complications, albeit the study being underpowered [56].

Brown et al. found erosion rates to be significantly higher with LAP-BAND 10 cm® (4.1%) when compared to the LAP-BAND Advanced Platform (AP) series®, both AP Small® and AP Large® types (0.09% and 0% respectively) [41]. Kurian et al. found the Vanguard Band® to pose a greater risk of erosion when compared to 9.75-cm/10-cm band® [42].

### Revisional Surgery

As previously discussed, patients who have undergone LAGB may experience weight loss failure, band-related complications, or severe symptoms of band-related intolerance such as dysphagia or GERD. These patients meet criteria for explantation. Revisional surgery rates for LAGB range from 10% to 60% depending on the studied cohort [57, 58]. Standard options for revisional surgery include conversion to either revisional laparoscopic Roux-en-Y gastric bypass (R-LRYGBP) or revisional laparoscopic sleeve gastrectomy (R-LSG). Other less popular options include one-anastomosis gastric bypass and biliopancreatic diversion with duodenal switch (BPD-DS). Revisional bariatric surgery after LAGB can be both tedious and technically challenging. Safety regarding the approach to gastric band revision is debated and varies based on surgeon and/or institutional preference. Additional considerations include the timing of approach. The procedure can be done in one or two stages. In the one-stage procedure, the gastric band and capsule are removed with simultaneous creation of either a sleeve gastrectomy or gastric bypass. When performed in two stages, revision is delayed for 6–12 weeks following band removal.

## Comparing One-Stage Versus Two-Stage Procedures

Proposed advantages of a single-stage approach include subjecting the patient to a single procedure, eliminating the potential for the patient to regain weight that may occur during a waiting interval after band explantation, as well as decreased hospitalization, time off work, and an overall decrease in resource utilization. However, operating in a situation where the band has resulted in significant scarring and inflammation may place the patient at higher than desirable risk [58].

A two-stage approach may be considered when the operative field is considered too high risk to hold a staple line or if dissection is thought to be too dangerous. Such situations may occur with severe band erosion or infection [58]. Advocates for a two-stage approach theorize that the time elapsed between initial explantation and revision allows for a reduction in perigastric inflammation and fibrosis caused by the band and thus renders the operative field safer for revision and reduces the chances of incomplete firing of staple lines, staple line dehiscence, and anastomotic leak [59, 60].

Multiple studies have since been published on the issue of one-stage versus two-stage safety. Overall, the majority of published series have demonstrated comparable outcomes [61–63]. Though no randomized controlled trials have been published to date, a large systematic review and meta-analysis ($n = 1370$) sought to determine

if a difference exists between one-stage versus two-stage revisional surgery when looking at complication rates. They found no statistical difference between one-step and two-step when looking at rates of abscess, postoperative bleeding, anastomotic leaks, fistula formation, anastomotic strictures, and overall morbidity and mortality. However, it should be noted that in the included studies, two-stage revision had a tendency to be reserved for patients that had high-risk indications for revisional surgery including pouch dilatation, band slippage, band erosion, and hardware infection. The authors thus warn about confounding results secondary to selection bias. Therefore, generalized statements regarding the safety and equivalence of the two types of procedures should be made with caution [63]. In our practice we routinely select a two-stage procedure for our patients who elect for another bariatric surgery after LAGB removal. After LAGB removal, the patients are enrolled into our bariatric surgery program as a new patient and undergo the same dietary and psychological counseling a new patient would undergo. We find this strategy of counseling to be of particular benefit as patients who are having the band removed most often are those who have failed to lose weight with the band and thus require further coaching on appropriate lifestyle modifications. The patients would also need to meet all BMI and insurance requirements to undergo a repeat operation.

## Comparing Weight Loss Efficacy – R-LRYGB Versus R-LSG

As there is reportedly a high rate of poor responders to LAGB in terms of effective long-term weight loss, studies have sought to determine the efficacy of revision, specifically which option provides the most effective EWL. Looking at initial 6- and 12- month outcomes, R-LRYGB and R-LSG seem to offer equivalent weight loss [58]. Additionally, a study looking at %EWL at 1, 3, and 5 years after revision showed no statistically significant difference between R-RYGB and R-SG at years 1, 3, or 5 [64]. However, in one series, R-RYGB offered greater weight loss at 2-year follow-up [59].

There is significant variability in reported %EWL among studies. No randomized controlled trials are published to date. A systematic review and meta-analysis ($n$ = 2617) compared %EWL between band to Roux-en-Y gastric bypass (B-RYGB) and band to sleeve gastrectomy (B-SG). Combined %EWL at 6, 12, and 24 months were 45%, 56%, and 60%, respectively. No observable statistical difference was appreciated between both B-RYGB and B-SG revisions [25].

## Comparing Risks/Complications – R-LRYGB Versus R-LSG

Sharples et al. in their systematic review and meta-analysis ($n$ = 1583) found no significant difference between conversion from B-RYGB and B-SG when looking specifically at morbidity, leak rate, or return to the OR [25]. Conversely, a large retrospective analysis using MBSAQIP database sought to compare outcomes of conversion to laparoscopic Roux-en-Y versus sleeve gastrectomy within the first 30 postoperative days. The study looked at data in 2015 ($n$ = 2708, all procedures were single stage) and demonstrated statistically significant increase in operative times, leak rate (2.07% vs. 1.18%), bleed rate (2.66% vs. 0.44%), 30-day readmission rate (7.46% vs. 3.69%), and 30-day reoperation rate of (3.25% vs. 1.26%) when comparing revisional bypass to sleeve gastrectomy, respectively [65].

## Reduction in Comorbidities

Few studies have sought to compare reduction in comorbidity after revisional surgery for LAGB patients. Significant reduction in comorbidities can be appreciated in patients after revisional surgery. Reduction rates in diabetes (47%), hypertension (36%), and obstructive sleep apnea (81%) were appreciated in a systematic review and meta-analysis [25].

## Operative Technique

### Removal of the Gastric Band

Most gastric band removal cases are electively treated with a minimally invasive approach. Once preoperative evaluations have been completed, the patient is brought to the operating room. The patient is placed on the OR table in either a supine or a French split leg position, both with the use of reversed Trendelenburg. Abdominal port placement is surgeon specific; however, reuse of previous incisions should be attempted. At minimum, the 15-mm extraction trocar should be placed in the same location as the subcutaneous port for improved cosmesis. Adhesions are lysed to gain access to the upper abdomen. Adhesions are often found around the catheter and its course toward the stomach, as well as between the liver and band. Once the adhesions are divided, a liver retractor should be placed to elevate the left lateral segment of the liver. The tubing should be cut leaving a short tail on the band to assist in traction. Dissection is carried down directly onto the adjustable silicone gastric band, and the overlying gastric capsule is opened. In our practice this dissection is done with either a L-hook electrocautery or an ultrasonic dissector device. Once the clasp is completely visualized, an attempt is made to unclasp the buckle. If the band cannot be unclasped due to resistance, the buckle is cut with laparoscopic shears to allow the band to unfurl. Subsequently, the band is cut at the opposite end from the tubing. The band is then gently removed from the capsule. The silicone of the balloon portion of the band is carefully examined for discoloration. If there is any discoloration, it could signal an occult erosion and should prompt intraoperative endoscopy to evaluate. The band and transected portions are then removed from the abdomen. A count of all cut pieces should be made. It is our routine to reconstruct the band on the back table prior to ending the case to ensure complete removal of all pieces. We also send the band to pathology for gross examination to document complete extraction.

The stomach and gastrotomy are carefully examined. Primary closure of the gastrotomy is performed by freeing the gastric defect edges and reapproximating the defect with sutures. If an erosion is found anteriorly, it is also primarily closed. Regardless of its location, an erosion should prompt the use of an omental pedicle patch to cover the repair. The area is then irrigated, and a 10-Fr Jackson–Pratt drain is left adjacent to the repair if an erosion was found.

We then desufflate the abdomen and remove the 15-mm trocar. The incision is enlarged, and the subcutaneous port is removed. Repeated fingertip palpation of the port is crucial to ensure proper trajectory of dissection in the subcutaneous tissues. Once the port capsule is opened, the hub is located, and the tubing is delivered. Grasping the hub with a Kocher clamp allows retraction of the port and allows for easier posterior dissection. The method of how the port is attached to the fascia depends on the type of band used; either sutures or metal hooks anchor the port to the fascia. The Realize® band utilizes hooks to affix the port; the hooks during placement were deployed by twisting the ring around the port. The ring can be twisted the opposite direction to retract the hooks; however, dissection around the hooks is generally quicker. All sutures are removed. The capsule is removed. The abdomen is re-insufflated, and the 15-mm trocar site is closed with a suture passer under direct vision. While utilizing laparoscopy, hemostasis and complete removal of all portions of the band are confirmed. The abdomen is once again desufflated, and the wound is irrigated and closed [27].

Endoscopic techniques have been described for cases of gastric intraluminal erosion, though at this time no standardized approach exists. Spann et al. have described their technique in detail. A gastroscope is advanced into the patient and the band is identified. Dual action endoscopic scissors are used to cut the silastic band. If the band is too tough for scissors, a biliary guidewire can be advanced around the eroded material. A mechanical lithotripter can be used to tighten the wire and cut through the eroded band. Devices specifically designed for endoluminal gastric band removal are available in non-US markets (i.e., the A.M.I.® Gastric Band Cutter System, Agency for Medical Innovation) [66]. The band is then extracted using

a snare or large endoscopic forceps. The mucosal defect is left open [39]. A caveat to an endoluminal approach is the requirement for the band's buckle to be eroded into the lumen. Thus, treatment may be delayed giving time for this to happen [41]. If an endoscopic technique is used, it should be performed within the operating suite in the event the procedure needs to be converted to a more invasive approach, whether it be laparoscopy or laparotomy [66].

## Revisional Surgery

As mentioned previously, at our institution all patients are revised in a two-stage fashion. We agree with the theory of delaying surgery to allow gastric tissue to heal, reduce edema, and decrease inflammation. Upon discussion with the patient regarding revisional surgery, it is imperative to inform them of the increased risk of damage to nearby structures as well as the potential for staple line issues. Once the patient is in the operating room, they are prepared in a standard fashion to how the surgeon would approach a primary gastric bypass or sleeve gastrectomy. The ports are placed, and the liver retractor is mounted. Initially, dissection frees the stomach from the liver, and dissection is carried to the angle of His. During revisional surgery after an LAGB has been removed, we invariably find a hiatal hernia. The hernia is dissected in a routine fashion by opening the pars flaccida and approaching the hiatal dissection on the right side first. This is followed by circumferential dissection of the hiatus and mobilization of the esophagus in the posterior mediastinum to allow for at least three centimeters of intraabdominal esophagus.

We then turn our attention to the gastric plication which was done during band placement. The overlaying scar tissue is dissected and carefully divided to unfold the stomach. To confirm complete unravelling of the stomach, we perform an intraoperative endoscopy and distend the stomach with carbon dioxide. There are several reasons for performing the aforementioned steps. We can ensure, from both extra- and intra-luminal visualizations, that the stomach is completely unfolded. This prevents inadvertent staple placement across four walls of a folded stomach. The intraluminal view also allows us to ensure an absence of transmural injuries which may have been incurred to the esophagus or stomach during dissection. Also, the intraluminal view allows us to examine the Z-line and ensure it is located within the abdomen, which confirms complete reduction of the hiatal hernia. Overall, this technique allows us to perform a more thorough examination of the stomach before committing to the remainder of the revisional procedure.

Whether the subsequent revision is performed in a single- or two-stage fashion is the surgeon's choice. Emphasis on tailoring the patient's care cannot be stressed enough. Options should be discussed with the patient at length, allowing for potential risks and benefits to be discussed so that both healthcare provider and patient are able to come to an agreement.

During revision, it is imperative that the plicated region of the stomach is taken down entirely to ensure that the stomach sits anatomically prior to revision. If there is significant scarring or inflammation, it is within the operating surgeon's judgement on whether or not to upsize the stapler in creating either the gastric pouch for R-LRYGB or forming the gastric sleeve. Close monitoring in the postoperative period is paramount. The postoperative management should follow the surgeon and institutions routine for revisional bariatric surgeries. Generally, in our practice, these patients have a similar length of stay and diet progression as primary procedures.

Given the complexity of revisional bariatric surgery and the technical challenges it poses, these procedures should be the left to the hands of experienced bariatric surgeons. These procedures have become increasingly more common and will continue to be perfected with the passage of time.

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# 2 Revisional Surgery for Sleeve Gastrectomy

Steven J. Binenbaum and Ethan T. Paulin

## Introduction

Laparoscopic sleeve gastrectomy (LSG) is the most common restrictive weight loss operation performed today to treat morbid obesity. The procedure was first described by Marceau in 1993, originally as part of the biliopancreatic diversion with duodenal switch (BPD/DS) [1]. Sleeve gastrectomy (SG) helps achieve reduction in weight via a combination of intragastric volume restriction and hormonal changes. Approximately 66–80% of the overall stomach volume is resected, resulting in a remnant gastric "sleeve" that is unable to accommodate large volumes of food. Less food is required to stimulate gastric stretch receptors to send signals via the vagus nerve to the nucleus of the solitary tract in the brainstem, hypothalamus, and ultimately the cerebral cortex, thereby creating the perception of satiety [2]. In addition to reduced intragastric volume, resection of the gastric fundus results in greatly decreased levels of ghrelin, thereby leading to greater satiety [3]. Many studies have successfully confirmed the safety and efficacy of sleeve gastrectomy (SG) operation, which is now the most commonly performed bariatric procedure [4]. Due to relative ease of performance and success rates in achieving weight loss, many bariatric surgeons have adopted laparoscopic sleeve gastrectomy as the first choice in weight reduction surgery. It has demonstrated durability of weight loss and resolution of medical comorbidities almost equal to that of other procedures [5].

However, ease of practice does not mean that the procedure is without its complications and technical challenges. Staple line gastric leaks, strictures, gastroesophageal reflux, and weight regain are some of the most common sleeve gastrectomy complications that ultimately may require revision of the sleeve. The rate of revisional surgery after SG varies widely in the literature. Van Rutte et al. showed that 3.4% of patients had a planned two-stage conversion to gastric bypass and 5.5% had undergone an unplanned revision [6]. In a long-term review of outcomes by Arman et al., 31.7% of patients required reoperation [7]. The demand for bariatric procedures has made revisional bariatric surgery (RBS) a separate surgical entity. Although, thousands of surgeons worldwide perform bariatric procedures, only a small number of them offer revisions. In a survey of 456 surgeons who practice revisional surgery, Mahawar et al. found that most performed only between 1 and 25 RBS procedures. A total of 50 (10.96%) bariatric surgeons perform >100 procedures per year [8].

Most commonly, those seeking revision of their sleeves are patients who failed to achieve

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the desired weight goal or those who regained weight. Failure of weight loss has two components: one is the weight regain and the other is insufficient weight loss. As previously mentioned, the other complications that eventually lead to revisions are intractable gastroesophageal reflux disease (GERD), staple line leak, fistula, sleeve stenosis, or stricture.

To correct those complications, revisional surgery often times is preceded by multiple unsuccessful endoscopic procedures and attempts at surgical repair, which ultimately require conversion to another bariatric procedure.

The objective of revisional operation should be to achieve the goals of the original procedure such as maximum possible weight loss, remission of medical comorbidities, and resolution of complications. Depending on circumstances, most common surgical options include conversion to Roux-en-Y gastric bypass (RYGB), biliopancreatic diversion with duodenal switch (BPD/DS), and re-sleeve gastrectomy (Re-SG).

## Weight Loss Failure

Dietary noncompliance, lack of daily exercise, and inconsistent follow-up play a large role in regaining weight or not losing enough weight after sleeve gastrectomy. Diamantis et al. had reviewed 16 studies with short-term and mid-term weight loss results. The overall mean %EWL at 5 or more years after sleeve gastrectomy was 59.3%. The overall attrition rate was 31.2% [9]. The peak weight loss seems to occur between the first and second year after SG surgery, followed by gradual regain by some patients. In a 10-year follow-up series, Gissey et al. observed that weight regain in their study resulted in a mean 52.5%EWL with mean BMI of 31.5 kg/m$^2$ [5]. Recently, Noel et al. published an 8-year outcome analysis of weight loss, modification of comorbidities, and revisional operations in a prospective cohort of 168 sleeve gastrectomy patients. They reported 67% EWL in 116 patients who underwent LSG. Twenty-three patients underwent revisional surgery for weight regain and severe reflux. These included re-sleeving, conversion to RYGB, and duodenal switch (DS) [4]. Although many authors combine weight regain and weight loss insufficiency into one category, the etiology of weight loss failure is multifactorial. A different approach is needed when deciding on what kind of revision is appropriate. Loss of restriction from noncompliance with meal portions which leads to stretching of fundus resulting in gradual regaining of the weight is different from a total high calorie noncompliance with normal sleeve anatomy and further contrasts with insufficient weight loss in a compliant patient with a larger original sleeve.

There are a limited number of studies to date that discuss the sleeve volume in direct correlation to regaining of weight or insufficient weight loss. Using a gastric-computed tomography, Deguines et al. measured residual gastric volume (RGV) in SG patients and offered re-sleeve surgery when RGV was determined to be >250 cc. They observed a direct correlation between LSG success/failure 2 years after surgery and RGV. High residual gastric volume after SG may lead to inferior weight loss results. A median 65.9+/−20.2% %EWL was observed 1 year after re-sleeve gastrectomy [10]. Recently, Rebibo et al. offered re-sleeve gastrectomy to patients with a residual gastric volume ≥250 mL and reported a mean %EWL of 71.3% at 1 year after surgery. Re-sleeve gastrectomy was most beneficial when performed for weight regain rather than insufficient weight loss. They concluded that patients with a residual gastric volume <350 mL and insufficient weight loss after the initial SG may be better served with a malabsorptive procedure such as gastric bypass [11].

The success of SG is based on volume restriction, and high residual gastric sleeve volume may result in insufficient weight loss because of higher ghrelin levels. Ghrelin is secreted mostly by the ghrelin-producing cells located predominantly in the gastric fundus. Resection of a retained fundus should potentially result in lowered ghrelin levels, decreased appetite, and improved weight loss. Patients with SG operation using larger bougie sizes have larger remaining fundi, which have the potential to stretch and secrete more ghrelin leading to less weight loss.

Accordingly, Yousseif et al. discovered reduced ghrelin levels after sleeve gastrectomy operations [12]. Whether ghrelin levels differ in patients who had sleeve gastrectomy using different bougie sizes have not been studied. A recent systematic review and meta-analysis of 11 studies conducted by Wang et al. showed that operations performed with smaller bougie sizes experienced greater %EWL without any difference in incidence of complications or GERD. They concluded that the ideal bougie size should not exceed 36 Fr [13]. To the contrary, earlier systematic reviews by Aurora et al. and Yuval et al. found a strong correlation between smaller bougie sizes and increased incidence of leaks. The use of 40 Fr bougies was associated with leak incidence of 0.6% and 0.92%, respectively. Interestingly, Yuval et al. did not observe any change in %EWL with smaller bougies [14, 15].

The type of revision necessary is based on many factors, and radiological imaging with upper GI series (UGIS) helps ascertain the shape of the sleeve. Toro JP et al. obtained postoperative UGIS with water-soluble contrast in 100 patients in an attempt to standardize the morphologic classification of gastric sleeve. Sleeve shapes were classified as upper pouch (8%), lower pouch (22%), tubular (37%), and dumbbell (32%). They assessed mean hunger scores and mean %EWL at 1 (16.8%), 3 (29.9%), and 6 (39.1%) months. Stomach shape after SG did not correlate with weight loss, although patients with retained fundus endured lower satiety and more severe reflux symptoms [16]. Similarly, Salamat A et al. showed that postoperative upper gastrointestinal series in 149 patients with "retained fundus" did not experience inferior weight loss in juxtaposition to those with optimal shaped sleeves [17].

Silecchia et al. compared weight loss results of laparoscopic fundectomy in 19 patients divided into two groups, both with severe reflux symptoms and presence of residual fundus/neofundus. The first group had a history of successful weight loss, and the second group had insufficient weight loss/weight regain prior to fundectomy. Those patients with preoperative history of poor weight loss or regained weight reported an additional 53.4% EWL at 24 months [18]. A study by Huseyin et al. described 32 patients who required revisional surgery after a failed LSG. Failure was considered in cases of poor weight loss (<50% EWL after 1 year), weight regain (>30% of lost weight), and persistent GERD despite anti-acid therapy. Most patients in this study underwent revisional Re-SG due to findings of residual fundus, dilated antrum, or pouch. All patients experienced >50% EWL after follow-up of at least 1 year [19].

Iannelli et al. collected data on 430 patients after SG and 77 (17.9%) patients were converted to RYGB (40), DS (31), and Re-SG (6). There were two indications for conversion: weight loss failure (<50% EWL) at 18 months and intractable GERD refractory to PPI therapy. Patients experienced the most %EWL after conversion to BPD-DS (73–80%) at 18.6 months. Gastric bypass patients had 65–66%EWL and Re-SG resulted in the least %EWL, 43–58% [20]. Re-sleeving a segment of the original sleeve may appear to be easier, but it does not always result in better or equal weight loss by comparison to other procedures and must be weighed against higher risk of complications [11, 18, 21]. The incidence of leakage following fundectomy or re-sleeve gastrectomy varies from 10.5% to 14.2% [18, 21]. In a 2018 review of revision complications, Benois M et al. compared 138 patients converted to RYGB and 38 patients after pouch resizing with 756 initial RYGB patients. While they found no difference in outcomes between primary RYGB and those converted to gastric bypass, patients who underwent pouch resizing had a higher incidence of leaks (3.2% and 3.6% vs. 13.2%, respectively) [22].

Conversion to BPD/DS has been associated with excellent additional weight loss results after the initial sleeve failure in patients with comorbidities, especially when compared to other bariatric procedures such as repeat sleeve gastrectomy or conversion to Roux-en-Y gastric bypass. In a recent study of 118 patients after laparoscopic sleeve gastrectomy by Biertho et al., 42% of patients were converted to BPD/DS. A significant increase in remission rate of Type II diabetes mellitus (59–94%), and an excess weight

loss increase from 39% to 81% was observed [23]. Likewise, Homan et al. found that in patients with insufficient weight loss, median excess weight loss was greater after BPD/DS than conversion to Roux-en-Y gastric bypass (59% vs. 23%) after 34 months [24]. Dapri et al. also reported a greater weight loss after BPD/DS when compared to repeat sleeve gastrectomy (%EWL of 43.7 ± 24.9% for the re-SG group vs. 73.7 ± 27.7% for the DS group). However, conversion to laparoscopic BPD-DS is more technically demanding and is associated with protein calorie malnutrition, vitamin deficiencies, and anemia [21, 25]. Sethi et al. reviewed long-term outcomes after BPD with and without DS in 100 patients. Thirty-four percent (34%) underwent laparoscopic biliopancreatic diversion (BPD) and 64% had BPD-DS. Twenty-two patients had a history of previous bariatric surgery. Although BPD-DS patients with BMI <50 kg/m$^2$ achieved 11% greater weight loss, five patients had to have open surgery and one patient was converted to open. Overall, 37% of patients developed long-term complications requiring some form of additional surgery. Moreover, BPD-DS patients had a high incidence of thiamine deficiency, vitamin D, vitamin K, and zinc deficiencies. Protein malnutrition was found in 40% of patients [26].

In an attempt to decrease the incidence of complications and the effects of severe malabsorption, a modification of the original biliopancreatic diversion with duodenal switch, the single-anastomosis duodeno-ileal switch (SADIS), has been introduced and recently utilized as a salvage procedure following failed laparoscopic sleeve gastrectomy. Current indications for conversion to SADIS following sleeve gastrectomy include insufficient weight loss or progressive weight regain [27–30]. In a meta-analysis of 581 patients undergoing SADIS, 12.6% of patients required the procedure as part of revisional surgery. The average %EWL was 30% at 3 months and progressed to 85% by 2 years [27]. Although the total %EWL rivals that of Roux-en-Y gastric bypass or traditional BPD/DS, Moon et al. reported a slower rate of weight loss in patients who received SADIS when compared to conversion to gastric bypass [30]. The overall complication rate following SADIS is estimated at 4.8%. Postoperative diarrhea comprises the majority of complications, but SADIS has also been associated with nutritional deficiencies (vitamin A, selenium, iron), anastomotic leak, wound infection, sleeve stricture, bowel obstruction, postoperative bleeding, and internal hernia in select cases. Many of these complications are more commonly reported with revisional SADIS when compared with primary SADIS as the initial weight loss procedure [27]. However, further long-term studies are needed to determine its safety and efficacy in revision of sleeve gastrectomy. In contrast to BPD-DS, conversion to RYGB may result in less weight loss, but it is technically easier, causes less malabsorption, and increases restriction because of the small gastric pouch. Furthermore, it has been shown that conversion to gastric bypass significantly reduces or eliminates GERD symptoms and reverses Barrett's esophagus [24, 31, 32]. Lastly, the SADIS procedure causes less malabsorptive complications in comparison to BPD-DS but fails to address symptoms of reflux unlike RYGB.

When considering sleeve revisional surgery for weight loss failure in cases of abnormal anatomy (retained fundus, dilated sleeve) versus weight loss failure in patients with normal size sleeve, the goal should be to improve weight loss and restore restriction with minimal complications.

## Gastric Sleeve Stenosis

Gastric sleeve revision is sometimes necessary to treat chronic strictures that do not respond to endoscopic intervention. The incidence of strictures after SG varies from 0.1% to 3.9% [33]. Strictures or stenosis may appear as early as 1 month after SG. Rebibo et al. reported gastric stenosis symptoms in 17 patients out of 1210 who underwent LSG (primary or secondary). The median time to diagnosis was 47.2 days [34]. Chronic sleeve stenosis or angulation causes obstruction which leads to increased intragastric pressure proximally and stretching of the body

and fundus. Subsequently, a combination of chronic stenosis, enlarged fundus, and loss of restriction is responsible for complaints of chronic dysphagia, epigastric pain, persistent nausea, vomiting, and sometimes gastroesophageal reflux. The problem usually becomes apparent after an UGI series or during endoscopic examination. Sleeve stenosis appears as a smooth tapered narrowing of the stomach with a thin line of oral contrast typically in the proximal or distal portion of the sleeve radiographically [35]. The endoscope may not even pass through the stenotic area or in a functional stenosis, and the sleeve may appear rotated or twisted. In a review by Dhorepatil et al., 33 of 1756 patients developed a stricture after SG. The most common location of the stricture was mid-body (54.5%), incisura (30.2%), and upper third of the sleeve (15.2%) [36]. Nath et al. noted that narrowing or stenosis of the gastric sleeve was associated with dysphagia, and the prevalence of gastric sleeve stenosis after sleeve gastrectomy was 2.3%. Dysphagia was the most common symptom in 22.7% at up to 2 years after SG. However, revisional operation for sleeve stenosis may not be necessary. All 33 patients diagnosed with a narrowing, sharp angulation or spiraling of the sleeve underwent successful treatment with balloon dilatation. Symptoms of dysphagia were resolved in 69% of patients [37]. Manos et al. observed 94.4% success rate with endoscopic balloon treatments of stenosis. In 39.4% only one endoscopic dilatation was required. Only one patient required conversion to RYGB [38]. When repeated balloon dilatations fail, placement of a stent or surgical revision becomes the only option. Placement of fully covered self-expandable metal stents (SEMS) to treat gastric sleeve stenosis and staple line leaks is well described in the literature [34, 39]. However, stent placement is not without risks. Stent migration is a common occurrence and requires repeated deployment or replacement. Singer et al. found that 20% of stents migrated and 63% had to be replaced. Stent placement was complicated by mucosal friability, tissue integration, bleeding, and even an aorto-esophageal fistula [40]. In addition, they may not be well tolerated by patients due to severe heartburn. Surgical revision such as pyloroplasty, stricturoplasty, seromyotomy, and median gastrectomy (wedge resection) are among additional surgical alternatives for gastric sleeve stenosis [41–43]. A majority of these procedures are associated with high leak rates and recurrent stenosis. Conversion to an RYGB is safer because it results in lower intragastric pressure and decreases the chance of a leak.

## Intractable Gastroesophageal Reflux

Intractable postoperative gastroesophageal reflux disease (GERD) is also a compelling reason for revision. There is a wide range in incidence of "de novo" GERD symptoms after SG from 5.4% to 36% [44, 45]. The prevalence of gastroesophageal reflux in the morbidly obese patient population was 45% and, according to Pallati et al., sleeve gastrectomy was the least likely procedure to improve GERD symptoms [46]. Gastroesophageal reflux can be debilitating to the patient and is associated with development of erosive esophagitis, intestinal metaplasia, and Barrett's esophagus. Repeated injury to the esophageal mucosa by acid–bile reflux can potentially lead to the development of esophageal adenocarcinoma [47–49]. In the event of esophageal cancer in an SG patient, surgical treatment is complicated by the limited options for reconstruction. While gastroesophageal reflux disease is widespread in morbidly obese patients, the effects of SG on GERD and the reasons for worsening reflux or development of "de novo" reflux following SG are unclear. Most studies evaluate a small number of patients with only subjective symptom questionnaires and do not include 24-h pH monitoring, endoscopy, manometry, or upper GI series. Understandably that kind of extensive postoperative follow-up may not be feasible outside of large academic centers. Sleeve gastrectomy (SG) patients with complaints of persistent heartburn while taking proton pump inhibitors (PPI) should undergo a postoperative flexible upper endoscopy (EGD) or at least an upper gastrointestinal series.

Flexible upper endoscopy is diagnostically and therapeutically invaluable. Besides being useful in readily identifying sleeve stenosis, spiraling or twisting of the sleeve stomach, and the presence of retained fundus or hiatal hernia, it can easily determine the presence of erosive esophagitis, Barrett's esophagus, or bile reflux. The incidence of erosive esophagitis and Barrett's esophagus in patients after SG is underestimated while the incidence of biliary reflux after SG is seldom discussed and remains unknown [50]. Genco et al. found a complete lack of correlation between GERD symptoms and endoscopic findings. At a mean follow-up of 58 months, a concerning increase in incidence and severity of erosive esophagitis and nondysplastic Barrett's esophagus (BE) was observed in 110 patients. The incidence of newly diagnosed BE was 17.2%, and biliary-like esophageal reflux was discovered in 75.5% of cases [50]. In a follow-up study, Soricelli et al. observed that the frequency of esophageal findings of erosive esophagitis and Barrett's esophagus in patients taking PPIs was similar to those not taking PPI medications. In 140 patients, 59.8% were diagnosed with erosive esophagitis while 13.1% had a new finding of Barrett's esophagus. Additionally, 68% was determined to have bile reflux [51]. In another review, Rebecchi et al. discovered symptoms of reflux correlated with pH monitoring in only 5.4% (2/37) of patients that had a real "de novo" gastroesophageal reflux 2 years after surgery [52]. Therefore, evaluation of GERD based solely on symptoms is unreliable and more aggressive postoperative surveillance should be recommended.

Several mechanisms have been hypothesized to be responsible for the increased frequency of GERD after SG operation: increased intragastric pressure, decreased tone of the lower esophageal sphincter (LES), injury to sling fibers of Helvetius by the angle of His, and the presence of a hiatal hernia. Loss of fundus, the most expandable portion of the stomach, results in diminished compliance during ingestion of a meal and in return increases the intragastric sleeve pressure, which promotes esophageal reflux and postprandial regurgitation [53, 54]. Increase in gastroesophageal reflux can also be attributed to decreased lower esophageal sphincter (LES) tone due to division of the sling muscle fibers when stapling too close to the gastroesophageal junction [55]. However, esophageal manometry data are confusing. Braghetto et al. showed a significant decrease in LES pressure in 85% (17/20) of patients 6 months after SG while Petersen et al. reported an increase in LES pressure independent of weight loss [55, 56]. Meanwhile, in a prospective study of 65 patients, Rebecchi et al. did not find any significant manometric changes in LES pressure [57]. Lastly, presence of a hiatal hernia or migration of the proximal portion of the gastric sleeve into the mediastinum may result in a decreased pressure gradient between the low pressure in the mediastinum and the high pressure in the abdomen. Genco et al. discovered upward migration of the Z line into the chest in 73% of cases [50]. During endoscopic examination, diaphragmatic impression is easily seen during retroflexion and signifies the presence of a hiatal hernia. As the gastroesophageal junction and the proximal portion of the sleeve become incarcerated in the chest over time, the gastric sleeve is partially obstructed as it traverses the diaphragmatic hiatus into the mediastinum. This contributes to the already functionally abnormal LES and increases intragastric pressure in the sleeve above the diaphragmatic hiatus, which leads to stasis and regurgitation of food and persistent reflux of gastric acid secreted by the remaining fundus. In any sleeve gastrectomy patient with complaints of "de novo" gastroesophageal reflux, a thorough search for hiatal hernia is necessary. Small hiatal hernias (1–2 cm) are often missed on preoperative upper endoscopy. Because of small sizes, they are also difficult to identify intraoperatively even when the fundus is mobilized and the posterior left crus is exposed. This is especially true in patients with BMI >50. Shada et al. compared two groups of patients undergoing SG or RYGB with and without concurrent paraesophageal hernia (PEH) repair. The smallest number of patients to have a concurrent PEH was those with BMI >50 kg/m$^2$ and the ones undergoing RYGB. Even though laparoscopic paraesophageal hernia repair with

concurrent LRYGB or LSG was shown to be safe, only 7.8% underwent the repair at the time of the bariatric procedure [58]. Performing bariatric surgery concurrently with PEH repair can be more technically challenging especially when it includes RYGB. One must be comfortable enough in the ability to achieve a full mediastinal dissection of the distal esophagus required in repairing PEH/HH. Every attempt must be made in exposing the posterior crura to make sure hiatal hernia is not missed intraoperatively. Therefore, the true incidence of hiatal hernia at the time of the initial bariatric procedure is often underestimated. Undiagnosed or missed hiatal hernias are associated with worsening postoperative reflux and development of new onset symptoms of heartburn and dysphagia, eventually leading to progressive herniation. Soricelli et al. showed that routine crural and hiatal hernia repair in patients undergoing SG provided excellent control of reflux symptoms. The incidence of "de novo" GERD symptoms was 22.9% in SG patients without hiatal hernia repair [59]. In our own series we found that preoperative EGD was unreliable at diagnosing paraesophageal hernias. Twenty-three patients underwent paraesophageal hernia repair at the time of SG and only four had hernias diagnosed on preoperative upper endoscopy [60]. Boules et al. discovered that only 39% of hiatal hernias were diagnosed preoperatively [61]. Casillas et al. found a strong association between preoperative GERD and a discovery of a hiatal hernia at the time of revision from an SG to RYGB. A total of 48 patients underwent conversion to RYGB for intractable GERD, poor weight loss or regain, strictures, and recurrent diabetes. In this study, 24 patients were determined to have a hiatal hernia at the time of revision and 20 patients had reflux preoperatively. GERD improved in 97% of patients [31]. Many reports show significant improvement in gastroesophageal reflux and even increased %EWL when hiatal hernias are repaired at the time of the sleeve gastrectomy [62, 63]. Daes et al. reported on their experience with SG and described surgical technique that resulted in significant improvement in reflux symptoms. Sleeve gastrectomy was performed on 382 patients of which 170 patients were preoperatively diagnosed with GERD; 142 patients had intraoperative confirmation of hiatal hernia and they had it repaired. During follow-up of 22 months, only 10 (2.6%) patients had GERD symptoms and 94% of patients were asymptomatic [64]. This only emphasizes the importance of a hiatal or paraesophageal hernia repair at the time of either primary SG and, especially, at subsequent revision surgery.

Intractable GERD and weight regain are the most common indications for conversion to Roux-en-Y Gastric Bypass (RYGB) with excellent resolution of reflux and additional weight loss [65]. Felsenreich et al. followed 103 patients for over 10 years after SG with 33% eventually undergoing conversion to gastric bypass for weight regain and reflux. All patients who converted to gastric bypass had complete remission of GERD. The incidence of Barrett's esophagus in the nonconverted group was 14% and the presence of metaplasia was independent of reflux symptoms [66]. The authors suggested that upper endoscopy examination should be offered every 5 years after SG, which could help detect asymptomatic patients with esophagitis and Barrett's metaplasia. However, if metaplasia is found, then yearly endoscopy is recommended and conversion to gastric bypass should be strongly considered. Lastly, Crawford et al. proposed that patients with severe reflux should not be considered suitable candidates for SG operation. The only reliable treatment for SG patients with intractable reflux is conversion to a Roux-en-Y gastric bypass [67]. In conclusion, there is ample evidence that conversion to Roux-en-Y gastric bypass after sleeve gastrectomy leads to resolution of gastroesophageal reflux and complete regression of Barrett's esophagus [68, 69].

## Staple Line Leak

Staple line leak is one of the most feared complications following sleeve gastrectomy operation due to its high morbidity and difficult management. The incidence of leaks following sleeve gastrectomy varies from 0.16% to 3.9% [70]. A commonly accepted classification system of

gastric leaks proposed by Csendes et al. divides postoperative leak into two types based on clinical presentation: Type I (Subclinical) and Type II (Clinical). In summary, Type I leaks are characterized by leakage without early septic complications with corresponding drainage through a fistulous track and with or without generalized dissemination to the pleural or abdominal cavity. In contrast Type II leaks are defined by early septic complications and generalized dissemination into the pleural or abdominal cavity and without a defined fistulous tract. Most experts though classify leaks based on the time of presentation such that early leaks appear 1–3 days postoperatively, intermediate leaks appear 4–7 days postoperatively, and late leaks declare themselves ≥8 days following surgery [71–75]. However, leaks can manifest themselves months after the initial sleeve gastrectomy and even those that heal may recur [76]. Typically, early leaks are attributable to technical issues intraoperatively such as staple misfiring or tissue injury from electrocautery devices, whereas intermediate and late leaks are more associated with ischemia secondary to over-dissection [77].

There are many treatment options in case of a staple line leak after sleeve gastrectomy, but no consensus has been reached on the best approach. According to the Fifth International Consensus Conference on the current status of sleeve gastrectomy, acute leaks were mostly approached with endoscopic stenting and percutaneous drainage of abscesses, while others preferred laparoscopic drainage and feeding jejunostomy. Conversion to gastric bypass was the preferred option for treatment of chronic leaks and the second option was fistula-jejunostomy [78]. The largest series of laparoscopic Roux-en-Y fistulojejunostomy as a salvage procedure was described by Chouillard et al. and was shown to be successful in 27 patients with chronic postsleeve gastrectomy fistula who failed conservative management [79, 80]. Surgical treatment is also dictated by the location of a leak, and the most common location is near the esophagogastric junction. Leaks occurring right at the angle of His may require Roux-en-Y esophagojejunostomy with resection of a fistula and the effected stomach.

The exact cause for a leak is unknown but many theories exist. It has been hypothesized that postsleeve gastrectomy leaks tend to be prolonged secondary to a high-pressure system created by the reduced intragastric volume and low compliance of the gastric tube. According to Mion et al., increased intragastric pressure of more than 30 mm was discovered in 77% of patients after SG [81]. Similarly, Yehoshua et al. demonstrated that although mean intragastric basal pressure was the same before (19 mmHg) and after sleeve gastrectomy (18 mmHg), when the sleeve stomach was filled with saline intragastric pressure rose to 43 mmHg (32–58 mmHg) [54]. Conversion of a sleeve gastrectomy to gastric bypass leads to faster resolution of a leak because of a lower intraluminal pressure. Using high-resolution manometry, Björklund et al. studied motility at the esophagogastric junction in 18 patients 2 years after gastric bypass. He observed that following ingestion of a meal, intraluminal pressure increased only by 6–8 $cmH_2O$, and the gastric pouch and Roux limb behaved as a single cavity [82]. Since low intraluminal pressure favors faster healing, conversion to RYGB early after the initial diagnosis of a leak could spare patients repeated endoscopic treatments. There is only one case report of three patients successfully converted to RYGB in an acute setting of a leak from sleeve gastrectomy [83]. Currently, endoscopic stent placement is the most common next step in the treatment of a leak. It is safe and effective, but as mentioned earlier, it is not without complications. In addition, it takes a considerable time to heal a leak while maintaining unhappy patients on total parenteral nutrition (TPN), intravenous antibiotics, and liquid diet. When management of leaks following SG was compared to leaks after RYGB, sleeve leaks were diagnosed 26.2 days versus 6.0 days later after the initial procedure, and it took 57.8 versus 44.2 days longer for the resolution of a leak. Furthermore, multiple endoscopic procedures were needed to manage a leak after sleeve gastrectomy while drainage alone was sufficient enough to treat a leak after RYGB [84]. Leaks after RYGB were easier to manage. Repeated endoscopies are routinely required to treat a leak

after sleeve gastrectomy. An esophageal covered, flexible self-expanding metallic stent may be used to exclude the site of leak if it is small and present just beyond the esophagogastric junction. According to Eubanks et al., postleak stenting has had success rates between 50% and 84% in the treatment of acute leaks and chronic fistulas, but at the cost of a 60% chance of stent migration [85]. Krishnan et al. conducted a retrospective review of 37 patients who underwent stenting for leaks with an overall success rate of 94.5%. In their experience over the years the incidence of stent migration has been significantly decreased from 41.1% to 15% [86]. Technology and endoscopic procedures constantly evolve, and that reduces the necessity of surgical intervention to treat some complications. If laparoscopic drainage, stent placement, endoscopic overstitching, and over-the-scope clip (OTSC) fail to heal a leak, endoscopic septotomy can be an effective alternative. Endoscopic septotomy is a technique of incising the septum between the abscess cavity and the gastric sleeve lumen which ensures internal drainage of the abscess, decreases intraluminal pressure, and promotes healing. Mahadev et al. reported on nine patients treated with endoscopic septotomy following failure of all minimally invasive modalities. All patients with abscess collections ranging from 3 cm to 10 cm presented at a mean of 8.6 weeks after leak diagnosis and were successfully treated. It required multiple procedures and a mean follow-up of 21 weeks to achieve complete resolution of a leak [87]. Endoscopic vacuum therapy (EVT) is another interesting method recently described to treat early leaks after laparoscopic sleeve gastrectomy or gastric bypass. Morell et al. reported on six consecutive patients successfully treated with EVT, but the median duration of treatment was 23.5 days consisting of repeated endoscopic procedures [88].

Treatment of leaks following sleeve gastrectomy continues to evolve, and many endoscopic and surgical techniques show promise. However, the return to the operating room for laparoscopic exploration and drainage is the fundamental first step in the treatment of any leak. Laparoscopy combined with intraoperative endoscopy may be of benefit in helping identify the location of a leak and guide stent anchoring and placement. Conversion to Roux-en-Y gastric bypass should be strongly considered early following leak diagnosis and can potentially be the most effective and safe way for expedient control of intraabdominal sepsis and healing of a leak [22].

## Preoperative Evaluation

Thorough preoperative evaluation consisting of nutritional and psychiatric consultations, applicable endocrinology work-up, blood work to assess nutritional and hormonal status, flexible upper endoscopy (EGD), and an upper gastrointestinal series (UGI) are essential for a successful outcome. Preoperative compliance with nutritional recommendations is the cornerstone of weight loss success after revisional bariatric surgery for weight loss failure. Radiological preoperative evaluation most commonly involves an upper gastrointestinal series with water-soluble contrast that enables visualization of the dilated gastric fundus, body, or antrum [89–91]. At our institution we routinely perform an initial gastrografin series followed by a thin barium swallow because it better defines the anatomy of the remnant sleeve.

### Upper GI Series

The indispensable value of preoperative upper GI series in diagnostic evaluation of a patient with the history of past foregut surgery was lately described by Dempsey et al. [92]. Upper GI series helps in defining anatomy, especially in cases where operative reports describing previous bariatric procedures are not available. The quality of the study depends on an experienced radiologist who understands bariatric procedures and is included in the bariatric team. Furthermore, upper GI series should not be considered as redundant to upper endoscopy but complementary to this and other diagnostic modalities useful in the management of patients with foregut symptoms. In patients with history of previous

bariatric surgery and complaints of chronic nausea, abdominal distention, vomiting, dysphagia, and upper GI series may identify anastomotic strictures, gastrogastric fistula, hiatal hernia, reflux, small intestine obstruction at jejunojenostomy, achalasia, and many other conditions. Furthermore, we routinely obtain upper GI series postoperatively which serves as a reference point for comparison, should more surgery be required in the future for any reason. The purpose is not to rule out a leak but to document the shape of a sleeve or a gastric pouch, evaluate anastomosis for stricture, or detect a recurrent hiatal hernia. Hiatal hernia can potentially recur during extubation in a patient who just had it repaired concurrently with a bariatric procedure. Without postoperative upper GI series, a decision to return to the operating room for repair of recurrence within 24 hours of initial surgery would be difficult to make.

If initial imaging with contrast studies is equivocal, one may consider computed tomography volumetric evaluation as described by Rebibo et al. [93]. CT volumetry of the gastric sleeve greater than 250 cc is suggestive of a patient benefitting most from sleeve revision for further volumetric reduction [91, 93].

## Flexible Upper Endoscopy

Flexible upper endoscopy must be a part of any revisional bariatric surgery planning. The value of routine preoperative endoscopy as part of the initial bariatric surgery assessment continues to be questioned by some. A recent systematic review by Bennett et al. showed that a proportion of upper endoscopies that result in changes in management is low [94]. However, preoperative EGD can potentially change the management before committing to revision. For example, in a sleeve gastrectomy patient, endoscopy would help in evaluation of severity of stenosis or angulation of the sleeve, identify the location of a leak or fistula, and indicate presence of hiatal hernia. In addition, the therapeutic value of flexible upper endoscopy should not be overlooked. EGD examination has proven useful in the treatment of sleeve gastrectomy leaks, gastric fistulas, and stenosis [95, 96]. Furthermore, intraoperative endoscopy is an extremely valuable tool in assisting bariatric revisions by directly identifying the area of the problem, helping position the stapler without torqueing the tissues, controlling the size of the pouch, and intraoperative leak testing. Intraoperative endoscopy is useful in guiding operative strategy and avoiding technical complications [97, 98].

## Laparoscopic Sleeve Gastrectomy Operation: Original Technique

We perform laparoscopic sleeve gastrectomy operation with five blunt trocars: four 5 mm trocars and one 15 mm trocar placed usually in a single longitudinal line across the upper abdomen. The patient is positioned with both arms extended and with a foot board. The operation begins with the exposure and identification of the pylorus. An ultrasonic device is used to enter the lesser sac at the incisura of the stomach. A greater curvature is first mobilized toward the pylorus, stopping approximately 2 cm proximally. The gastroepiploic arterial arcade should be preserved to maintain viability of an omental pedicle flap, which is used to buttress the staple line. The gastrocolic ligament and short gastric vessels are divided. We try to free enough of the gastroesophageal fat pad away from the gastric wall to ensure clear visualization of the stomach wall. Only gastric tissue is included in the staple line, especially when stapling near the Angle of His and gastroesophageal junction. The entire fundus is dissected away from the left crus. This exposure helps identify the presence of a posterior gastric component of hiatal hernia and avoids leaving extra fundus tissue during stapling. Posterior gastropancreatic adhesions are divided sharply with endo-shears, staying away from lesser curvature vessels and avoiding injury to the left gastric pedicle. We use a 36-Fr bougie during stapling. Most importantly, the staple height should correspond to the thickness of the stomach tissue. Stapling begins 3 cm

proximal to pylorus to avoid leaving a large antrum, and the first fire of the stapler should be oriented almost in parallel to the lesser curvature. Once locked, the stapler is rotated upward to expose the posterior stomach wall. This maneuver is repeated with every fire of the stapler to make sure that the stomach wall is flat, and the stapler does not involve the lesser curvature blood supply. There is no need to hug the bougie. When stapling around the incisura, it is critical to avoid coming close to the lesser curvature, because subsequent staple application will require placement of the stapler to the left or medial to the "crotch" of the staple line. The stapler should be at least 3 cm lateral to where the arterial branches disappear into the stomach. Failure to do so can result in a flap–valve mechanism at the incisura and early stenosis [37]. Equal traction is maintained on the anterior and posterior stomach wall and avoids spiraling or rolling of the sleeve which may result in stenosis or angulation. The last stapler application should be 1–2 cm away from the Angle of His. We use buttressing material throughout the staple line which helps with hemostasis. Two 5 mm endo-clips are placed on the staple line, one at the beginning of the staple line and one on the end. This helps identify the location of the staple line on postoperative upper GI series. We closely inspect the entire staple line for any potential defects or bleeding. Bleeding areas can easily be controlled with 5 mm endo-clips. We do not perform routine intraoperative testing for leaks. It has been shown to have poor sensitivity and is not associated with decrease in incidence of postoperative leaks [99, 100]. However, any suspicions of staple line dehiscence should be addressed with intraoperative endoscopy and immediate suture repair. Intraoperative endoscopy is associated with decreased risk of postoperative complications [101]. The greater omentum is then used to buttress the sleeve staple line in place with fibrin glue, which is safer than suturing the flap to the staple line. In general, suturing of the staple line can potentially cause ischemia and should be avoided. In the end, the resected stomach is removed in a specimen bag via the 15 mm trocar.

## Sleeve Gastrectomy Conversion to Roux-en-Y Gastric Bypass

A conversion of a sleeve gastrectomy to Roux-en-Y gastric bypass is usually performed in the setting of severe stenosis or angulation of the sleeve, intractable gastroesophageal reflux, failure to achieve sufficient weight loss, dilated sleeve or fundus, and sometimes to treat a staple line leak. It has less potential for complications compared to re-sleeving or fundectomy because it results in lower intragastric pressure. We perform all operations laparoscopically. Endoscopy should be available if the anatomy is unclear to test a gastrojejunostomy (GJ) anastomosis for leaks or to be used as a bougie to guide the pouch construction. It is important to note that only carbon dioxide is used for insufflation during intraoperative endoscopy to avoid overdistention of small intestine. We use four 5 mm blunt trocars and one 12 mm trocar which is placed slightly lateral to the mid-clavicular line in the right upper quadrant of the abdomen. Because we perform the majority of GJ anastomoses by hand, the use of a foot-board is preferred. The surgeon standing on the right side of the patient provides better angles and triangulation during intracorporeal suturing.

Dissection is begun by finding the least challenging area to enter the lesser sac and then dividing all perigastric adhesions and scar with an ultrasonic dissector along the entire length of the sleeve staple line. The entire sleeve fundus must be freed from adhesions to the left crus, and the entire proximal staple line must be seen within the abdomen. Visualization of the base of the crus helps with identification of a hiatal hernia even if preoperative studies did not show it. If there is still doubt, then exploration of the base of the right crus must be performed. However, that exposure can be treacherous, especially if there is a history of previous hiatal hernia repair, lap-band procedure, or mesh placement. Past history of any mesh implantation in that location can make the anatomy very confusing due to extensive scarring. After division of pars flaccida, extreme caution must be exercised and dissection should begin medially (toward patient's left) and more superior

on the crus if possible. This will keep you away from accidently entering the inferior vena cava which is immediately to the right (surgeon's left) of the right diaphragmatic crus and is usually hidden by the caudate lobe of the liver. When dissecting anterior on the right crus toward the anterior phrenoesophageal ligament, avoid moving too far to your left and injuring the left hepatic vein or its branches. Keep in mind that the branches of the celiac trunk can be in a different location due to adhesions and scarring from previous surgery. Particularly important is to preserve the left gastric artery as the main blood supply to gastric pouch. It is often displaced into the posterior mediastinum in the presence of a large hiatal hernia. Hiatal hernia and both crural bundles should be free of all the adhesions, and mediastinal dissection must be completed prior to gastric pouch creation for the bypass. A Penrose drain is used around the gastroesophageal junction (GEJ) to facilitate circumferential mediastinal and hiatal dissection. Preserve anterior and posterior vagus nerves. Mediastinal dissection should result in at least 2–3 cm of intraabdominal esophagus. We recommend creation of a gastric pouch be done first and posterior crural closure last. This sequence of steps helps avoid any difficulty with positioning of a bougie and provides excellent visualization of GEJ and angle of His. Posterior cruroplasty is performed with interrupted permanent, preferably, monofilament suture. We perform gastrojejunostomy anastomosis after distal jejunojejunostomy is completed. A 40 cm biliopancreatic limb is used in a side-to-side stapled jejunojejunostomy and a 100 cm antecolic Roux limb is brought up to the posterior wall of the gastric pouch. The mesenteric defect is closed with a running 2–0 nonabsorbable suture. Gastric pouch creation starts with a careful perigastric dissection approximately 5–7 cm distal to the gastroesophageal junction (GEJ) on the lesser curvature above the incisura angularis. Preferably only one fire of a linear stapler is required to divide the stomach sleeve directly perpendicular to the lesser curvature. If the sleeve is dilated, then re-sleeving of the pouch is necessary. When re-sleeving is performed, we use a 36-Fr bougie. However, we prefer a 32-Fr bougie for creation of the gastrojejunostomy anastomosis if re-sleeving is not needed. Buttressing material is usually unnecessary during conversion to gastric bypass and may only contribute to the already thickened gastric tissue. The entire gastrojejunostomy anastomosis is completed with 2–0 running absorbable sutures in a two-layered fashion. Finally, the GJ anastomosis is tested with air insufflation under saline and distention of anastomosis with 60 ml of diluted methylene blue dye.

## Re-Sleeve Gastrectomy (Re-SG)

"Re-Sleeving" of the dilated gastric remnant has been gaining traction in recent years [90, 91, 93, 102, 103]. Previously mentioned indications for re-sleeve gastrectomy include progressive weight regain or insufficient weight loss as a result of dilated fundus, body, or antrum. Proposed benefits of re-sleeve gastrectomy when compared to malabsorptive procedures include restoring volume restriction, decreasing gastric acid output, minimizing the dumping effect secondary to pylorus preservation, decreasing the risks of anemia, osteoporosis, and nutritional deficiency [91]. Further factoring in the decision to perform laparoscopic re-sleeve gastrectomy, one must assess the initial anatomy of the sleeve, the presence of other medical comorbidities, and the patient's goals.

The operative steps of performing a "re-sleeve" gastrectomy are nearly identical to that of the initial procedure. A standard blunt five-trocar port placement with four 5-mm trocars and a single 12- or 15-mm trocar is typically used to gain access to the peritoneal cavity. Following laparoscopic investigation of the peritoneal cavity, lysis of adhesions should be performed, making sure to adequately mobilize the initial staple line. Dissection of the hiatus follows initial adhesiolysis, ensuring adequate visualization of the left crus and mobilization of the dilated portion of the stomach sleeve. Before proceeding with the re-sleeve, care should be taken to systematically search for hiatal hernia, even if not previously identified on preoperative upper gastrointestinal imaging or endoscopy. Should hiatal hernia be

discovered, the circumferential mobilization of GEJ and mediastinal lysis of adhesions should be performed first. At least 2–3 cm of intraabdominal esophagus is necessary to achieve adequate reduction and repair of the hiatal hernia. We routinely use a 36 French bougie as a guide during stapling. Appropriate staple height selection for the given tissue thickness is important to minimize chances of a leak due to misfiring of the stapler. Selective intraoperative endoscopy is sometimes needed to visualize the intragastric staple line and examine the shape of the new sleeve. Placement of a drain may be performed at the surgeon's discretion [90, 93, 103].

## Conversion to Biliopancreatic Diversion with Duodenal Switch (BPD/DS)

Patients suffering from insufficient weight loss or those who regained weight following sleeve gastrectomy with no apparent sleeve dilation are considered to have failed restrictive bariatric procedure. Such patients may benefit from an addition of malabsorptive component as the preferred choice of revisional surgery. Conversion of the SG to BPD-DS provides a well-documented option for further weight reduction, resolution of diabetes mellitus and hypertension, and treatment of reflux [104].

Indications for conversion to BPD/DS include <50% EWL, weight regain reflected by a BMI >35 kg/m$^2$, poorly controlled diabetes mellitus, and hyperlipidemia [25, 105]. Relative contraindications include distal small bowel or ileocecal resection, vitamin $B_{12}$ deficiency, low ferritin levels, or otherwise poor preoperative nutritional status. BPD/DS offers unique benefits not provided by other forms of revisional weight loss procedures, specifically the avoidance of the previous surgical field and associated scarring as well as the reversibility of its malabsorptive component [25]. In addition, chronic protein-calorie malnutrition secondary to malabsorption may be treated either through common channel lengthening, or as a last resort, reversal of the BPD/DS [105]. Conversion to BPD/DS may be performed laparoscopically, barring any absolute contraindications to laparoscopic surgery. Cholecystectomy is an option that may either precede or follow the completion of the conversion. The duodenum should be stapled approximately 2 cm distal to the pylorus with a linear stapler. It is important to adequately visualize the retro-duodenal structures to avoid injury to the porta hepatis or pancreas when positioning the stapler to divide the duodenum. Divide the ileum approximately 250–300 cm proximal to the ileocecal valve; the proximal loop will become the biliopancreatic limb, and the distal loop will serve as the alimentary limb. A 100-cm common channel is measured from the cecum, and a side-to-side stapled enteroenterostomy is created with the biliopancreatic limb. An antecolic, postpyloric, end-to-side anastomosis of the sleeve with the alimentary limb is constructed using a hand-sewn technique. Closure of any mesenteric defects with a nonabsorbable running suture is strongly recommended to minimize the risk of internal hernia. The newly formed anastomoses should be tested with instillation of methylene blue in the orogastric tube or via direct inspection with endoscopy [23–25, 105].

## Conclusion

The laparoscopic sleeve gastrectomy operation has become the most commonly performed operation for weight loss in the world. It is technically relatively simple and can be completed in a shorter operative time compared to other bariatric surgeries. Considered safe and effective in achieving weight loss, recent long-term studies have also demonstrated appreciable rate of weight regain or insufficient weight loss. Although the incidence of complications remains low, management of leaks, stenosis, and intractable gastroesophageal reflux is not entirely clear. There is currently no consensus on the best treatment of sleeve gastrectomy complications. As surgeons continue to perform sleeve gastrectomy operations, failure of weight loss and resurgence of medical comorbidities are becoming more

apparent. Eventually many patients will require a second operation to ensure sustained weight loss and resolution of comorbid conditions. The most suitable bariatric procedure for the revision of sleeve gastrectomy is still a matter of debate. Revisional bariatric surgery has higher risks and long-term complications. Therefore, the reasons and the goals of revisional surgery should coincide with the patient's expectations. In this chapter we attempted to review some of the literature and outline the basic principles and reasoning behind the choices for revision of the sleeve gastrectomy operation.

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# Gastric Bypass Reversal

3

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Bariatric surgery has been found to be an effective tool for the increasing prevalence of morbid obesity [1]. RYGB surgery is one of the commonly performed surgical procedures with excellent outcomes in reducing both obesity and its associated comorbidities [2, 3]. With the increasing number of RYGB surgeries being performed, there are increased reports of early and late postoperative complications like nutrient deficiencies, excessive weight loss, malnutrition, or marginal ulcers [4–6]. Most of the long-term complications can be treated without surgical intervention, but reversal of the anatomy may be required in some cases.

This chapter reviews the published literature on techniques and outcomes of RYGB reversal.

## Patient Demographics

In published literature, majority of the cases were women [7] with range of age at reversal between 21 years [8] and 64 years [9]. There was wide variation from the time of RYGB to reversal ranging from 3.5 months [10] to 298 months [8].

## Indications for Reversal

There are multiple reasons for reversal, but the most common indications are for malnutrition, especially if there is TPN dependence [11–13], dumping syndrome [9, 14], postprandial hypoglycemia [15–17], and excessive weight loss [7]. Other indications include marginal ulcer [8, 12, 18, 19], abdominal pain [13, 20], intractable nausea and vomiting, protein deficiency, recalcitrant hypocalcemia [21], GI stricture, narcotic or tobacco abuse, severe anorexia nervosa, hyperoxaluria and oxalate nephropathy [22], micronutrient deficiency, internal hernia, advanced cancer, and short gut syndrome [7].

There can be multiple causes of malnutrition after RYGB and the patients should be worked up to exclude other causes, especially psychiatric diseases (anorexia nervosa), cancers, or drug abuse prior to reversal. Placing a feeding gastrostomy before reversal may define a subset of patients who are unlikely to benefit from reversal

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of a RYGB to normal anatomy [9]. Using this approach, nutritional status can also be optimized before reversal [23].

Recurrent Retrograde intussusception (RINT) and roux stasis syndrome are motility disorders brought on by the creation of a Roux limb which may occur because of ectopic bowel pacing signals that develop in the Roux limb and compete with other signals originating in the proximal small bowel, duodenum, or stomach [24]. Symptoms have been reported in approximately 30% of patients undergoing Roux-en-Y reconstruction after gastric surgery for conditions other than weight loss. The symptoms include nausea, vomiting, and epigastric or periumbilical pain made worse with eating. The symptoms often appear several years after surgery, and female patients have an increased risk compared with male patients [24]. In patients with recurrent RINT or its symptoms after other treatments have failed, reversal of the gastric bypass appears to resolve the symptoms [24].

Postprandial hypoglycemia has been reported after RYGB [25] with incidence in some series as high as 10.4% [26]. There is a 25.5 times increase in prevalence of oral glucose tolerance test-induced hypoglycemia 12 months after an RYGB [26]. Dietary counseling, especially low carbohydrate diet and medications like acarbose, diazoxide, calcium channel blockers, and/or verapamil, should be attempted as initial treatment [15]. These treatments eliminate the symptoms and improve dumping syndrome after RYGB in majority of the cases, but in some patients, reversal may be needed [27, 28]. Patients with post-RYGB hyperinsulinemic hypoglycemia have been offered such procedures as gastric tube placement, resection of gastric pouch, or pancreatectomy with controversial results [8, 29].

There have also been case reports suggesting that the reversal of RYGB is not always effective as a therapeutic alternative to improve the postprandial hyperinsulinemic hypoglycemia related to RYGB [11, 17]. Another study found marked increase in glucose-dependent insulinotropic polypeptide (GIP) levels and concurrent decrease in glucagon-like peptide-1 (GLP-1) levels, suggesting a possible role of GIP in persistent hyperinsulinemic hypoglycemia after the reversal of RYGB [17].

## Workup Prior to Reversal

Workup varies based on patient presentation as in some cases the reversal is non-emergent. A thorough clinical history should be taken including psychological assessment and a full vitamin and nutritional panel. Gastrointestinal imaging series and upper endoscopy are helpful to evaluate the anatomy, especially the size of the gastric pouch, location of gastroesophageal junction, and location/size of the prior gastrojejunostomy. Radiologic images are helpful in assessing motility and excluding hiatal hernias. They also help identify the presence and location of any clips or radiopaque foreign bodies which may interfere in revisional surgery, especially staple firings.

## Reversal Techniques

Different approaches to reversal have been described and these include open, endoscopic, robotic, and laparoscopic techniques. Most of the recent published studies have used the laparoscopic approach, but a review found 19% underwent reversal by an open approach [7]. In laparoscopic technique, there is always a risk of conversion to open surgery, especially if there is history of open surgery, leak, or mesh placement [8, 11].

Case reports of endoscopic reversal have been described [16, 20, 30, 31]. Endoscopic-guided gastroenterostomy or enteroenterostomy with lumen-apposing metal stent has been used for both gastrogastrostomy (gastric pouch to gastric remnant) and jejunogastrostomy (Roux limb to gastric remnant) for the reversal of Roux-en-Y bariatric surgery [31]. One study using endoscopic technique reported closure of the proximal end of the Roux limb to prevent passage of food into the Roux limb [16].

Use of the robot has also been described for bypass reversal [32].

Nearly all surgical approaches include take-down of the original Gastrojejunostomy with creation of new gastro-gastric anastomosis. Techniques to do the gastro-gastrostomy include either hand-sewn [14, 24], side-to-side stapling using a linear cutting stapler [8, 12, 13] or end-to-end anastomosis using a circular stapler [15, 23].

Laparoscopic technique has been described to be safe and well tolerated in numerous articles and is our institution's preferred technique as described below

## Standard Operative Steps (Hand-Sutured Technique)

Patients are placed in supine position with a padded footboard and both arms are kept on arm boards at 70° to the body. Preoperative weight-based antibiotics are administered and sequential compression boots are applied. A foley catheter is usually used. After induction of pneumoperitoneum in the left-upper quadrant using Veress needle, a 12 mm trocar is placed approximately 20 cm below the xiphoid just to the left of the midline through the rectus muscle. An OptiView trocar is used with a 10 mm zero degree scope to enter the peritoneal cavity and the Veress needle removed after confirmation of safe entry. The zero degree scope is exchanged for a 45° angled scope. Four additional trocars are placed under direct visualization including a 5 mm and 12 mm in the right-upper quadrant and two 5 mm in left-upper quadrant. Each port is approximately one-hand breadth apart to avoid crossing of instruments. A Nathanson retractor is used to retract the left lobe of the liver through a subxiphoid incision. Lysis of adhesions is done to delineate the anatomy. These adhesions may be extensive, especially if there is history of prior open surgery. The anatomy is then confirmed evaluating the gastric pouch, gastric remnant, and small bowel for adhesions, dilation, ischemia, etc. The jejunojejunostomy is localized and the three components (alimentary, biliary, and common limbs) are clearly identified. Intraoperative endoscopy is very useful for confirming the anatomy. The Roux limb is transected several centimeters distal to the gastrojejunostomy using a linear stapler and is then fully mobilized to the level of the jejunojejunostomy. Mesentery of this part of the roux limb is divided using vessel sealing device and then a linear stapler with white cartridge is fired to transect this limb just proximal to the jejunojejunostomy with care being taken not to narrow the anastomosis. The mesocolic defect is then closed using running nonabsorbable suture. The ischemic demarcation of the transected roux limb helps in identification of the viable gastric pouch and a linear stapler is then used to transect the gastric pouch just proximal to the gastrojejunostomy. During dissection, care is taken not to devascularize the stomach pouch, which usually survives on one or two branches of the left gastric artery [14]. The excluded remnant stomach is mobilized and brought close to the new pouch without tension. Gastrostomies are then created on both the pouch and the remnant stomach measuring approximately 6 cm in length. We prefer to make these gastrostomies closer to the lesser curvature. A hand-sutured four-layered gastro-gastric anastomosis is then created using absorbable sutures. A nasogastric tube is guided into the antrum under direct visualization as a stent during creation of the anastomoses. The anastomosis is leak-tested by pushing 60 cc of air through the nasogastric tube while covering the newly created anastomoses with saline. 19-French Blake drains may be placed and brought out through the lateral 5 mm trocar sites. The fascial defects of the 12 mm trocar sites are closed using absorbable suture and a fascial closure device. Bilateral transverse abdominis plane blocks are then performed using long-lasting local anesthesia under visual and tactile guidance.

A gastrograffin swallow is done on the first postoperative day. The patient was usually discharged on a liquid diet on the first or second postoperative day, and a pureed diet is started after the first office visit at the second postoperative week.

## Circular Gastro-Gastrostomy Technique

While this is not part of our usual technique, circular stapled gastro-gastrostomy is used at some centers [15]. A 25 mm anvil is passed into the gastric pouch trans-orally usually using a delivery tube and a small gastrostomy is created in the gastric pouch. The delivery tube is then pulled through this opening to exteriorize the anvil through the gastric pouch. The tube is then disconnected from the anvil while holding the anvil in place. The anastomosis is completed by joining the anvil to an end-to-end circular stapler inserted into an opening at the greater curvature of the excluded stomach. Then, the EEA stapler and anvil are removed and the anastomosis inspected and may be reinforced at the corners with sutures [15].

## Linear Gastro-Gastrostomy Technique

The linear stapled gastro-gastrostomy is performed with firing of a linear stapler through gastrostomies made in the gastric pouch and excluded stomach. The resultant opening is closed with absorbable running sutures. During firing of the linear staple, care is taken to ensure that there is no crossing of staple lines, which may result in ischemic tissue. The staple load used is dependent on the thickness of the tissue and typically involves either the green or black loads. The staple lines are carefully visualized to ensure that the staples are well formed and there is no bleeding.

## Resection of the Roux Limb Versus Reanastamosis

Segment of the Roux limb left after creation of gastro-gastrostomy can either be resected or preserved. In our practice, we typically opt to resect the Roux limb to reduce the number of anastomosis and decrease operative times and the theoretical risk of postoperative leak from another anastomosis. Excision of the Roux limb may confer a malabsorptive benefit in the post-revision period, though this has not been widely studied. While mandatory with ischemic limbs, it is discretionary in all other settings. The Roux limb may also be preserved in patients with pre-existing short bowel. In a review of published literature on gastric reversals, Shoar et al. found that the technical consideration regarding the roux limb was available in 56% of cases, and of these, the roux limb was reconnected in 57.2% cases [7]. Should preservation be chosen, the steps are usually as follows. The biliopancreatic limb and the common channel are identified and the biliopancreatic limb is transected at the level of the JJ using a linear stapler. The distal end of the biliopancreatic limb is then anastomosed side to side to the proximal end of Roux limb. The resulting enterotomy is then closed either in a hand-sewn fashion or linear stapler. The mesenteric defect is closed using nonabsorbable sutures. Avoiding a long blind end is recommended to avoid limb stasis and infection.

A case report of resection of excluded stomach and use of the roux limb to recreate the normal anatomy, has also been described. In this report, excision of the excluded gastric remnant was done followed by division of the alimentary limb at the jejunojejunostomy level and anastomosis of its distal end to the duodenum [21].

## Special Operative Considerations

### Small-Sized Gastric Pouch

If the gastric pouch is small, then an end-to-end gastro-gastrostomy anastomosis may be done. Some teams perform an esophagogastrostomy, especially if there is doubtful vascularity of the pouch after dissection. Drains at the level of an EG anastomosis may be prudent given the increased leak rate of an esophageal anastomosis.

### Hiatal Hernia

Hiatal hernia that is either symptomatic or with endoscopic evidence of esophageal dysplasia should be addressed. We recommend reduction of the hiatal hernia and primary re-approximation of the crura.

### Pylorus

Many surgeons aid in emptying of the stomach by either injecting botox into the pylorus, performing balloon dilation [33], or selective pyloroplasty, especially if there is doubt of vagal integrity [11].

### Placement of Preoperative Gastrostomy Tube in Excluded Stomach

Placing a gastrostomy before the reversal operation can help improve nutritional status of the patient, avoid refeeding syndrome, and provide valuable information to evaluate the later effect of reversal on conditions such as therapy-resistant hypoglycemia or dumping [33]. However, placement of the gastrostomy, especially in the antrum, may increase the complexity of subsequent surgery and lead to increased leak rates at the gastro-gastrostomy site [33]. Placing the gastrostomy in the fundus and using a smaller size has been proposed to decrease the leak rates [33].

## Additional Surgical Options

### Sleeve Gastrectomy Post-reversal

Sleeve gastrectomy following reversal of gastric bypass has been described to avoid post-reversal weight regain and may be an option for patients with higher BMI. This can be done at the time of reversal or at a later date. Sleeve gastrectomy should be avoided in primary setting if indication for reversal is severe malnutrition. Creation of the gastro-gastrostomy closer to the lesser curvature aids in subsequent sleeve creation. Reversal with sleeve gastrectomy causes some weight loss, but does not guarantee sufficient weight reduction when performed for weight loss failure. Sleeve gastrectomy done simultaneously is also fraught with a higher surgical complication rate—particularly when a gastrostomy has been placed before the reversal procedure and appears to frequently induce GERD, even when HHR is performed concomitantly [33].

### Duodenal Switch Post-reversal

Post-reversal duodenal switch has been described as a management option for future weight gain or associated comorbidities. Surgeons usually create a larger sleeve using a 54 french bougie. Duodenal switch may be performed as single anastomoses or the traditional two anastomoses technique, according to surgeon preference.

## Postoperative Care

Postoperatively, patients are usually admitted with anticipated hospital course of 1–2 days. On postoperative day one, a water-soluble esophagram is usually performed evaluating for patency, leak, reflux, and transit time. If within normal limits, the patient is then advanced to a clear liquid diet.

## Post-Bypass Reversal Events

There is always a risk of weight regain after reversal and, in a review, was reported in 28.8% of cases [7]. It is important to follow patients and enroll them in a supervised program to prevent significant weight regain and monitor the vitamins and nutritional changes. Adding a sleeve gastrectomy at reversal does protect against weight gain in the postoperative period, but increases the risk of postoperative leak at the gastro-gastric anastomoses [33].

The other postoperative concern is development of severe GERD, which has been found between 10.2% [7, 9, 14] and 68% [33] of cases after reversal. GERD may develop despite hiatal hernia repair performed at reversal [33]. Approaching the hiatus from left to right side and preserving the phrenoesophageal membrane during dissection may decrease the reflux [33].

Though gastro-gastric anastomosis usually has adequate blood supply, reversal has a risk of leak, especially if there is tension at the anastomosis, decreased vascularity, or crossing staple lines. The incidence has been reported to be between 6.8% [7, 9] and 16% [33]. The leak rates

are higher if a sleeve gastrectomy is done at the same time [33] or if a gastrostomy had been done before the reversal procedure. Imbricating rather than resecting the distal stomach was found in one study to lower leak rate [33].

Poor emptying of the bypassed stomach and delayed gastric emptying are known risks after gastric surgery [11]. Although the precise mechanism of delayed gastric emptying has not yet been clarified, it is thought to be caused by various risk factors such as pylorospasm caused by disruption of the vagal nerve and vascular supply to the antropyloric region, angulation or torsion, or due to other complications such as intra-abdominal abscess. Given the incidence of symptomatic gastric outlet obstruction after bypass reversal, adding a botox injection, balloon dilation [33] or pyloroplasty to the bypass reversal can be done, especially if vagal branches were divided during the initial operation. Correcting electrolyte imbalance and medications like erythromycin have also been used to decrease the incidence of delayed gastric emptying [34].

Other complications include persistent abdominal pain [8, 10] and inability to gain weight [14, 19, 30]. In one study, all three patients who had reversal for intractable nausea and vomiting required readmission after the reversal. The authors felt that due to their persistent symptom and discomfort, it may be possible that some patients developed dependence on narcotics [8].

Hypoglycemia resolved in most of the patients after reversal, but failure to correct severe hypoglycemia after bypass reversal was observed by groups which had performed gastric bypass reversal to treat endocrine complications related to the intial gastric bypass [11, 15, 17].

Other postoperative events described include intraluminal bleeding requiring transfusion [9, 15], chronic diarrhea [9], gastric ulcer [9], persistent hypoglycemia with hyperinsulinemia [17], portal vein thrombosis [12, 24], septicemia [13], deteriorating hypoglycemia [15], persistent dumping syndrome, muscle cramp, long-term development of insulin resistance, gallstone pancreatitis, surgical site infection, and splenic bleeding [7].

## Conclusion

Gastric bypass reversal is a technically challenging procedure, which is being increasingly performed mainly for excessive weight loss, dumping syndrome, post-prandial hypoglycemia, or as a step to convert bypass to sleeve or duodenal switch. The procedure is well tolerated though with increased rate of complications. It is feasible to be performed through minimally invasive techniques, but patients should be extensively counseled regarding the increased rates of complications and the fact that all their symptoms may not resolve after surgery. There is a high incidence of weight regain and persistence of symptoms. It is important to select patients and optimize them prior to the reversal, which ideally should be done by centers with considerable experience, performing revisional surgery frequently.

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# 4 Management of Banded Gastric Bypasses: Revisional Bariatric Surgery After a Fobi–Capella-Banded Gastric Bypass

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## Evolution of the Banded Gastric Bypass

The prevalence of obesity in the United States is increasing, reaching a peak of 39.8% in 2016 [1, 2]. Bariatric surgery has demonstrated long-term success with not only weight loss, but also improvement of obesity-related comorbidities. Since its introduction by Mason in 1967, the gastric bypass has undergone several iterations and is now considered the gold standard in bariatric surgery [3–6]. One of the iterations was a banded RYGB, which was developed in response to mid- to long-term weight recidivism.

Historically, several variations of banded gastric bypasses have been attempted. The polypropylene mesh band (Capella), the Dacron and GoreTex bands by Linner, and the silastic ring band by Fobi are just some of the different bands which were tried in the past. Some bands seemed to have higher erosion rates, such as Linner's silastic band, which was placed directly over the GJ anastomosis [7]. Kini and Gagner attempted a biologic band composed of porcine submucosa, while others used fascia lata in an attempt to avoid foreign materials in case of a leak. Many had unacceptably high complication rates that led to their abandonment [8, 9].

Ultimately, the two more common versions were the Fobi–Capella-banded gastric bypasses. In these operations, the gastric pouch is vertical, linear, and fashioned proximally against the lesser curvature using a bougie. In the middle portion of the gastric pouch, proximal to the anastomosis, a ring is placed. In the Fobi bypass, the ring is made of silicone, while in the Capella version, a band of polypropylene mesh is used (Fig. 4.1). These banded RYGB were found to be successful in mitigating long-term weight recidivism. In addition, the long-term %EBWL was higher in these patients when compared to non-banded RYGB and fewer patients regained their weight [6, 8, 10, 11].

## Complications and Management

Complication rates for banded bypass vary widely depending on the method. Prior to any elective revisional procedure, appropriate preoperative evaluations are in order to clearly identify the problem and to be able to plan the operative approach and strategy. The patient must also be nutritionally optimized to reduce complications.

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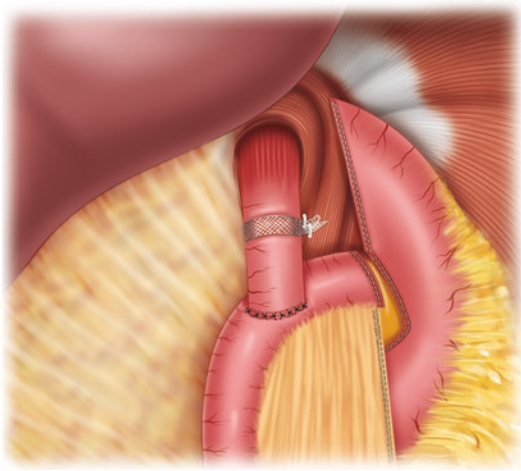

**Fig. 4.1** The Capella banded gastric bypass is shown. The longitudinal pouch, created against the lesser curvature, has a piece of 1 × 7 cm polypropylene mesh wrapped around it, held together by clips. It is well above the gastrojejunostomy to avoid erosion into it

Revisions can be approached laparoscopically/robotically or open, depending on the surgeon's skillset and comfort.

Band-specific complications include *slippage and migration*. Slippage rates range from 0% to 1.5% [6, 12] and ring migration rates range from 0% to 1.7% [6]. In cases of a slippage causing an obstruction, the band could be repositioned or removed. Slippage is encountered among silastic ring bands, as mesh bands tend to adhere to tissue well. Very often, adhesions will be encountered which will need to be lysed carefully to avoid injury to surrounding structures. Thermal energy should be used judiciously. Intraoperative endoscopy can be particularly helpful when the anatomy is distorted. While the Fobi band can be unbuckled, we recommend that it be transected. The unbuckled band may present sharp or bulky components which may cause an unseen injury if pulled posterior to the pouch during removal. Removal of the band should relieve any obstruction, and this can be verified by intraoperative endoscopy. Any underlying capsule can also be carefully resected.

*Erosions* are one of the most feared complications of a banded RYGB. Fobi found no erosions within 2 years of 84 banded bypasses [13, 14]. A larger study of 2949 patients spanning 10 years identified 48 erosions (1.6%). Five were asymptomatic and found during either routine testing or in preparation for other unrelated surgery. The most common sign exhibited was weight regain. There can also be partial obstruction due to the inflammatory response to the band eroding into the pouch wall. Patients may experience pain, nausea, and vomiting. The root causes of early erosions are largely technical. If the band is placed too tightly around the pouch or too close to the GJ, it can erode postoperatively.

The erosion is best diagnosed via upper endoscopy. If most of the band can be seen intraluminally, reports of endoscopic retrieval have been reported with minimal to no sequelae and the attempt can be made once. Erosions may also occur in the setting of mesh bands. Anecdotally, we had two such erosions of mesh bands in our personal series. Both were nearly completely intraluminal and endoscopic retrieval was successful. Should endoscopic retrieval fail, the band should be removed operatively. A laparoscopic approach has been reported for both silastic ring and mesh band erosions. As is often encountered in adjustable gastric band erosions, there can be significant inflammation, edema, distortion of anatomy, and adhesions. There is no substitute for meticulousness, patience, and attention to detail during the conduct of the procedure. This will aid to avoid inadvertent devascularization of the pouch and injury to adjacent critical structures. Again, intraoperative endoscopy is an indispensable tool. It can help identify the location of the pouch among the inflammation and adhesions and the point of erosion. Closure of the erosion site is important to prevent ongoing leakage and sepsis. This can be accomplished by primary closure (if tension-free) and buttressing with omental fat or, as in closure of perforated ulcers, a vascularized pedicle of omental fat secured in place with sutures. An alternative to omental fat is the falciform ligament, which may reach after full mobilization off the anterior abdominal wall. Wide drainage is also advised. Using adjacent remnant for buttressing the repair is less than ideal, as it may lead to formation of a gastro-gastric fistula. It remains

as an option of last resort. Postoperative proton-pump inhibitors and antibiotics are indicated. A postoperative upper GI series to ensure no leak can be obtained in 2 or 3 days, if desired.

*Dysphagia* was reported as a long-term postoperative symptom more frequently among banded RYGB [6]. Despite the increased long-term dysphagia, QoL is not different from non-banded RYGB patients. There are cases where the dysphagia is significant, causing renewed weight loss years later and resultant malnutrition. These patients often need an in-depth evaluation to clearly identify the source of the dysphagia. This will include upper GI series, esophageal manometry, impedance testing, upper endoscopy, and CT scans. If the band is shown to be the cause, removal or revision of the original procedure will be indicated [10].

The degree of dysphagia in question is related to stricturing at the level of the band rather than the GJ and it seems to be more common in polypropylene mesh bands (i.e., Capella). Detailed studies to evaluate esophageal function are critical to ensure the cause of the dysphagia. These include esophagram/upper GI series and manometry studies in addition to endoscopy. After nutritional optimization, the band should be removed, either partly or *en toto* to relieve the stricture. If it is a mesh band, the tissue ingrowth may limit the ability to achieve a full removal of the mesh.

In the setting of the Fobi-banded RYGB, the adhesions around the band should be divided with the use of electrocautery or ultrasonic shears and the band cut and removed. After removal, a decision must be made whether a portion of the capsule has to be excised to fully release the stricture. If an endoscope can be passed, it is likely to be sufficiently wide as to not cause postoperative dysphagia. If it is still deemed to be too narrow, the capsule should be incised, and a portion resected to allow expansion of the gastric wall and widening of the tract. We recommend performing this maneuver sharply to avoid thermal injury and a potential delayed perforation. Upon completion, a leak test should be performed to ensure that there is no missed injury, preferably using an endoscope to also visualize the lumen. Should the endoscope be unavailable, passage of a bougie can be used to ensure appropriate size of the tract, while a leak test with either methylene blue or insufflation of air under irrigation can suffice. While utility in primary procedures is limited, drainage in these complex revisions is advised given the higher potential for complications. Ultimately, depending on the proximity of the band to the GJ, the entire pouch-anastomosis and Roux complex may need to be resected and the GJ recreated in the case of unremitting dysphagia.

*Marginal ulcers* (MU) may develop due to nicotine exposure, oral steroid use, chronic NSAID use, alcohol abuse, chronic anticoagulation, or ischemia. These occur at a rate of about 0.6% to 16% in RYGB. Gastro-gastric fistula accompanies marginal ulcers in about 19% of cases. Early ulcers tend to be ischemic, while those occurring later tend to be related to external factors. These patients may present with pain, most often only epigastric and related to eating, while others can also have left upper quadrant pain. If a gastro-gastric fistula is present, there may also be gastric remnant ulcers coinciding with weight regain. Evaluation will include endoscopy and upper GI series to help identify a fistula, if present. If removing the offending external factors and maximal PPI therapy fail, revision of the gastrojejunostomy may be indicated, with a partial remnant gastrectomy to address a gastro-gastric fistula, if one is identified. The presence of a band adds an additional layer of complexity to the treatment of this pathophysiologic process.

Marginal ulceration may also present emergently with bleeding or perforation. These operations are damage-control operations that aim to save the patient's life and deal primarily with the offending issue. Bleeding should be oversewn under direct vision, while perforations should be closed and buttressed, as they are in the setting of perforated duodenal or gastric ulcers. If the band is uninvolved in the process, it should be left alone except in the case of ischemia. If the ulceration is related to the band causing ischemia, it should be removed. Should the perforation span >50% of the lumen of the bowel, the anastomosis will need to be recreated to avoid stricture. This

will entail circumferential freeing of the distal pouch, anastomosis, and Roux limb. The entire Roux limb should be freed to ensure that enough length is available for resection and re-anastomosis without undue tension. Great care must be taken to ensure the Roux is not devascularized during dissection. Should the Roux be in a retrocolic position, the entire section will need to be freed and the transmesocolic window reopened. To aid in this dissection, one strategy is to enter the lesser sac through a thin area on the greater omentum just off the greater curvature of the stomach. Once within this space, the dissection can be aided greatly from this vantage point. When the entire limb is freed and the pouch and anastomosis all identified, then transection can begin. The pouch can be transected with staples for medium or thick tissue depending on the tissue thickness. This needs to be accounted for carefully to avoid stapler misfire. Distally at the level of the Roux limb, the resection should be close to the anastomosis, but far enough away to be on fresh, unscarred tissue. The anastomosis can then be recreated in any manner, but if a stapler is used, tissue thickness must be taken into consideration. If there is any concern, the anastomosis should be done in a two-layer hand-sewn fashion. A provocative leak test is also recommended in such cases. Wide drainage is also recommended in this setting.

Alternatively, MUs may require elective operative intervention if maximal medical therapy fails. All offending agents should be removed—including all forms of nicotine. The patient should be asked specifically about all potential avenues of nicotine exposure including second-hand smoke, vapor cigarettes, hookah, nicotine gums and lozenges, and chewing tobacco. A urine or serum nicotine level should be obtained to ensure its absence if any concern exists. After a thorough evaluation, the patient can undergo an operation to address the ulcer. In an elective setting, the conduct of the procedure will be similar, except that the ulcer should be identified endoscopically at the time of surgery to ensure inclusion within the resected specimen. If a gastro-gastric fistula is present, it will need to be identified and divided to prevent recurrence. The fistula can be identified endoscopically and then, once dissected circumferentially, transected with a surgical stapler. It is highly recommended to buttress the staple lines of this transection by oversewing them in a running Lembert manner and interposing fat in between. An alternative approach would be for a partial remnant gastrectomy up to the level of the fistula. Here, the vascular supply to the remnant stomach up to the level of the fistula is identified and divided. The stomach is then transected with surgical staplers chosen appropriately for the thickness of the tissue at hand. Oversewing the staple-line in a Lembert fashion is recommended, but not necessary. Keeping the staple-line away from the pouch is essential in minimizing the potential for a recurrence. Again, a provocative intraoperative leak test is appropriate with wide surgical drainage. If there is any concern for remnant gastric atony, a temporary decompressing gastrostomy tube should be placed to vent it. This is particularly true if a truncal vagotomy is performed as part of the procedure. This can be considered in someone who has H. pylori with no external factors, has failed maximal medical therapy, and in whom ischemia is not a concern. It is debatable if pyloroplasty is needed in these patients.

In the event chronic ischemia is the cause of MU, the etiology of the ischemia must be delineated. Intraoperatively, adjuncts to aid in identifying the area and cause of ischemia can be used such as indocyanine green with fluorescent laparoscopy. Should the band be found in the region of ischemia, it should be removed. When the area of ischemia is identified, it also must be resected.

Lastly, patients who had undergone a banded RYGB can regain weight, as with any other bariatric operation; the cause is often multifactorial. Careful patient selection is essential as is the appropriate detailed preoperative evaluation. Select patients from this category may be offered a surgical revision to stimulate renewed weight loss.

Revision of the banded RYGB for weight regain depends on the etiology of the weight regain. Gastro-gastric fistula can be a cause and would be addressed as described above. Loss of restriction can be another cause due to the band

breaking—which is very rare. Should there be a mechanical failure of the band, it should be removed. In either case, revision surgery can involve one of two approaches. The first can be a resection of a widened pouch. After assessing the gastric pouch, any evidence of pouch dilatation may be addressed with a stapled resection against an endoscope or bougie. The staple-line should be imbricated with suture in Lembert fashion. Surgical drainage should also be employed, and we advocate the use of fibrin sealants for staple lines and anastomoses. We would not recommend replacing the band at this time as this technique has been described and is noted to have a high rate of erosion if a new band is placed at the time of the revision [15].

Secondly, approaches to induce weight loss can also be accomplished with a limb-lengthening procedure. There are a number of different approaches which can be undertaken, but there is not a single one in particular that has been deemed optimal in failure of a RYGB patient. Limb-lengthening procedures avoid the complications associated with revising the pouch, band, and anastomosis so long as no technical issue exists in these locations. Operatively, the ileum is measured for a length of 100–150 cm from the ileocecal valve and, at this location, the anastomoses are created. The biliopancreatic limb of the original jejunojejunostomy will have to be transected. The jejunum of the biliopancreatic limb will be anastomosed at the mark on the ileum. This will give rise to a very long Roux limb and much shorter common channel. The patients will need to be counseled preoperatively for the nutritional requirements, potential vitamin deficiencies, and the sequelae that can occur as a result. Given these potential complications, this should be offered only to select patients who will be compliant with guidelines and adhere to close, lifelong follow-up.

Obesity is a lifelong disease and all methods engaged in this fight are subject to complications and/or failure. It is essential that a good understanding of the original procedure is obtained before pursuing reoperative management. Revisional surgery is quite challenging, but can provide the necessary tools for patients to gain or regain a meaningful quality of life.

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# 5 Revision of Vertical Banded Gastroplasty

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## History and Decline of VBG

The vertical banded gastroplasty (VBG) operation was first described by Edward Mason in 1982 [1]. This was preceded by a decade of experimentation with different types of gastric partitions with or without gastrojejunostomy (bypass) [2] and aided by the advancement in stapling technology. In 1978, the first National Institutes of Health (NIH) consensus conference addressing obesity discouraged the use of jejunoileal bypass in favor of gastric procedures [3]. The following years, VBG quickly gained popularity due to its relative technical simplicity (no anastomoses), safety (no nutritional deficiencies), and good initial weight loss. For a period of time, VBG became the most popular bariatric procedure in the US. In 1987, Dr. Harvey Sugerman published a prospective randomized trial comparing VBG to Roux-en-Y gastric bypass (RYGB) [4]. The study was terminated early because of significantly better results in the gastric bypass group. Of note, 5 out of the 20 patients who had the VBG required conversion to gastric bypass within the 3-year follow-up period due to failure. In 1994, Wittgrove and Clark [5] published the first experience with gastric bypass performed laparoscopically (LRYGB), greatly improving the safety and appeal of the operation. A year later, Pories [6] reported the effects of RYGB on adult-onset diabetes as being the best available treatment. In the early 2000s, large series of laparoscopic gastric bypass were published (DeMaria [7], Higa [8], Nguyen [9], Schauer [10]) and LRYGB became the most frequently performed bariatric and *metabolic* procedure. During the same time period, the first report of laparoscopic placement of an adjustable gastric band (LAGB) was published [11]. There was now a less invasive and more effective option to treat obesity—the LRYGB, but also a minimally invasive, simpler to perform, purely restrictive, adjustable operation—the LAGB. These two options and the accumulating long-term data on the VBG eventually rendered the procedure obsolete.

## Technique and Variations

Knowledge of the technique used to perform a VBG (and its multiple variations) is important to avoid unexpected findings and confusion during a revisional operation. The rationale and mechanism of action of VBG is restriction. That is achieved by excluding the distensible fundus with a vertical staple line using a linear, non-cutting stapler.

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The result is a 20–50 ml lesser curvature gastric pouch which communicates with the rest of the stomach through a narrow outlet or "stoma." Based on previous experience with stoma dilation, the other essential part of the VBG is a prosthetic band of polypropylene, 1.5 cm wide, wrapped 360 degrees around the pouch outlet and sutured to itself. A window is created though the anterior and posterior gastric wall using a circular stapler. The window is then used to place the band around the outlet. A linear, non-cutting stapler is fired toward the angle of His, completing the pouch. Multiple variations of the procedure were subsequently described and utilized. In 1986, Eckhout [12] published a large series on 1463 patients using a much narrower 2.5 mm silicone ring. This was an effort to prevent stenosis at the stoma observed with the polypropylene band. Using a linear, cutting stapler for the vertical staple line or excising a portion of fundus for a Collis-type gastroplasty [13] were other modifications [6]. These advancements made a circular-stapled window unnecessary. The first laparoscopic VBG experience was published in 1994 [14] and the procedure remained popular in Europe until the early 2000s.

## Outcomes after VBG

The early, short-term, weight loss results of VBG were promising. Dr. Mason's initial report in 1982 stated "fewer complications and greater weight loss than have been obtained with any other operation for obesity, to my knowledge" [1]. Eckhout's large series reported 63.4% EWL [12]. As better-quality data became available, this perception changed. Sugerman's prospective randomized study compared 40 patients who underwent either VBG or RYGB (using the same size pouch (~30 ml), biliopancreatic limb of 15 cm, and Roux limb of 40 cm) [4]. The study was terminated after 9 months, because of significantly superior weight loss in the bypass group (43% vs. 68% EWL at 1 year). Interestingly, the study population was divided in "sweets eaters" and "non-sweets eaters" and VBG was more likely to fail in the first group—an effect which was not significant in the RYGB group presumably due to dumping syndrome. Another prospective randomized study of similar size and design echoed these results [15]. In 2005, a prospective randomized study reported the 2-year outcomes from 100 patients undergoing either LAGB or laparoscopic VBG. VBG was more effective in terms of weight loss and had fewer reoperations [16]. A more recent longer follow-up study of 652 patients, the majority of whom have undergone laparoscopic VBG, showed 61% EWL at 1 year, which decreased to 40% at 10 years [17]. The rate of follow-up, however, decreased from 74% to 16% during that time period. In the same study, the authors reported VBG weight loss results as inferior to laparoscopic sleeve gastrectomy (LSG) but superior to LAGB, at their institution. Revision rate of VBG was 13%. Finally, possibly the best-quality data comes from the Swedish Obese Subjects (SOS) study. It includes 1369 VBG patients, which represent the majority of patients in the surgical arm (68%) [18]. VBG resulted in 25% TBWL at 2 years, which decreased 16% at 10 years follow-up. This was inferior to RYGB but superior to LAGB. In 2019, the same group reported 26-year follow-up results (mean follow-up of 19 years). The revision rate of VBG was 28.3%, compared to 40.7% for LAGB and 7.5% for RYGB [19].

## Complications of VBG

### Inadequate Weight Loss or Weight Regain

The VBG is a purely restrictive procedure and weight regain is due to either anatomical failure (staple line disruption, pouch dilation), maladaptive eating behavior, or both. The original open VBG procedure was performed with a non-cutting, linear stapler and staple line disruption is seen in as many as a third of these patients, resulting in loss of restriction and rendering the procedure completely ineffective. While a mesh-reinforced stoma will not dilate over time, the gastric pouch can expand in response to the chronic outlet obstruction, allowing the patient to consume greater quantity of food. Maladaptive

eating behavior is a characteristic pattern that develops in VBG patients, who "defeat" the restriction imposed by surgery, by learning to consume high-calorie liquid and soft food.

## Other Complications

Early complications of VBG like bleeding and staple line leaks have less significance today since the procedure is rarely performed. Long-term complications are common and are related to the prosthetic material and/or the chronic outlet obstruction. Stoma stenosis can lead to dysphagia and esophageal reflux with its potential consequences of Barret's esophagus and aspiration. The prosthetic band/ring can erode through the lumen similar to erosion of a LAGB. The presence or absence of these complications should be well-defined preoperatively, since it will affect the choice of revisional procedure for the particular patient.

## Incisional Hernia

Morbidly obese patients are at increased risk for developing an incisional hernia after laparotomy. Incisional hernia rate after open VBG can be as high as 50% in super-obese patients [20]. Consequently, a significant number of patients requiring revision will present with concurrent hernia. The hernia can be addressed prior, during, or after the bariatric procedure. The optimal timing and approach are unknown, as there is insufficient data on this subject. A recent guideline published by the American Society of Metabolic and Bariatric Surgery and the American Hernia Society highlights the limited evidence available and could not provide strong recommendations [21]. Hernia repair is more successful after weight loss, but delaying the repair poses a risk for incarceration in the early post-bariatric surgery period. Concurrent laparoscopic hernia repair and bariatric surgery is feasible in some patients, but there is concern about using prosthetic mesh in a contaminated field. Due to the complexity of the problem and paucity of data, the authors approach incisional hernias in this patient population on an individual basis. Smaller, isolated fascial defects <2 cm are closed primarily. Large, complex, multiple, or symptomatic incisional hernias are repaired with permanent prosthetic mesh electively, prior to bariatric surgery, avoiding intraperitoneal placement of the mesh. Hernias diagnosed intraoperatively that contain chronically incarcerated omentum are left undisturbed, preventing the possibility of bowel herniation during the early postoperative period. If hernia reduction is necessary to allow safe performance of the bariatric surgery, the authors prefer repair with a composite, slowly absorbable synthetic mesh, placed intraperitoneally and fixed with tacks and sutures. This prevents early incarceration of intestine, while the defect can be repaired definitively after successful weight loss.

## Preoperative Investigations

A thorough evaluation is necessary as with any major revisional surgery. Dietary and psychological evaluation is extremely important in this patient population where maladaptive eating behavior is common. Special attention should be paid to establishing the individual patient's altered anatomy preoperatively. An effort to obtain previous operative reports should be made. Upper GI series and endoscopy, ideally surgeon-performed, provide the anatomical information. This includes location and integrity of the staple line, pouch length, and presence of dilation and a hiatal hernia (Figs. 5.1 and 5.2). Endoscopy will diagnose reflux esophagitis, band/ring erosion, and other pathology in the stomach which could change the operative plan. In patients with band erosion, endoscopic retrieval may be the least invasive option and can be followed by a surgical revision as a second stage. Esophageal manometry and pH testing should be used selectively. As with any major revisional operation, it may be necessary to change the operative plan based on intraoperative findings. As part of the consent process, the surgeon should discuss the possibil-

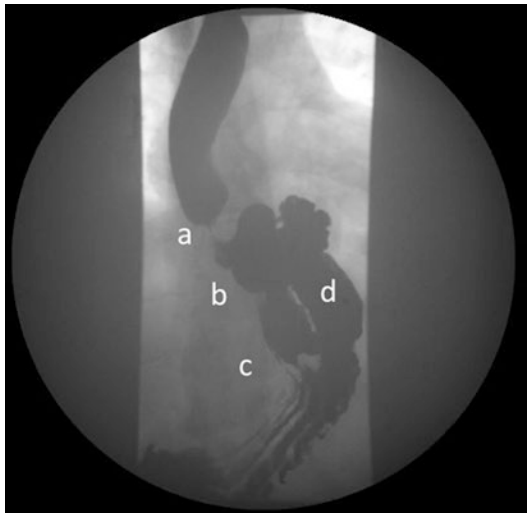


**Fig. 5.1** Upper GI series of a patient with history of VBG and hiatal hernia. (**a**) GE junction, (**b**) hiatus, (**c**) band, (**d**) vertical staple line. (Dr Teixeira)

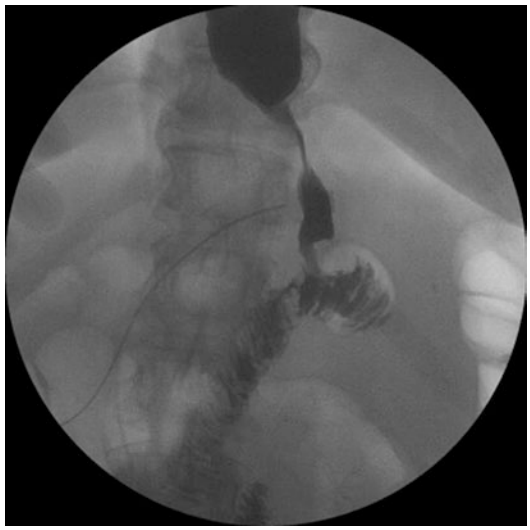

**Fig. 5.2** Postoperative upper GI series of the same patient after conversion to Roux-en-Y gastric bypass and repair of hiatal hernia. (Dr Teixeira)

ity of performing a different bariatric procedure, a staged procedure (i.e., restoring anatomy by removing the band/ring with or without gastrogastrostomy, followed by a second-stage bariatric procedure) or aborting the procedure all together before a serious complication arises. VBG revision is considered among the most challenging bariatric operations and the increased risk of complications needs to be understood and accepted by both the surgeon and the patient.

## Choice of Procedure

The goal of the revisional operation has to be clearly defined before making an operative plan—whether it is resolving a complication, further weight loss, metabolic disease resolution, or, frequently, a combination of these. Patients with an anatomical failure of VBG (vertical staple line disruption) and absence of maladaptive behavior may be the few to benefit from another restrictive-type operation. Patients with maladaptive eating behavior and intact VBG anatomy benefit more from adding an intestinal component to the revisional procedure. As with primary bariatric surgery, the individual patient's medical history (metabolic complications of obesity, GERD) and surgical history (ventral hernia, intestinal adhesions) as well as the cardiopulmonary risk influence the choice of revisional procedure. A history of open, as opposed to laparoscopic VBG, predicts a longer, more challenging and potentially riskier operation and should be taken into account.

The use of flexible endoscopic interventions has been described after VBG. Balloon-dilation of a stenotic pouch outlet can have short-term success, but is limited by the external prosthetic band [22]. More recently, an endoscopic needle-knife treatment of the stricture has been reported [23, 24]. Intraluminal eroded band/ring can be successfully retrieved endoscopically [25, 26]. Endoscopic pouch reduction has also been described [27].

Options available include endoscopic interventions, reversal of the VBG, re-VBG, conversion to LAGB, sleeve gastrectomy (SG), RYGB, or biliopancreatic diversion (BPD) with or without duodenal switch (DS). Esophagojejunostomy and classic BPD are salvage options in hostile anatomy.

Reversal of the VBG is reserved for patients who present with certain complications (GERD, outlet obstruction) and have no need or inter-

est in further bariatric surgery. The procedure involves removal of the ring/band or resection of the banded stomach with gastro-gastrostomy. The potential for weight gain in these patients is high. Re-VBG has been reported [28, 29], but is not recommended because of high rate of failure, complications, and reoperation. This revision involves creation of a new smaller pouch, by applying another band proximal to the old one and possibly re-stapling in a vertical direction closer to the lesser curvature. One should be aware of such altered anatomy if planning to operate on an already revised VBG patient. There are few reports of conversion of VBG to LAGB and, in the authors' opinion, it should be avoided because of the similar type of complications and mechanism of failure of these two procedures. Conversion to a classic Scopinaro-type BPD (two-third gastrectomy) has a theoretical advantage as being the only surgical option to completely avoid dissection in the area of the prosthetic mesh/ring This is the least popular approach for VBG revision due to the serious long-term metabolic effects of BPD. In the few published reports, the complication rate is high [28, 29]. BPD with DS is a viable option in the few patients who have already undergone a revision to sleeve gastrectomy and require further revision.

### Conversion to Sleeve Gastrectomy

Conversion of VBG to sleeve gastrectomy is a relatively newer option with few disadvantages. The procedure is performed by stapling medially (toward the lesser curvature) to the VBG staple lines and window, thus completely excising all of the old staples. This is possible in cases where a silicone ring has been removed and the gastric pouch is dilated. In patients with a polypropylene band, sleeve gastrectomy does not address the stoma stenosis. In those cases, the band can be divided to relive the stenosis, followed by vertical stapling below and above the banded area. Again, care is taken to completely excise the staple lines of the fundus to avoid leaving an undrained portion of stomach. The complication rate of this procedure is significantly higher than after primary SG—leak rate may be over 10% [30–33]. The high leak rate is likely due to the difficult dissection around the prosthetic material and the fibrotic tissues, making stapling less effective. While the long-term results of VBG to SG conversion are unknown, SG acts in part by restriction, to which post-VBG patients are less responsive due to the maladaptive eating behavior. Additionally, sleeve gastrectomy can predispose to reflux, similar to VBG. Due to the above reasons, conversion of VBG to SG is not recommended by the authors. SG may be an option in those select patients found to have severe intestinal adhesions and/or ventral hernia, in whom gastric bypass is deemed not feasible.

Conversion to RYGB is the most popular choice and it is the authors' preferred approach. Gastric bypass successfully addresses weight gain after VBG, as well as its complications of stoma obstruction and reflux. The surgical technique is described in detail in the following section.

## Surgical Technique—Laparoscopic Conversion of VBG to RYGB

Preoperative antibiotics and antithrombotic prophylaxis are administered and the patient is positioned supine, supported by a footboard with arms extended. The surgeon stands on the patient's right side and the assistant on the left.

The authors' preferred abdominal entry is by using a Veress needle at Palmer's point, followed by placement of an optical trocar away from previous scars and hernias. Port placement is identical to the one used for primary RYGB—four working ports are placed (Fig. 5.3). When the robotic platform is used, four robotic ports are used in addition to a 12 mm port for the bedside assistant (Fig. 5.4). An additional 5 mm port is placed in the right subcostal region laterally for a table-mounted liver retractor. The technique for entry and port placement is modified depending on the individual patient's habitus, abdominal scars, and the need for adhesiolysis.

Dissection begins by delineating the anatomy. Adhesions between the left lateral segment

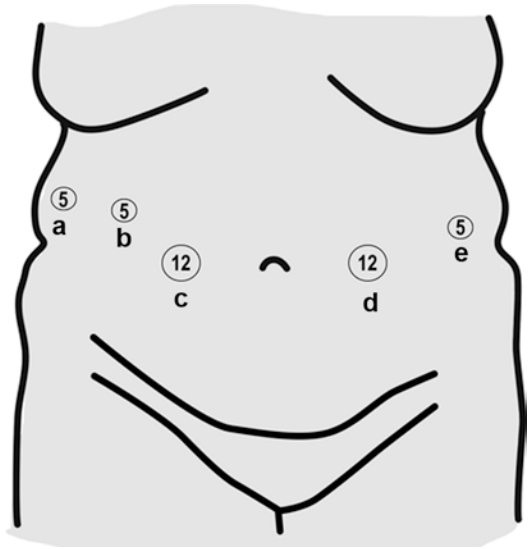


**Fig. 5.3** Port placement for a laparoscopic procedure. Port (**a**) is used for a table-mounted liver retractor, ports (**b**) and (**c**) for the operating surgeon, port (**d**) for the laparoscope, port (**e**) for the assistant. Alternatively, the laparoscope can be placed in port (**c**) and port (**d**) used by the operating surgeon to avoid the off-center view. (Dr Anam Pal)

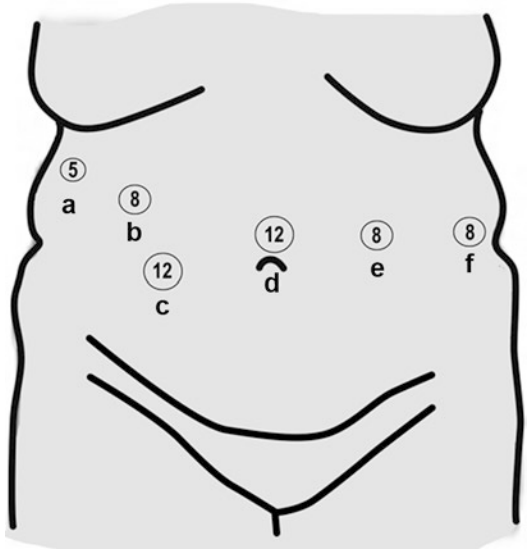


**Fig. 5.4** Port placement for a robotic procedure. Port (**a**) is used for a table-mounted liver retractor, port (**c**) for the bedside assistant, ports (**b**, **d**–**f**) for the robotic system. Port (**e**) is used for the camera (robotic arm 3). Alternatively, the camera can be placed in port (**d**) (robotic arm 2). (Dr Anam Pal)

of the liver and the gastric pouch and band are divided sharply. An encapsulated silicone ring should be divided and removed similar to a LAGB. Separating a polypropylene band from the stomach is difficult and it should either be excluded or resected with the stomach. The short gastric vessels are divided with an energy device until the left crus of the hiatus is reached. The posterior gastric wall is completely freed of adhesions. The gastroesophageal junction is dissected circumferentially, and any sizable hiatal hernia is reduced and repaired. This allows for delineation of the entire length of the old vertical staple line. Intraoperative endoscopy is helpful to evaluate the size of the pouch, the position of the band/ring, and the location of the vertical staple line. The gastro-hepatic ligament is opened at the level of the band/ring to allow passage of a linear stapler while preserving the lesser curvature blood supply proximally. This lesser curvature dissection is frequently the most challenging part of the operation due to the inflammatory response to the foreign body and the rich blood supply of the lesser curvature. A linear cutting stapler is fired in a horizontal direction, ideally staying just proximal to the area of the band (Fig. 5.5 – Line a). Indocyanine green (ICG) fluorescence angi-

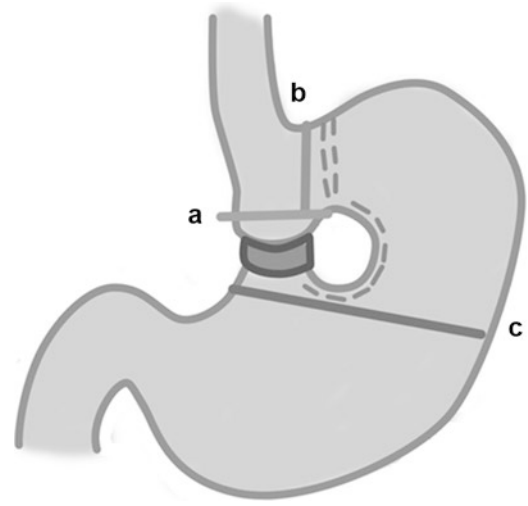


**Fig. 5.5** Gastric lines of division (staple lines). (**a**)—Horizontal staple line, (**b**)—Vertical staple line, (**c**)—line of gastric fundus resection. (Dr Anam Pal)

ography can be used to visualize the stomach's perfusion and may occasionally guide the position of the stapler firing and the future gastrojejunostomy. In cases in which the band is too proximal, an undivided bypass can be performed by creating a gastrojejunostomy to the anterior wall of the old pouch, leaving the distal stomach attached. While this can be a safe option and successfully addresses stoma stenosis and reflux, it has the potential for inadequate weight loss (effectively leaving a gastro-gastric fistula) and may increase marginal ulceration rate by stimulation of the distal stomach.

Creation of the new gastric pouch is completed by vertical firings of a linear stapler over a 32 Fr bougie. The ideal position of the stapler is to the right (toward lesser curvature) of the old staple line, but away from the GE junction to avoid stenosis and/or leak. (Fig. 5.5 – Line b). Creating the gastric pouch in this way can lead to a unique complication of VBG revision—leaving an undrained portion of fundus. This complication is reported not infrequently and always requires reoperation. For this reason, the authors prefer to resect the fundus including the entire old staple line and the banded area of stomach (Fig. 5.5 – Line c). This step adds the theoretical advantage of decreasing ghrelin levels and appetite postoperatively, as well as eliminating the risk for future gastro-gastric fistula. The disadvantage of resecting the fundus is the need to extract a specimen by enlarging a port site and its associated risk of wound complications and hernia. Additionally, depending on the level of resection of the banded stomach distally, future gastro-gastrostomy may become impossible, closing the door to future reversal or conversion of the gastric bypass to BPD-DS. If the fundus is to be left in place, it is essential to confirm its communication with the distal stomach by intraoperative endoscopy prior to stapling. Any blind segments of stomach need to be excised.

Next, the ligament of Treitz is identified and the jejunum is measured (biliopancreatic limb) and brought to the gastric pouch in an ante-colic fashion. The authors typically create a 150 cm biliopancreatic limb after measuring the patient's entire bowel length. A restrictive 1-cm-wide gastrojejunostomy is created on the posterior wall of the gastric pouch over a 32 Fr bougie. A handsewn two-layer technique is used with continuous 2–0 unabsorbable braided suture (polyester). Another 150 cm of small intestine is measured distally (Roux limb) and a side-to-side anastomosis is created to the jejunum just proximal to the gastrojejunostomy using a double-stapled technique. Dividing the bridge of intestine between the two anastomoses completes the Roux-en-Y configuration. The Petersen's and the jejunojejunostomy mesenteric defects are closed with running nonabsorbable barbed sutures. The gastrojejunostomy is tested and the resected portion of stomach is removed in a specimen bag by enlarging one of the port sites. A drain is placed in the left subphrenic space selectively. It is removed prior to discharge. Liquid diet is started on the first postoperative day after an upper GI contrast study. The patient is discharged from the hospital when adequate oral intake is reached, usually by day 2 or 3 from the operation. Postoperative follow-up is identical to that of our primary RYGB patients.

## Outcomes of Revision to RYGB

Outcomes data are relatively limited for revisional bariatric surgery and particularly for VBG. Conversion of VBG to RYGB generally yields excellent results at an added cost of increased complications with revisional surgery. In a study of open surgery published in 1996, Sugerman reported weight loss equivalent to primary RYGB, in 43 patients who underwent revision [34]. In 2011, Gagné reported the results of 105 laparoscopic conversions to RYGB [35]. All the patients except two had history of open VBG. The EWL was 47%, GERD resolution was seen in 95%, but the complication rate was high at 38%. There was no mortality. In the largest series of VBG to RYGB conversion [36], Suter reported the outcomes of 203 laparoscopic revisions performed at four centers in Europe. The complication rate was 11.8%; there was one mortality from an incarcerated hernia left unrepaired during the

bariatric procedure. The indications for revision were weight regain in 63.1%, reflux 46.8%, and food intolerance in 33.5%, with many patients having multiple indications. The long-term results were good with mean post-revision BMI of 28.8 at 9 years follow-up. The number of patients with prior laparoscopic versus open VBG was not reported, but laparoscopic VBG was a popular operation in that geographical region, which could in part account for the relatively low complication rate. Of note, 65 out of the 205 patients (31.7%) underwent an esophagojejunostomy, which the authors recommend as a safer alternative to a Scopinaro-type BPD in cases of hostile anatomy precluding a gastric bypass.

## Conclusion

Vertical banded gastroplasty is one of the most challenging bariatric operations to revise. Knowledge of the history of VBG with its multiple technical variations, together with a thorough preoperative evaluation and sound judgment, allows performing a safe and effective operation.

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# Part II

# Reoperation for Complications of Bariatric Surgery

# 6 Laparoscopic Adjustable Gastric Band Complications

Naveen Ballem, Bartosz Dusik, Jeffrey T. Landers, and Sara K. Alothman

## Perioperative Challenges

Perioperative challenges include all the challenges associated with gastrointestinal surgery, laparoscopy, and anesthesia. Specific challenges in morbidly obese patients include the following.

**Body Habitus** A thick abdominal wall, which is more often encountered in obese females or extensive visceral fat more often found in obese males, contributes to technical challenges during bariatric procedures [1]. The anthropometric distribution of adipose cells varies tremendously between individuals. In the authors' opinion, the ability to readily palpate the patient's rib cage is a good indicator of the difficulty accessing the abdominal cavity with a laparoscopic approach. A fatty or cirrhotic liver makes appropriate anatomical exposure difficult, with the risk of potential fracture and bleeding from the liver. Some authors have used preoperative ultrasound to help identify the size of the liver and for perioperative planning. The thickness of abdominal, subcutaneous fat is also a consideration in gastric band port placement and needle access.

**Respiration and Airway Management** Laparoscopic bariatric procedures require a high-pressure pneumoperitoneum which may result in increased intrathoracic pressures, decreased functional capacity, pneumothorax, extraperitoneal insufflation, gas embolism, and surgical emphysema [2, 3]. Restricted mouth opening, limited flexion/extension of the cervical spine, and redundant oral tissue also contribute to the airway management difficulties. Presence of an illuminated portable video laryngoscope may be useful in these difficult airway patients. Postoperative oxygenation and monitoring is important as this patient population has significant risk for obstructive sleep apnea.

**Drug Pharmacokinetics** Morbid obesity alters the pharmacokinetics of lipophilic anesthetics. Having an anesthesia team that has experience with this patient population is important.

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## Morbidity

Overall morbidity rates after LAGB range from 0% up to 68%. Relatively few studies reported rates above 20%; overall median morbidity rate is of approximately 11.3%∗ [4]. Matched-pair study with 442 cases, with 6-year follow-up in patients with BMI less than 50, reported early overall morbidity rate of 5.4% (vs. 17.2% RYGB). However, the overall long-term morbidity rate was significantly higher at 41.6% (vs. 19% RYGB) and more revisions, that is, 26.7% (vs. 12.7% RYBG), were reported [5]. A 30-day morbidity study from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database analyzed 4756 bariatric patients (1176 LAGB vs. 3580 RYGB). The study reported a lower rate of major complications (1.0% vs. 3.3%), overall morbidity (2.6% vs. 6.7%), and reoperation rate (0.94% vs. 3.6%) [6]. This considerable difference in complication rates between studies suggests a multifactorial nature of morbidity in bariatric patients (presence of comorbidities, body habitus, operative technique, experienced vs. inexperienced surgeon, volume of procedures performed, institutional resources, hardware differences, study design); therefore, morbidity rates should be treated with caution.

## Iatrogenic Complications

Iatrogenic complications include both anesthesia and surgical events. Laparoscopic access to the peritoneal cavity may result in major blood vessel injury, intestinal perforation/injury, liver injury (resulting bile leak and biloma), spleen injury (requiring a splenorraphy or splenectomy), and injury to pleura (resulting in a pneumothorax). After access to the peritoneal cavity, positioning of a large friable or cirrhotic liver may cause fracture of the liver and necrosis or bleeding. Pars flaccida technique, during which a tunnel is created in the posterior gastric fatty tissue at the level of the gastroesophageal junction, has potential for injury to both the esophagus and posterior stomach in the lesser sac.

**Table 6.1** Adverse intraoperative events by Chapman et al. [4]

| Adverse intraoperative events | | |
|---|---|---|
| | LAGB ($n$ = 8504) | |
| Complication | $n$ | Percent |
| Gastric perforation/injury | 68 | 0.80 |
| Liver injury/bile leak | 4 | 0.05 |
| Band positioned incorrectly | 3 | 0.04 |
| Spleen injury/splenectomy | 1 | 00,1 |
| Insufficient pneumoperitoneum | 1 | 0.01 |
| Injury to pleura | 1 | 0.01 |
| Esophageal tear | 0 | 0 |

Other complications are band-related and can result in disruption of the integrity of the band or tubing and/or disconnection of the tubing from the port. Band aneurysm and fat embolus into the tubing after needle access are other iatrogenic complications.

Longitudinal Assessment of Bariatric Surgery (LABS) database that included 1608 patients estimates the adverse intraoperative events rate (AIE) at 3.0% for LAGB procedures. Specific AIEs rates (for combined LAGB and RYGB) were reported as follows: anesthesia events 1.0%, instrument/equipment failure 0.8%, bowel injury 0.8%, hepatic injury 0.4%, splenic injury 0.2%, major blood vessel injury 0.1% [2]. Specific AIEs rates exclusively for LAGB reported by Chapman A, Kiroff G, Game P, et al., who evaluated 8504 LAGB patients, can be found in Table 6.1 [4].

## Early Complications

Early complications include acute gastric obstruction, port/band infection, gastric perforation, hemorrhage, respiratory complications, delayed gastric emptying, and venous thromboembolism.

Late complications include pouch or esophageal dilatation from prolonged distal obstruction, band slippage, gastric prolapse, port or tubing malfunction, leakage at the port site tubing or band, band erosion, esophagitis and reflux. Fat embolus and obstruction of port tubing and extensive, gastric necrosis after band slippage are other complications.

**Acute Gastric Obstruction** Gastric obstruction may occur in up to 14% of LAGB patients [7, 8]. It is usually caused by implantation of a band of insufficient diameter, the inclusion of excess perigastric fat, or significant postoperative tissue edema. Presenting symptoms usually include persistent nausea, vomiting, and inability to tolerate secretions or oral intake. The diagnostic modality of choice is an upper gastrointestinal series demonstrating no passage of contrast beyond the band.

Stomal obstruction can be initially managed conservatively with NPO and nasogastric tube decompression until the edema subsides; however, one must be cautious due to the risk of stomach ischemia and aspiration pneumonia [9]. If obstruction persists, surgical revision or removal of the band is indicated. The use of larger diameter band may reduce the incidence of postoperative obstruction. Meticulous dissection of excess perigastric fat during band placement may help prevent this complication [10]. IV Solumedrol and Lasix have anecdotally helped relieve acute, postoperative obstruction status post band placement .

**Port or Band Infection** The incidence of the port site or band infection ranges between 0.3% and 9% [4, 11, 12]. Patients present with abdominal pain, fever, nausea, vomiting, and erythema/induration with or without purulent discharge from the port site. The diagnosis is made upon clinical and/or endoscopic finding.

Infection of the hardware is managed with surgical removal, especially if band erosion is present. An isolated port infection might be managed with the infected port removal alone and a new port reimplantation once the infection clears. Often times, an infected port site is a harbinger of a band erosion, so a thorough workup including radiologic imaging and an upper endoscopy can be diagnostic.

**Respiratory Complications** It was reported that 0.6% of patients treated with any bariatric surgical procedure developed postoperative pneumonia (PP). Additional 0.6% developed postoperative respiratory failure (PRF). PP risk factors include congestive heart failure, stroke, and smoking. Previous percutaneous coronary intervention, dyspnea at rest, diabetes mellitus, and prolonged anesthesia time are the factors most strongly associated with PRF. Bleeding disorder, age, COPD, and type of surgery were risk factors for both [13].

**Venous Thromboembolism** Study based on data from Bariatric Outcomes Longitudinal Database (BOLD) evaluating 73,921 bariatric patients reported venous thromboembolism (VTE) rate (including deep vein thrombosis and pulmonary embolism) of approximately 0.14% [36]. Risk factors for VTEs include: BMI >50 kg/m$^2$, a history of a VTE, a history of a hypercoagulable disorders, pulmonary hypertension, venous stasis disease, poor functional status, open or revision surgery, and operative time >3 hours [14, 15].

**Infection** Other infections including sepsis are fairly uncommon in LAGB patients with incidence rate of approximately 0.19% [4]. Most common cause of sepsis in these patients would be due to gastrointestinal viscus injury, which may occur during lysis of adhesions from previous operations.

## Late Complications

**Esophageal and Pouch Dilatation** Dilatation of the distal esophagus, also called "pseudoachalasia syndrome," has been observed in up to 10% of patients [16]. The primary cause of this complication is linked to excessive band inflation or excessive food intake. Pouch dilatation has been reported in patients with a history of binge eating behavior pattern (Fig. 6.1). Patients often present with food and saliva intolerance, vomiting, nausea, halitosis, reflux, and epigastric pain. Upper gastrointestinal series can be diagnostic, demonstrating bird beak sign or pouch dilation. The initial treatment involves deflation of the band and behavioral diet modifications, which commonly results in reversing of esophageal

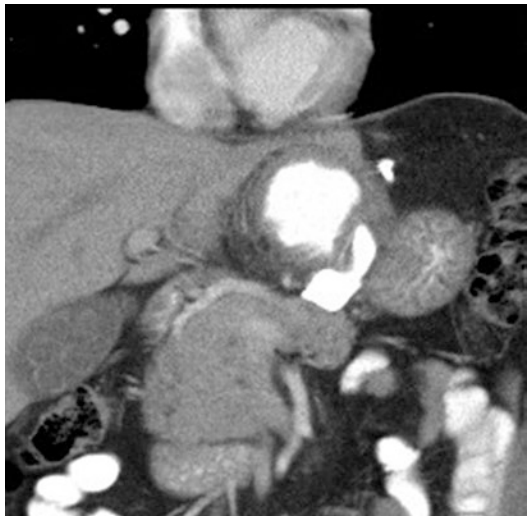

**Fig. 6.1** Gastric pouch dilatation. (Photo credit Dr. Richard Ruchman, Monmouth Medical Center Division of Radiology)

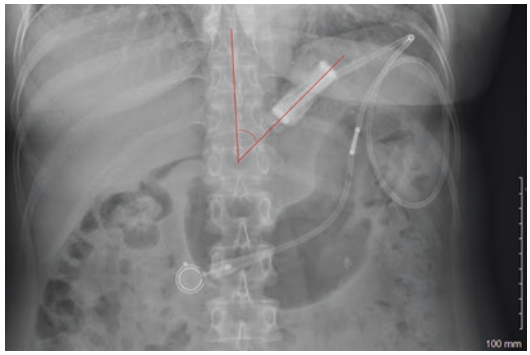


**Fig. 6.2** Appropriate band orientation. (Photo credit Dr. Jeff Landers, Overlake Medical Center)

dilatation. If dilatation persists, replacement of the band in a new location on the stomach or conversion to RYGB, where indicated, is required.

**Band Slippage and Gastric Prolapse** Band slippage may occur in 2% to 14% of LAGB patients [4, 17, 18]. It implicates prolapse of part of the stomach through the band, with varying degrees of gastric obstruction (Figs. 6.2 and 6.3). Although this is listed under late complications, excessive nausea and vomiting in the immediate postoperative period may cause early band slippage. Band slippage can be categorized anatomically; posterior gastric prolapse occurs when the

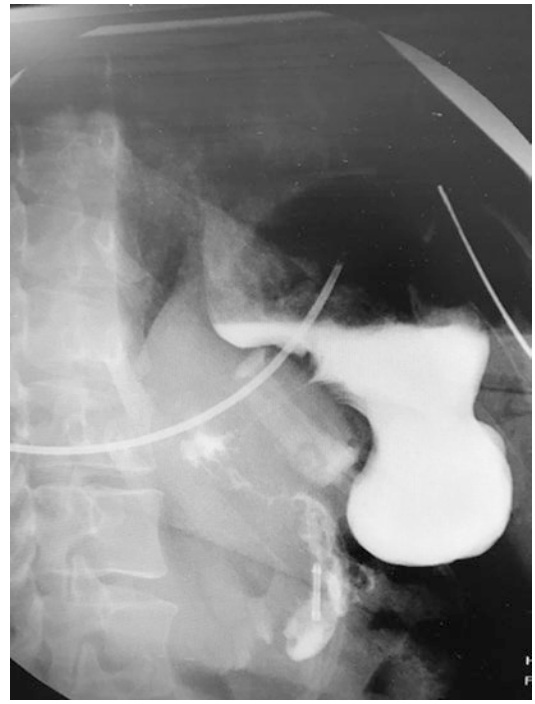

**Fig. 6.3** Band slippage & gastric prolapse. (Photo credit Dr. Christine Ren Fielding, Professor of Surgery, NYU School of Medicine)

band migrates caudally and creates a new enlarged pouch. Anterior prolapse involves migration of the band cephalad, which in turn results in gastric obstruction due to the creation of an acute angle between the band, stomach pouch, and esophagus. Leading symptoms include food intolerance, epigastric pain, and acid reflux. Diagnosis is confirmed with an upper gastrointestinal series demonstrating either displacement of the band or dilatation and prolapse of the gastric pouch. A simple abdominal X-ray positioned to capture an image from the nipples to the umbilicus will also delineate the position of the band. An "O"-shaped configuration of the gastric band on X-ray indicates potential slippage (47). The band in a proper orientation would appear as rectangular because we would see it from a side profile. The rectangular position of a properly placed band is from 2 o'clock to 7 o'clock in an AP X-ray. Placement of the band through pars flaccida without exposure of the stomach wall has decreased this complication

dramatically [19–21]. Anterior band fixation with gastro-gastric sutures proved to reduce band slippage rate down to 4% [22]. Depending on the presentation, surgery is required urgently or emergently. On rare instances, reduction of the prolapse can be accomplished by repositioning the band. However, the vast majority of slipped bands need to be replaced or removed, especially if significant edema and inflammation are present [23, 24].

**Port Malfunction** Tubing disconnection, leakage within the system, or subcutaneous port flip are possible causes of port malfunction. Reported incidence of port malfunction ranges from 0.4% to 7.0% [4, 17, 25]. Presenting symptoms are a loss of restriction, weight regain, and inability to access port. The incidence of port dislocation and slippage can be reduced by attaching the port to a polypropylene mesh before anchoring to the rectus fascia [26]. Port malfunction requires surgical repair or exchange of the hardware in order to regain band adjustability and reestablish restriction.

**Band Erosion** It is estimated that gastric band erosion through the wall of the stomach occurs in up to 7% of LAGB patients (Figs. 6.4 and 6.5). The reported mean occurrence is 22-month placement. It is believed that gastric wall ischemia from an excessively tight band combined with the band buckle–linked mechanical trauma and thermal trauma from electrocautery use and inadvertently leads to band erosion [27, 28]. Introduction of new band hardware and placement technique may reduce the incidence of this complication. Rotating the band buckle medially and creating a gastric fundoplication laterally over the band where the buckle remains outside of this fundoplication may reduce the risk of erosion. Clinical signs of band erosion include nausea and vomiting, epigastric pain, failure to lose weight, and infection. Hematemesis and epigastric pain may signify the erosion of the band into the left gastric artery [29]. This complication often occurs when the lap-band erodes into the posterior part of the stomach in the near proximity of the cardio-esophageal junction. Careful placement of the gastric band without embracing the ascending branch of the left gastric artery may prevent torrential hemorrhage due to band erosion.

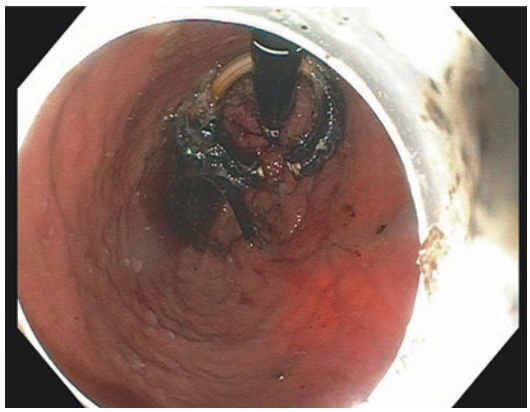

**Fig. 6.4** Endoscopic view of a band erosion. (Photo credit Dr. Christine Ren Fielding, Professor of Surgery, NYU School of Medicine.)

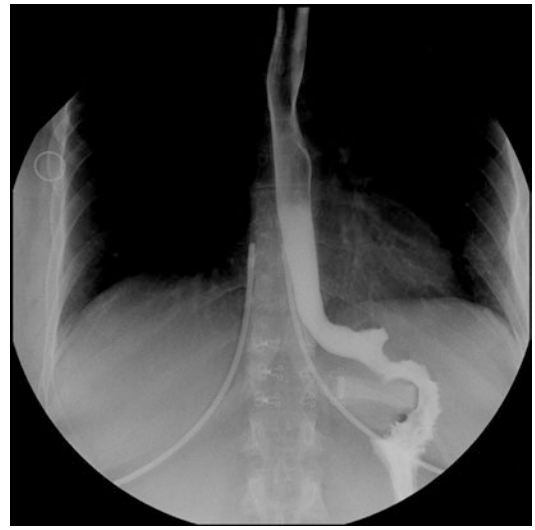

**Fig. 6.5** Fluoroscopic image of a band erosion. (Figure credit Dr. Christine Ren Fielding, Professor of Surgery, NYU School of Medicine)

Endoscopy is an effective diagnostic modality in patients with suspected band erosion. A gastrografin-fluoroscopic swallow study with a "double lumen" sign is also diagnostic of band erosion. Treatment involves removal of the band, either laparoscopically, endoscopically, or via a

combined approach if greater than 50% of the band has eroded through the stomach wall. It has been reported that even in cases of partial intragastric migration, successful endoscopic removal has been performed [29, 30]. Since the complication rate with immediate conversion to another bariatric procedure in the presence of an erosion is increased, it is generally recommended that conversion be postponed for at least 2–3 months after band removal. A laparoscopic Roux-en-Y gastric bypass (RYGB) is a commonly considered procedure after gastric band removal.

**Vomiting and Food Intolerance** The rate of vomiting and food intolerance in patients with LAGB varies from 0% up to 60%. Several of the LAGB studies reported a reduction of vomiting incidence with time elapsed since surgery. Early intolerance may be a result of gastric edema. Postoperative diet varies tremendously as does the progression from liquids to purees to solids. Early intolerance can be reduced or avoided by a slow progression back to a soft regular diet, allowing any surgical edema to subside. Since adjusting the volume of the band is an intrinsic part of the follow-up, reduction in the incidence of vomiting and food intolerance may possibly be attributed to the partial deflation of the band. One study, with 3-month follow-up, reported significantly lower rate of total dysphagia (defined as an inability to drink or eat without vomiting) with Swedish Adjustable Gastric Band (SAGB) when compared with the Lap-Band ™ (7.3% vs. 31%) [31]. Over time, manufacturers have increased the dimensions of the band and have allowed for a larger capacity of fluid within the band, to allow for more flexibility with adjustments. Vomiting and food intolerance are initially managed by deflation of the band. Appropriate studies should be performed if intolerance persists despite complete deflation of the band, as this may indicate a band slippage or erosion. In nonresponders, band removal and subsequent conversion to and alternate procedure should be considered where indicated.

**Cholelithiasis and Choledocholithiasis** High incidence of new onset cholelithiasis and choledocholithiasis following rapid weight loss after bariatric procedures has been widely reported. Despite extensive literature on the incidence of gallstones following RYGB and sleeve gastrectomy (SG), literature on gallstones secondary to LABG is lacking. The Australian Safety and Efficacy Register of New Interventional Procedures based on 5780 LAGB patients reported the incidence rate of cholelithiasis/cholecystectomy of 0.19%∗ [4]. This rate is considerably lower than that of general US population (6% for men and 9% for women) [32]. In our personal experience, those rates seem to overestimate the problem. Further studies are needed to estimate a factual rate of gallstones formation after LAGB.

**Hiatal Hernia** It is estimated that 19.5% of patients undergoing LAGB have a coexisting but frequently unrecognized hiatal hernia (HH). Combining LAGB with hiatal hernia repair (HHR) significantly reduces reoperation rate for HHR alone, with band slippage, or gastric pouch dilatation; without an increase in blood transfusion incidence, length of hospital stay, or band-related complications. For this reason, diagnosis of HH and HHR with simple crural repair ± MESH during initial placement of gastric band should be performed [33]. In patients with GERD, an addition of HHR to LAGB had a negligible effect on postoperative improvement of reflux symptoms [34].

**Esophagitis and Reflux** Esophagitis and reflux are uncommon complications following LAGB [18]. In the majority of patients, deflation of the band and PPI therapy control the symptoms. If no response to the medical therapy is noted, band removal or conversion to RYGB, where indicated, may be necessary.

**Failure to Lose Weight** Due to relatively modest weight loss (EWL), coupled with rather high rates of revisions and weight recidivism, LAGB is no longer a commonly performed bariatric procedure. In 2011, LABG constituted 35.4% of all bariatric procedures, while in 2017 it declined to only 2.77% [35–37]. Patients may anticipate one-pound-per-week weight loss rate until a plateau is reached at approximately 2 years [38, 39]. Most patients initially lose weight, but some

**Table 6.2** Specific complications across all studies reporting complications by Chapman et al. [4]

| Specific complications | | |
|---|---|---|
| | LAGB ($n$ = 8504) | |
| Complication | $n$ | Percent |
| Dilatation | 338 | 3.97 |
| Band slippage | 138 | 1.62 |
| Port rotation/movement | 74 | 0.87 |
| Catheter rupture/disconnection/leak | 68 | 0.80 |
| Erosion | 50 | 0.59 |
| Infection of band or reservoir | 31 | 0.36 |
| Respiratory complications | 24 | 0,28 |
| Wound infection | 24 | 0.28 |
| Infection (other, inc. sepsis) | 16 | 0.19 |
| Cholelithiasis/cholecystectomy | 16 | 0.19 |
| Pulmonary embolism | 14 | 0.16 |
| Incisional hernia | 13 | 0.15 |
| Seroma/hematoma | 13 | 0.15 |
| Occluded/kinked stoma | 12 | 0.14 |
| Oesophagitis | 12 | 0.14 |
| Painful port site | 11 | 0.13 |
| Stenosis | 10 | 0.12 |
| Defective/leaking/broken/damaged band | 8 | 0.09 |
| Psychological problems | 5 | 0.06 |
| Subphrenic abscess/abscess | 4 | 0.05 |
| Bleeding (inc. GI) | 4 | 0.05 |
| Bleeding/discharge/necrosis at incision | 4 | 0.05 |
| Urinary tract infection | 4 | 0.05 |
| Gastritis | 1 | 0.01 |
| DVT | 1 | 0.01 |
| Miscellaneous | 35 | 0.41 |

[a]Since the data were derived from a multitude of varying quality and heterogeneous studies, considerable variation in long-term follow-up times, any results drawn from such a process should be treated with the utmost caution

fail to sustain their improvements. Cases of no significant weight loss at all have also been reported. Therefore, frequent follow-up appointments during the first 2 years after surgery are of critical importance in order to ascertain fundamental changes in eating habits and lifestyle and achieve long-term success in maintaining weight loss. A study of a total of 3227 LAGB patients with 15-year follow-up reported a durable 47% EWL [36]. In our personal clinical experience, LAGB is a valid mode of surgical treatment of obesity in highly compliant and young patients (Table 6.2).

## Mortality

The Australian Safety and Efficacy Register of New Interventional Procedures based on 5780 LAGB patients reported a short-term mortality rate of 0.05%∗, long-term mortality rate of 0.17%∗, and overall mortality rate of 0.22%∗ [4]. Pulmonary embolism (PE) accounts for approximately 30% to 50% of mortality causes [40, 41]. Other causes of in-hospital mortality include sepsis, cardiac events, and respiratory failure. Most of these events are not surgically related, but rather are related to the general risks of a morbidly obese patient undergoing any form of surgery.

## Conclusion Paragraph

LAGB is associated with a variable rate of morbidity and mortality as reported in the literature. However, overall, it is considered a safe procedure, especially when performed by experienced bariatric surgeons following appropriate patient selection. It is reversible and does not exclude patients from further surgical interventions when needed. It is a valuable asset in the bariatric surgeon's armamentarium, especially when chosen as part of an informed decision-making process.

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# Sleeve Gastrectomy Complications

7

Gurdeep S. Matharoo and Grace A. Lepis

Sleeve gastrectomy was first described by Hess in 1988. At that time, it was being done as part of a biliopancreatic diversion and duodenal switch operation [1]. Gagner first described the procedure using a laparoscopic approach in 1999 again as part of a BPD-DS surgery [2]. Gagner later utilized the procedure as a standalone procedure in 2004. Initially the procedure was not covered by the Centers for Medicare and Medicaid Services in the United States. In June 2012, the procedure was approved as a standalone procedure to treat morbid obesity. From that time, the procedure has steadily grown in popularity and has now become the most frequently performed bariatric surgery procedure. The ASMBS estimates that in 2017 laparoscopic sleeve gastrectomy accounted for 59.39% of all bariatric surgeries performed in the United States. This has grown from 17.80% in 2011 [3].

As the popularity of the procedure has increased, surgical techniques have gotten better and controversies have been solved. There, however, remain several postoperative issues that continue to plague both patients and bariatric surgeons across the world. Throughout this chapter, we will highlight the common complications after a sleeve gastrectomy and illustrate the evidence-based recommendations for best practices.

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## Hemorrhage

Postoperative hemorrhage most frequently occurs from the staple line [4]. Hemorrhage along the longitudinal staple line usually occurs early in the postoperative time period. This can lead to a quick deterioration in the patient's clinical status and become life-threatening bleeding. The documented prevalence of postoperative bleeding is between 2% and 5% [4].

The ability of the surgeon to predict bleeding has been a focus of study. This led to the development of the SLEEVE BLEED calculator [5]. This calculator was developed after reviewing records of 552 patients undergoing a laparoscopic sleeve gastrectomy. The authors identified four variables that were associated with hemorrhagic complications. The variables were hypertension, obstructive sleep apnea, surgeon experience, and use of staple line reinforcement. The factors with the highest odds ratio were low surgeon experience and the lack of staple line reinforcement at 2.85 and 3.34, respectively.

We have identified factors that can lead to bleeding; however, the prevention of bleeding is integral for the postoperative success of our patients. Staple line reinforcement is a popular adjunct to sleeve gastrectomy. There are many methods employed to reinforce the staple line. These include suturing the staple line, synthetic materials, biologic materials, and fibrin glue. In 2004, Consten et al. described that synthetic



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staple line reinforcement strips decreased the intraoperative blood loss when compared to bare stapling [6]. This finding was further supported by a 2010 publication from Belgium which found that staple line reinforcement with bioabsorbable material decreased stomach sectioning blood loss and total blood loss during the sleeve gastrectomy operation [7].

A meta-analysis from Shikora and Mahoney screened 16,967 articles and ultimately reviewed 295 articles covering 41,864 patients for bleeding [8]. In this extensive review, they found that without staple line reinforcement the bleeding rate is 4.94%. Both the glycolide copolymer and bovine pericardium strips decreased the bleeding rate more than over suture, 2.09 and 1.16%, respectively, versus 2.41%.

In our practice, we routinely use SeamGuard (WL Gore. Flagstaff AZ USA) reinforcement strips on all staple loads for the sleeve gastrectomy. We do often find that the first staple fire at the antrum does bleed at the junction between the gastrocolic ligament and the stomach. This is presumably due to the large staple depth at this location that does not compress the thin gastrocolic ligament enough for hemostasis. This bleeding is easily controlled with a 5-mm clip applier. We are judicious with our dissection of the gastrocolic and gastrosplenic ligaments as well. The ultrasonic dissector or bipolar cutting device is used to seal all the smaller vessels. When larger short gastric vessels are encountered at the splenic hilum or retrogastric dissection, 5-mm clips are placed on the staying side prior to using the energy device to transect the vessel. The energy device used is to the surgeon's preference; however, our experience is with the Harmonic Scalpel (Ethicon, Somerset, NJ, USA) and LigaSure (Medtronic, Dublin, Ireland).

## Stricture

An infrequent complication of the sleeve gastrectomy is the development of a stricture. This has been reported in the literature to have an incidence up to 4% of patients [9, 10]. There are two timelines for presentation of a gastric stricture. Early gastric strictures present within 1 month of surgery and usually have symptoms immediately after starting an oral diet. The cause for these strictures is related to immediate postoperative changes such as a hematoma causing compression of the sleeve or mucosal edema [11]. Delayed gastric strictures present after 1-month postsurgery. These patients tolerate an oral diet initially and then progressively have symptoms. They complain of nausea, vomiting, reflux, and regurgitation.

In patients who present with complaints that raise concern for a gastric stricture, the initial testing should be a contrast upper gastrointestinal series. These series of images will show the anatomy of the gastric tube and the progression of the contrast in real time. It is highly recommended that the surgeon be present during the examination to visualize the progression of contrast in dynamic images rather than the still images provided. (See Fig. 7.1) If the imaging suggests a gastric stricture, the next investigation should be an upper endoscopy. The endoscopy can be diagnostic and has the potential to be therapeutic when adjuncts are used.

The treatment of patients with gastric strictures has been developed into an algorithm of escalating therapy [9]. The first step in treatment

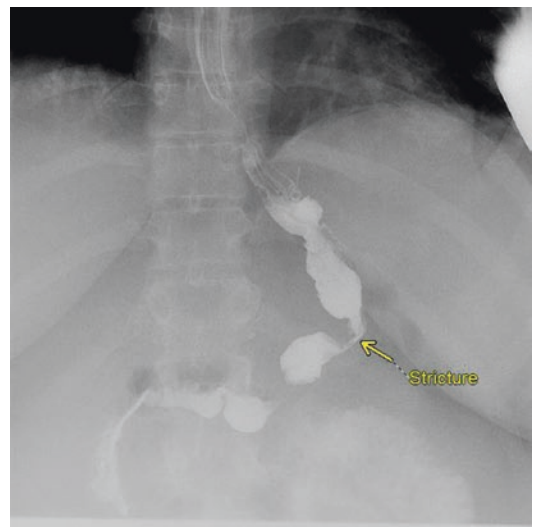


**Fig. 7.1** Stricture in patient 6 months after sleeve gastrectomy. Upper GI series demonstrates contrast passing through narrowed section in the mid-sleeve portion

depends on the findings from the upper endoscopy. Short strictures are amenable to endoscopic dilation. Multiple studies have demonstrated that dilation is an effective method of treatment for gastric strictures [9–11]. The dilations should also follow an escalation of therapy. Rigid achalasia balloons with a 30 mm diameter are recommended for the initial dilation. The dilation is done at 20–30 psi after confirming the location of the balloon with fluoroscopic guidance. The dilation is held for 1 minute [9, 10]; however, dilations for 20 minutes have been reported without adverse effects [11]. If this dilation is not successful, it can be repeated after 2 weeks by increasing the balloon diameter to 35 mm. The 35 mm balloon dilation can be repeated up to three times. Endoscopic dilation has been reported to be successful in treating strictures in 71–86% of patients [12, 13].

## Reflux

Reflux after sleeve gastrectomy is possibly the most common complaints among patients in the postoperative period. The prevalence of reflux has been reported in up to 83% of patients. This result has prompted some surgeons to believe that preoperative gastroesophageal reflux disease should be a contraindication to sleeve gastrectomy. The controversy over the topic indicates that, despite its prevalence, the management is not a well-agreed upon among surgeons.

The etiology of reflux is due to the change in volume of the stomach. When compared to a native stomach, the sleeved stomach has a more rapid increase in pressure upon volume distention. This is believed to be secondary to the removal of the fundus which is relaxed through accommodation to allow an increase in volume without an increase in pressure [14]. This change in gastric physiology impacts esophageal function. When esophageal function was studied with impedance and manometry after sleeve gastrectomy, there was an increase in ineffective motility and a drop in complete bolus transit [15]. The study found that there is an increase in total reflux episodes and nonacid reflux. This coincided with findings of an increase in post-prandial retrograde movements. When examined with high-resolution esophageal manometry, it was discovered that the increased intragastric pressure was causing the esophageal bolus to rebound proximally until the intragastric pressure decreased to allow clearance into the stomach.

Proper patient selection is the paramount method to ensure good results after surgery. There are, however, two surgical techniques that have been proven to reduce reflux after sleeve gastrectomy. The first of these techniques is proper management of the esophageal hiatus. This primarily involves meticulous inspection of the hiatus in the operating room. In our practice, the dissection is carried until the left crus of the diaphragm is clearly visualized. This allows inspection of hiatus both anteriorly and posteriorly. Any weakness or hernia results in a full inspection of the hiatus, with circumferential mobilization of the esophagus and posterior cruroplasty. Soricelli's group from Rome published their report on 378 patients undergoing sleeve gastrectomy [16]. In their report, all patients underwent a preoperative upper endoscopy. They found that preoperative exclusion of hiatal hernia on endoscopy was correct in 84% of patients. Also, they noted that approximately 18% of patients who reported no GERD symptoms had hiatal hernias. This supports meticulous inspection of the crura as neither endoscopy nor symptoms can reliably indicate which patients suffer from a concomitant hiatal hernia. Upon review of their clinical outcomes, it was found that no patients in the hiatal hernia repair group developed de novo GERD. These findings were supported by another study from Australia and the UK which enrolled 262 patients. In the group where a cruroplasty was done, there was a decrease in the mean reflux frequency and mean reflux severity scores [17].

The second operative technique which has been shown to impact postoperative reflux is the complete resection of the gastric fundus [18]. A comprehensive study from Israel and Spain reviewed 706 patients. They analyzed bougie size, staple starting point, and fundus excision as the causes for postoperative reflux. They noted

that the patients who complained of reflux were those with a particular shape of postoperative stomach. It was noted on upper GI series that a dilated proximal stomach due to incomplete fundal resection combined with a narrowed midportion of the stomach was contributing to the reflux. They concluded that sleeve volume, bougie size and the starting point of the antral resection do not affect reflux disease.

Treatment for the patient with postoperative reflux usually starts with an anti-secretory medication. In our practice, we routinely place patients on proton pump inhibitors postoperatively. The overwhelming majority of patients state that this regimen prevents reflux symptoms. Those that continue to complain of reflux despite pharmacological treatment have further workup which includes an upper endoscopy and a contrast-enhanced upper GI series. This is to evaluate the esophagus and stomach for signs of reflux disease, strictures, residual fundus, and hiatal hernias. The degree of esophagitis is reported on the endoscopy and serves as an indication of the severity of the reflux. Biopsies should be done to evaluate for Barrett's esophagus or dysplasia. The management of strictures has been previously discussed. The upper GI can be compared to the study that is done on postoperative day 1. If a retained or neo-fundus is found, the patient is scheduled for surgery. Also, if a hiatal hernia is found, then the patient is scheduled for surgery to repair the hernia. A group in Italy reviewed 19 patients who underwent a laparoscopic fundectomy after a sleeve gastrectomy. They found that all patients experienced an improvement in upper GI symptoms [19]. Hiatal hernia repair after sleeve gastrectomy has also been showed to have immediate improvement in symptoms [20]. In our practice, if the patient presents with redundant fundus after sleeve gastrectomy, we routinely open the esophageal hiatus and mobilize the esophagus prior to resection of the fundus. This mobilization allows for complete resection of the fundus. The resultant posterior cruroplasty allows for better control and possible elimination of reflux.

Conversion to gastric bypass for reflux disease has traditionally been the options which most surgeons prefer. There are many mechanisms that prevent GERD in the gastric bypass anatomy. During the procedure, the pouch must be evaluated to ensure removal of any residual fundus. Again, meticulous inspection of the esophageal hiatus should be done to avoid a missed hiatal hernia. The conversion to gastric bypass has been proven to resolve GERD. In 2017, Parmar and colleagues published a report on 10 patients who were converted due to persistent GERD [21]. They found that all patients had an improvement in symptoms and 80% had complete resolution of symptoms. Their study mimicked the results of five previous studies on this conversion.

## Esophageal Cancer

As discussed previously, gastroesophageal reflux is a known complication after sleeve gastrectomy. Chronic reflux is associated with multiple changes in the mucosa of the esophagus, ultimately leading to adenocarcinoma [22]. As sleeve gastrectomy has become more popular, there is an overwhelming concern that reflux disease and subsequently esophageal cancer would see an increasing incidence. This possibility is particularly troubling as the primary esophageal replacement is a gastric conduit based off the right gastroepiploic artery, which, after sleeve gastrectomy, is absent.

Despite this theoretical concern, at this point, there are only four case reports of esophageal adenocarcinoma after sleeve gastrectomy. The first report was published in 2011 by Scheepers et al. The case was a 57-year-old woman with a BMI of 51.8 kg/m$^2$ who was found to have a lower esophageal cancer 4 months after surgery. The patient did not have an upper endoscopy prior to surgery [23]. In 2017, there were two case reports published of patients with esophageal adenocarcinoma. The first case describes a 44-year-old New Zealand woman who was found to have a mass at the gastroesophageal junction on endoscopy done for anemia. The mass was biopsied and returned as a moderately differentiated adenocarcinoma. There was no metastatic disease and the patient

had an esophagogastrectomy with a Roux-en-Y esophagojejunostomy reconstruction after neoadjuvant chemotherapy. This patient did have a normal preoperative upper endoscopy [24]. The second case published in 2017 was from Argentina, where a 48-year-old man presented, 5 years after surgery, with complaints of dysphagia. An upper endoscopy found a mass in the lower esophagus which was biopsy-proven to be moderately differentiated esophageal adenocarcinoma. The patient was found to have metastatic disease to the liver and was treated with chemotherapy [25]. In 2018, a case was reported from France where a 55-year-old woman underwent an open sleeve gastrectomy. She was found to have Barrett's esophagus without dysplasia on a preoperative endoscopy which went untreated. Three years later, she presented with dysphagia and was found to have a pT1 esophageal adenocarcinoma without metastasis that was treated with endoscopic mucosectomy [26].

In our practice, all bariatric patients are required to have an upper endoscopy to evaluate the lumen of the esophagus, stomach, and duodenum. The presence of severe reflux based on LA grade or Barrett's esophagus prompts a discussion with the patient's gastroenterologist and the patient. The presence of severe esophagitis is usually related to a concomitant hiatal hernia which would be repaired at the time of sleeve gastrectomy. In cases where the patient has Barrett's esophagus, we inform the patient of its premalignant nature and require preoperative endoscopic treatment. This treatment is left to the discretion of the gastroenterologist. There are many options available; however, radiofrequency ablation is the most common method used in our patient population. The patient continues to follow up with the gastroenterologist until the disease is confirmed to be eradicated. At this point, the patient is then cleared to have a sleeve gastrectomy. Of course, when there are findings of severe reflux or reflux-associated diseases, the patient is given a strong recommendation for a gastric bypass surgery instead of the sleeve gastrectomy. It is imperative that the patient understands that sleeve gastrectomy will not allow the stomach to be used as a conduit should the patient develop esophageal cancer. This is a routine discussion that occurs in our informed consent procedure.

## Leak

The overall incidence of leak after laparoscopic sleeve gastrectomy has been shown to be 0.7%. The incidence of leak has been decreasing as experience has increased [27]. The leak is caused by a disruption of the staple line due to an intraluminal pressure that exceeds its burst pressure. This can be secondary to mechanical failure of the stapler or due to tissue characteristics such as ischemia or radiation which can lead to poor healing [28]. Although the incidence of leak is low, there is potential for significant morbidity and mortality should one occur. Therefore, proper management is essential to achieve the best chance for favorable patient outcomes. Gastrointestinal leaks after sleeve gastrectomy are complex issues with many different types of management techniques reported. The goal of this section is to identify known operative techniques that help to reduce the incidence of leaks and review the proven methods of treating leaks.

Prevention of leaks is something that every surgeon strives to perfect. There are many anecdotal methods for prevention of leak; however, only a few have been proven out in the literature. In a German review of 5400 sleeve gastrectomy patients, they found that the largest contributor to postoperative leak was the surgical approach. Primary laparoscopic sleeve gastrectomy had a leak rate of 1.7%. Primary laparotomy increased the rate to 4.4%; however, patients who were converted to open from laparoscopic had a leak rate of 14.6%. The same review reveals that reinforcing the staple line either with oversewing or buttress material decreases the leak rate when compared to no reinforcement; 1.5% and 1.6% versus 2.5%, respectively [29]. Although there are known methods to avoid leaks and the incidence of leaks has decreased, it is imperative for every surgeon who performs bariatric surgery to know how to manage a sleeve gastrectomy leak.

It is known that majority of gastric sleeve leaks have a delayed presentation that occur after the patient has left the hospital [30]. Most leaks occur greater than 5 days postsurgery [27]. It is also well demonstrated that the preponderance of leaks occurs in the proximal portion of the staple line [30]. The presence of a leak should always be in the surgeon's differential diagnosis of any patient in the postoperative period that is not progressing as expected. Tachycardia, fever, and abdominal pain with radiation to the shoulders are common signs of leak [27]. Once the patient presents with these symptoms, evaluation should be done to confirm or exclude the presence of the leak. Radiological studies have been used to assess the gastric sleeve for presence of a leak. There are surgeons who routinely have patients undergo an upper GI contrast series on postoperative day 1. Our group follows that trend as part of our protocol, although we are aware that it has low sensitivity. When the patients present with concern of a leak, the preferred radiological method for evaluation is a CT scan with oral and IV contrast due to its high sensitivity and specificity [27, 31]. This provides information regarding the site of the gastric leak and associated fluid collections. In addition, it can also show other complications such as hematomas, portal vein thrombosis, and, if the chest is included, pleural effusions and pulmonary embolus [32]. See Figs. 7.2 and 7.3.

Once the diagnosis of leak is made, the management depends on the patient's clinical status and timing of presentation. The patient should be made *nil* per os and have intravenous fluids started with plans for parenteral nutrition. The patient should also have proton pump inhibitors and antibiotics, pending clinical status [33]. The goals of care are to provide adequate drainage to manage abdominal sepsis and provide nutrition. Early operative intervention should be reserved for those patients who cannot have a drain placed by interventional radiology, those who require direct visualization to confirm diagnosis, or those who require a jejunostomy tube for feeding. In the very early (less than 72 hours) postoperative period, it has been reported that suture repair of the staple line defect can be effective, although the efficacy of this method decreases rapidly as time progresses due to the inflammatory change in surrounding tissues [27].

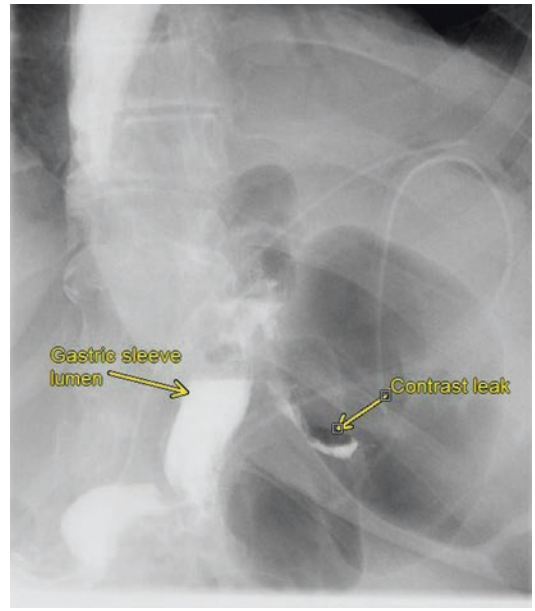


**Fig. 7.2** Upper GI series in patient with leak after a sleeve gastrectomy. The gastric lumen can be seen with contrast passing in the normal fashion. There is a leak from the proximal portion of the staple line leading to an extraluminal cavity

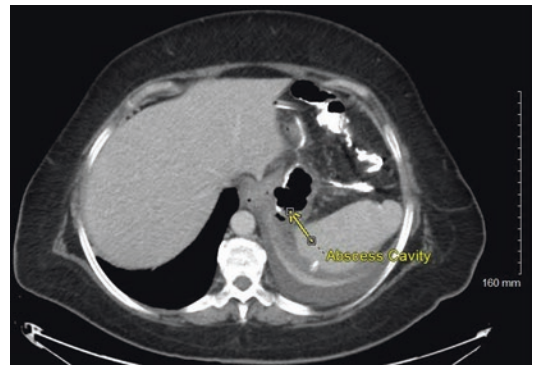


**Fig. 7.3** CT scan of same patient from Fig. 7.2 showing the abscess cavity between the gastric sleeve staple line and the spleen

Due to the high pressure within the stomach, leaks are difficult to seal even with adequate drainage and bowel rest. Nonoperative methods to treat the leak are preferred as direct operative

repair is usually not efficacious due to the delayed presentation and subsequent change in tissue architecture. These nonhealing leaks result in chronic fistulas. There are multiple management methodologies that utilize the full armamentarium of a medical center. Often, these methods require a multidisciplinary approach involving surgeons, gastroenterologists, and radiologist to obtain the optimal patient outcome.

Endoscopic stents come in many different forms. For gastric sleeve leak, the most common used stents are either partially covered or totally covered stents. The covered portion of the stent is used to exclude the gastric side of the open staple line. The partially covered stents have bare metal at both ends and allow tissue ingrowth into those segments. Through tissue ingrowth, the stents are less likely to migrate; however, the ingrowth also adds to the challenge of removing the stents [34]. The fully covered stents do not have bare metal segments and are less likely to suffer from ingrowth. A study from France revealed that significant tissue ingrowth causing incarceration of the stent occurred in 7.9% of patients. Partially covered stents were responsible for 92.8% of these incarcerations [34]. The use of fully covered stents was investigated by a Martin del Campo et al. and was found to have a migration rate of 22%; however, earlier studies had a migration rate of 46.1% [34, 35]. Fixation of a fully covered endoscopic stent has been demonstrated with an endoscopic suturing device [36]. A study of 125 patients showed that stent migration decreased from 33% to 16% when they were suture-fixated. In this study, the suturing was performed using the OverStitch device. (Apollo Endosurgery, Austin, Texas, USA) In our practice, we have utilized a combined laparoscopic and endoscopic method to suture-fixate the stents. The sutures are placed transmurally under endoscopic guidance to ensure the stent is incorporated into the suture. This combined approach also allows for operative exploration of the abscess cavity to ensure appropriate drainage.

To standardize therapy for patients with leak after gastric sleeve surgery, there have been reports on management algorithms. Endoscopic stent placement plays an integral role in the initial management of almost all patients diagnosed with a sleeve leak. In fact, the only patients who would not be candidates for a stent placement are those who are septic and those that are diagnosed late and have a chronic fistula. The septic patient would go to the operating room for a surgical exploration, drainage, and jejunostomy tube placement [37]. Patients with chronic fistulas have other surgical options to be discussed later in this chapter. Treatment of gastric sleeve leak with endoscopic stenting results in healing of the leak in 66–78% of cases [31, 34, 35, 38]. The success rate for closure of the leak decreases as duration of the leak increases [35]. Therefore, early recognition and stenting is recommended in patients who have a leak less than 12 weeks from surgery.

For patients with a chronic leak, more than 12 weeks from surgery, treatment strategies are varied, less standardized, and evolving. The patients with chronic leaks and fistulas will come from two groups: those that have failed management with stents, drainage, and nutrition for at least 12 weeks and those who present after 12 weeks without prior treatments. In either case, if the patient is septic, the patient should be taken directly to the operating room for washout and drainage. For the stable patient with a chronic leak, there are many document treatment methods. These include conversion to Roux-en-Y gastric bypass, conversion to Roux-en-Y esophagojejunostomy, Roux-en-Y fistulojejunostomy, endoscopic septotomy, and endoscopic negative pressure therapy [39]. These methodologies will be discussed below.

Conversion to Roux-en-Y gastric bypass is most often done in the setting of a chronic leak. It is believed that the increased intragastric pressure plays a major role in the persistence of a gastric sleeve leak by permitting contents to exit the stomach via the lower resistance of the fistula [40]. The Roux-en-Y gastric bypass is a low resistance system which will favor gastric contents exiting via the gastrojejunostomy, thereby allowing the staple line to heal [41]. Nedelcu et al. have reported two cases where patients were successfully treated [39]. As per the Fifth International Consensus Conference on Sleeve

Gastrectomy, conversion to gastric bypass is the preferred method to treat chronic leaks [42]. The use of Roux-en-Y gastric bypass has now been expanded to treat acute leaks as well. First reported by Praveenraj et al. in 2016, a patient presented with a leak on postoperative day 15. After investigational studies, she was successfully treated with conversion to Roux-en-Y gastric bypass [43]. Also in 2016, Yerdel reported a patient who developed an immediate postoperative stricture that was complicated with a leak on postoperative day 9 [44]. He was converted to a Roux-en-Y gastric bypass with the pouch transection proximal to the stricture. The patient was treated successfully. Similarly, Saglam et al. reported three cases where patients presented with leaks on postoperative day 4, 9, and 4. All patients were successfully treated with Roux-en-Y gastric bypass [45].

First described by Baltasar in 2007, use of a Roux-en-Y fistula-jejunostomy for chronic gastric sleeve leaks has been further described in the literature [40]. A report from France published in 2016 expanded on the previous reports. Chouillard et al. reported 33 patients who were treated with the fistula-jejunostomy. In this study, the patients had resolution of the leak confirmed by CT scan 1 month after surgery [46].

Both previously described methods involve salvage of a portion of the stomach. Some authors advocate for total gastrectomy with esophagojejunostomy creation for continuity of the alimentary tract. It is believed that the chronically inflamed tissue surrounding the site of the fistula is not amenable to anastomosis and will result in failure. This was demonstrated by van de Vrande and colleagues as they reported in 2013. Roux-en-Y fistula-jejunostomy was done in 11 patients and they had a persistent leakage rate of 46%. Although all persistent leaks did resolve, it opened the question if there was a better way to treat patients who have poor quality tissues. The authors advocated that more aggressive resection of the stomach should be done since transecting diseased stomach may lead to further staple line issues and transecting proximal to an area of stenosis may lead for further leaks in the remnant stomach. This was first described as a salvage procedure for complications of bariatric surgery by Serra and colleagues in 2006 in nine duodenal switch patients [47]. This was followed by Yaacov et al. in 2014 with a series of four patients and by Mahmood et al. in 2016 with another four patients requiring total gastrectomy [48, 49]. Total gastrectomy remains the most definitive and aggressive surgical option to treat chronic leaks. This is a major surgery that should only be undertaken by surgeons with experience in total gastrectomy.

In our practice, the gastrectomy is done laparoscopically with mobilization of the entire gastric sleeve. Prior to division of the alimentary tract, the esophageal hiatus is opened and the esophagus is mobilized and a safe transection point is identified. Then the distal stomach and the duodenum are mobilized. The enteroenterostomy is created in a standard side-to-side stapled fashion ensuring that the proposed roux limb will reach above esophageal hiatus in an antecolic, antegastric fashion prior to transection. We then divide the left gastric artery allowing the proximal stomach to demarcate ischemia. This will allow transection at a portion of the esophagus with adequate blood supply. Distally the duodenum and right gastric artery are transected completing the gastrectomy. The esophagojejunostomy is created in a stapled end-to-side fashion. The anvil is passed transorally attached to a nasogastric tube and then mated to the stapler that is passed through the cut end of the roux limb with the spike extending out the antimesenteric border. See Fig. 7.4.

The previously described methods for management of chronic sleeve gastrectomy leaks have been operative and invasive; some procedures reportedly done in an open fashion. As endoscopic technology has advanced, the possibilities for treatment of gastric sleeve leaks have expanded. Three techniques have emerged that are showing promise. Over the scope, clip usage for control of a leak after sleeve gastrectomy was first described by Conio et al. in 2010 [50]. Surace et al. and Aly have demonstrated that this technique is a feasible option; however, there are several technical considerations which require an experienced and skilled endoscopist [51, 52].

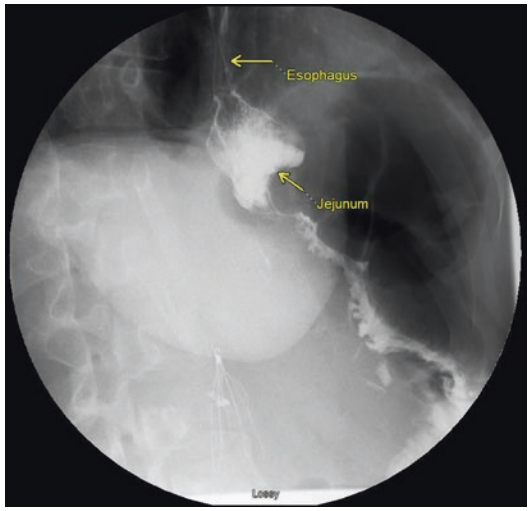


**Fig. 7.4** Upper GI series image of patient who underwent a total gastrectomy for chronic leak after a laparoscopic sleeve gastrectomy

Endoscopic abscess septotomy is a procedure where the common wall between the abscess and the gastric lumen is divided. This is to allow internal drainage of the contents into the gastric lumen. This is concomitantly performed with a distal balloon dilation of the gastric lumen to decrease intraluminal pressure [53]. This has been shown to resolve the leak and may reduce the need for additional surgical intervention [54, 55].

First used in the management of anastomotic leaks from esophageal and rectal procedures, the use of an endoscopically placed vacuum-assisted wound closure device has been expanded to sleeve gastrectomy leak management [56, 57]. The technique involves mating a foam material to a nasogastric tube. The foam is then guided to the leak site and abscess cavity using the endoscope. Once placed in the correct location, the nasogastric tube is connected to negative suction. This treatment modality utilizes the same principles of wound healing that are seen in traditional wound vacuum-assisted closure devices. In 2014, Liu and colleagues reported five patients with postsurgical esophageal leaks who were successfully treated with negative pressure therapy [56]. This was followed by Smallwood in 2016, who reported six patients were treated successfully after upper gastrointestinal leaks and perforations [57]. Both reports did not include sleeve gastrectomy patients. Leeds and Burdick, in 2016, reported the first use of the endoluminal (E-Vac) therapy in sleeve gastrectomy patients [58]. Their report details nine patients who were treated with E-Vac therapy and achieved 89% rescue rate. Although all patients did have resolution of the leak, one patient expired due to causes unrelated to the leak. As with the commercially available vacuum-assisted closure devices, the tube and foam must be changed regularly. Leeds' group recommended a 4-day serial exchange of the foam and the mean number of exchanges was 10.5.

The relative ease of the sleeve gastrectomy operation has caused rapid adoption of this procedure by both surgeons and patients. The popularity and success of the operation have also caused it to be thought of as "less invasive" than the other procedures. Although the surgery is technically less challenging than other currently performed bariatric procedures, we, as surgeons, must not overlook the potential for complications. We must be forthright with our patients during the informed consent procedure and discuss complications with them. Also, when encountering a patient who has suffered a complication, we must evaluate our own experience with the experience of the ancillary services in the community we serve to determine if the patient should be transferred to a higher volume center. As the preceding discussion of complications has demonstrated, the surgeon is only part of the entire specialist-led healthcare team that is required for optimal outcomes.

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# Gastric Bypass Complications

8

Sunil K. Sharma, Samuel Cottam, Ragini Sharma, Smita Sharma, and Daniel Cottam

## Introduction

The number of bariatric surgical operations performed in the United States has been steadily increasing for the last 5 years. It is estimated that 228,000 weight-loss surgeries were performed in 2017 [1]. Of those, 59% were sleeve gastrectomy, 18% were gastric bypass, 3% were gastric band, and 1% were biliopancreatic diversion with duodenal switch [2]. The remaining 14% were revisional procedures.

**Roux-en-Y gastric bypass** RYGB was first described by Mason in 1967 and it still remains as a gold standard operation against which other procedures are tested and compared. RYGB involves the creation of a small gastric pouch and an anastomosis to a Roux limb of jejunum that bypasses 75–150 cm of small bowel, thereby restricting food and limiting absorption (Fig. 8.1).

Gastric bypass has evolved over the 30 years following its initial description to include multiple modifications. Traditionally it was performed with exploratory laparotomy. With the advent of minimal invasive surgery, now most of the procedures

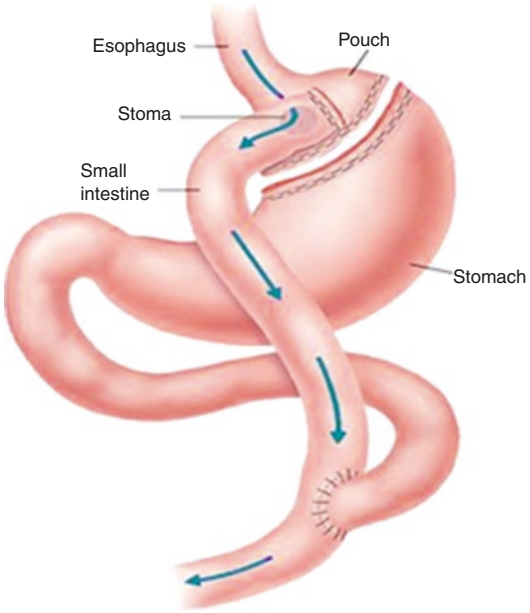


**Fig. 8.1** Gastric bypass anatomy

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are performed by laparoscopic technique or robotic-assisted surgery. The size of the gastric pouch has gradually been reduced to the present 20–30-mL capacity. The gastric pouch is most commonly constructed by dividing, rather than partitioning, the stomach. A Roux-en-Y gastrojejunostomy is done with variable lengths. The alimentary limb refers to the jejunal Roux-en-Y limb anastomosed to the stomach pouch. The biliopancreatic limb transmits bile and pancreatic secretions to the jejunojejunostomy where the ingested nutrients and digestive juices first mix. The common channel refers to the distance from the enteroenterostomy to the ileocecal valve. The Roux-en-Y limb may be transmitted to the small gastric pouch either anterior (anticolic) or posterior to the colon and stomach (Retrocolic). Variable lengths for the alimentary and biliopancreatic limbs and the common channel have been used in an effort to achieve maximum outcomes. If the Roux-en-Y or alimentary limb is >150 cm in length, the procedure is generally termed a long-limb Roux-en-Y gastric bypass. The gastrojejunostomy is generally constructed using one of three techniques. The first, hand suturing, creates an anastomosis that varies from 1 to 2 cm in diameter. With the second technique, circular stapling, the anastomosis may be reinforced with additional sutures or sealants. The diameter of the anastomosis varies from 1 to 2 cm based on the specific device utilized. Finally, a side-to-side linear stapler technique can be used with suture closure of the enterotomy defect. The anastomosis produced by the side-to-side technique also varies between 1 and 2 cm in diameter.

Complications of RYGB are diverse and may vary based on the specific technique. Some complications are relatively specific to the surgical approach (open versus laparoscopic). Certain complications are seen during the early postoperative periods, while others may present weeks to months following the surgery. Complications following gastric bypass can be as high as 40% [3, 4]. To improve the quality of care to the patient and the safety of these operations, there has been a momentum leading to the development of strict criteria for center accreditation, guidelines for safe and effective bariatric surgery, and careful monitoring of surgical outcomes [5].

In this chapter we will cover the common long-term complications after gastric bypass, discussing their management and prevention.

## Anastomotic Stricture

### Introduction

Anastomotic stricture, also called stomal stenosis, is usually considered when the diameter of gastrojejunal anastomosis is reduced to 10 mm or less. The stricture can occur in the immediate postoperative period or can present several years after surgery. Stomal (anastomotic) stenosis has been described in 6–20% of patients who have undergone RYGB [6], although the exact incidence is not known. The exact etiology of stomal stenosis is unclear. It is postulated that tissue ischemia plays a major role. The laparoscopic approach, particularly if 21 mm circular staples are used for anastomosis, has a higher incidence of stenosis [7]. Tension at anastomosis or foreign material can cause chronic irritation, leading to stenosis. The late occurrence of stricture is usually a complication of marginal ulcer during the healing process causing fibrotic changes.

### Workup and Diagnosis

Patients typically present several weeks after surgery with sustained nausea progressing to dysphagia to solids and eventually an inability to tolerate even liquid [8, 9]. The progression of these symptoms can be from a few days to a few weeks. Most of these patients deny any symptoms of abdominal pain but feel quite weak and exhausted. The physical examination is consistent with significant dehydration. The diagnosis is usually established by endoscopy or with an upper gastrointestinal contrast series. Fluro examination with gastrografin or barium will clearly show the narrowing at the anastomosis with delayed emptying from the gastric pouch (Fig. 8.4). Occasionally, you may see pouch dilatation or reflux from the gastroesophageal

junction. The upper GI endoscopy (EGD) is not only diagnostic for stenosis but can also be therapeutic in treatment.

The EGD will show narrowing of the anastomosis to less than 10 mm (Fig. 8.2). Occasionally, the scope cannot be negotiated because of significant narrowing and the dilatation may be required to evaluate the underlying jejunum (Figs. 8.3 and 8.4).

## Surgical Management

Most of the strictures of gastrojejunostomy are successfully treated by endoluminal dilatations.

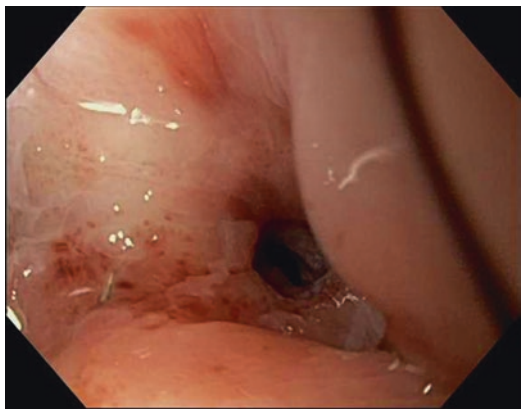

**Fig. 8.2** Anastomotic stricture

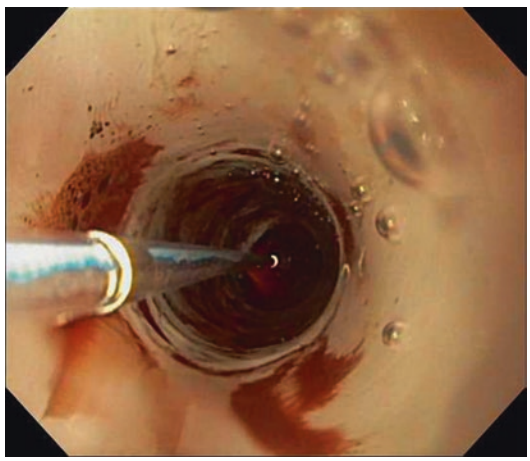

**Fig. 8.3** Balloon dilatation

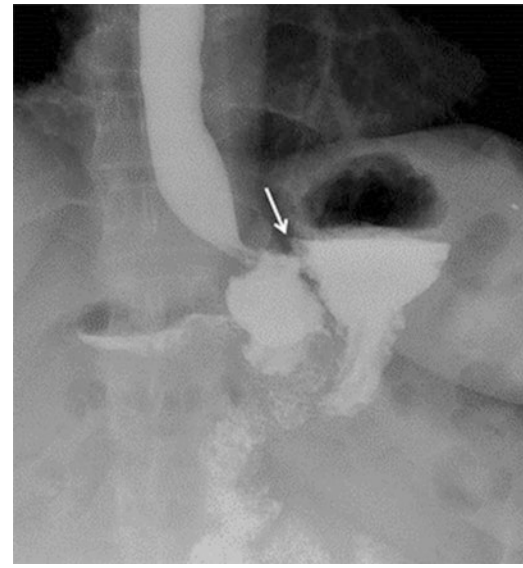

**Fig. 8.4** Upper GI showing stricture

It is imperative to correct electrolyte imbalance and dehydration prior to endoscopy. Balloon dilatation has a high success rate [10]. The stoma should be dilated to a diameter of approximately 15–20 mm. Dilation beyond 20 mm may reduce the restrictive effect of RYGB. The gastrojejunal (GJ) anastomosis should not be dilated by >3–4 mm at a time. Aggressive dilatation in a single sitting may increase the risk of perforation. Most patients will need two to three endoscopic procedures to reach a 15-mm anastomosis [11]. If possible, the time interval between two dilatations should be 10 to 14 days. For long length strictures and refractory to initial treatment can be considered for stent placement for few weeks. The complication rate for dilation is approximately 3% [11]. Careful communication between the endoscopist and the surgeon regarding the details of the original operation is important to minimize the risk of endoscopic complications. The most common complication after dilatation is micro perforation. A contrasting study is recommended after difficult dilatation. Most patients after micro perforation do well with conservative treatment. Patients with a chronic stenosis that is refractory to multiple dilations require a surgical revision of the GJ anastomosis after a delay of a few months to allow the gastric pouch to dilate.

Most patients with refractory strictures who fails balloon dilatations have ischemia to the tissue as an etiologic factor. These patients will require block resection of the anastomosis excising all the adjacent ischemic tissues. The laparoscopic approach is the favored approach. After the standard five port placement and insertion of the Nathanson retractor, adhesions between the stomach, liver, Roux limb, and omentum are taken down by blunt and sharp dissection. Endoscope is introduced into the pouch and the pathology is identified. The healthy portion of the Roux limb is first transacted using an endo GIA stapler. This will usually give mobility to further mobilize the pouch from underlying adhesion. Once adequate mobilization of the pouch is performed then the vascularity of the tissues can be checked using a fluorescent camera after injecting a tracer dye called ICG. The extent of pouch resection depends on the size of the pouch and its vascularity. The scope is then withdrawn and the pouch is resected using the endo GIA stapler. The anastomosis is then performed using the linear stapler technique or the handsewn technique. The size of the anastomosis should be around 2 cm. The enterotomy is closed using absorbable sutures creating a tension-free anastomosis. The endoscope is used as a stent to prevent any narrowing of the anastomosis.

The gastrojejunostomy is then submerged under water to test the anastomosis for air leak. Fibrin glue can be placed over the anastomosis at this time to help in hemostasis.

On postoperative day 1 (POD 1), the patient undergoes an upper gastrointestinal gastrografin study to delineate the reconstructed anatomy and rule out leak or obstruction. The patient is started on a bariatric clear liquid diet if the study is normal and is discharged with a proton pump inhibitor for the immediate 6–8 weeks postoperatively.

### Prevention

Early postoperative strictures at GJ can be avoided by sticking to good surgical principles while creating the GJ anastomosis. The anastomosis should be tension free. This can usually be accomplished by adequate mobilization of the pouch and the Roux limb. It is imperative to make sure that the pouch and the Roux limb have adequate vascularity before commencing the anastomosis. If there is a doubt about vascularity, then that segment of Roux limb or pouch should be excised. The use of 21 mm circular stapler has been shown to have a higher incidence of stricture formation and should be avoided. The enterotomy should always be closed with absorbable sutures as permanent sutures are associated with a higher incidence of ulcer and stenosis. In the long term, the stomal stenosis can be prevented by avoiding risk factors like smoking, the use of NSAID, and *H. pylori* infection which can lead to marginal ulcer. Prompt treatment and management of marginal ulcer will also reduce the occurrence of stomal stenosis.

## Candy Cane Syndrome

### Introduction

Candy cane syndrome is a rare complication reported in bariatric patients following Roux-en-Y gastric bypass. It occurs when there is an excessive length of the afferent Roux limb proximal to gastrojejunostomy, creating the possibility for food particles to lodge and remain in the blind redundant limb (Fig. 8.5). Patients present with a classic triad of symptoms. Abdominal pain typically colicky or spasmodic in nature,

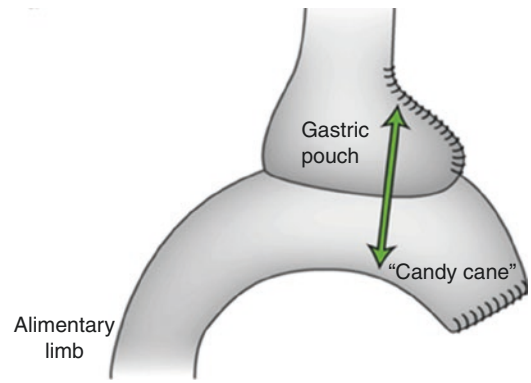


**Fig. 8.5** Candy cane

occurring after ingestion of meal. The pain typically lasts for a few hours followed by occasional vomiting, relieving the pain but the nausea persists.

Post Roux-en-Y gastric bypass patients who develop the symptoms of candy cane syndrome usually develop a variant in the anatomy over a period of time or it may be a technical error at the time of initial operation. These groups of patients have an excessively long blind afferent Roux limb at the gastrojejunostomy. There is preferential filling of this segment by food related to the orientation of anastomosis. This distension of the blind loop after meals causes postprandial pain. Ultimately the food either spills into the Roux limb or is vomited, thereby relieving the symptoms of pain.

We do not know the exact incidence of this deformity as most patients do not receive proper evaluation. Most patients develop the symptoms of the syndrome after several years from surgery; however, a few patients can have symptoms within a few months of surgery.

## Workup and Diagnosis

A high level of suspicion is required to diagnose a candy cane syndrome. With a good history and a physical examination along with a diagnostic workup, definitive diagnosis can be made and the deformity can be visualized. The symptoms that could be suspicious for candy cane syndrome are reported from as early as 3 months to up to 11 years [12, 13]. A patient with a history of colicky or spasmodic pain after ingesting a meal and relieved of pain after vomiting should raise the suspicion of candy cane syndrome. The symptoms are slow to start and over a period of time gets progressively worse with the onset of persistent nausea. Physical examination is usually negative for explaining the symptoms.

An upper gastrointestinal study and endoscopy (EGD) are the diagnostic studies used to diagnose this syndrome [14]. The ultrasound examination and CT scan are usually negative and not helpful in making the diagnosis.

The upper GI series with gastrografin or barium can easily identify the defect (Fig. 8.6). A large afferent blind limb will be seen on ingestion of contrast. The length of the blind loop can vary between 3 and 22 cm [15]. There is usually preferential filling of contrast in the blind loop as compared to the Roux limb. The upper endoscopy will confirm the diagnosis. The EGD will demonstrate large gastrojejunal anastomosis opening with a double barrel appearance (Fig. 8.7). The adjoining jejunum is usually distended to several centimeters. The larger side of the barrel when traversed usually ends up in the blind loop.

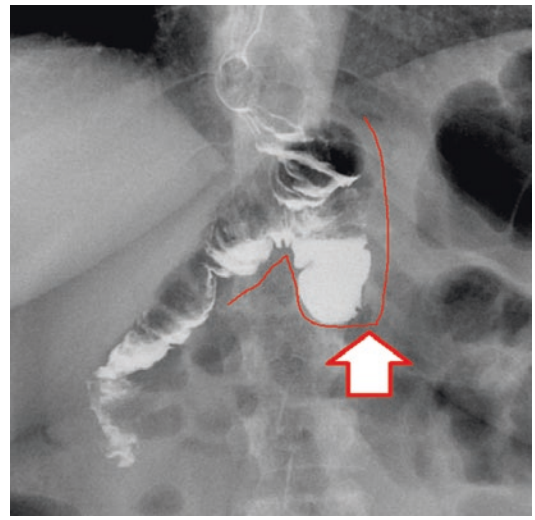

**Fig. 8.6** Upper GI showing candy cane

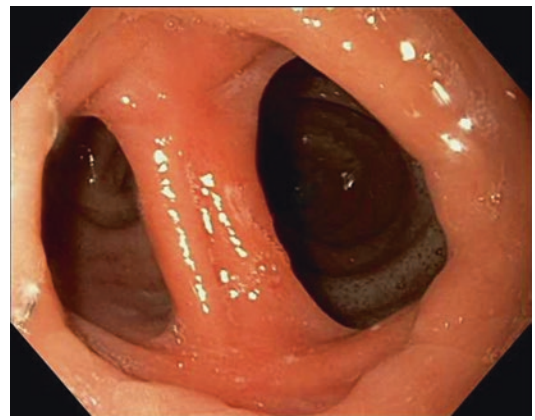

**Fig. 8.7** Endoscopic findings of candy cane

### Surgical Management

The deformity in candy cane syndrome is an anatomical defect and can only be corrected by surgical intervention. The minimal invasive laparoscopic approach is favored, if technically possible, due to its benefits of decreased postoperative pain, faster recovery, and less wound complications [16]. The technique involves placement of five trocars. The initial access can be made by a Verres needle or an OptiView port as there may be underlying adhesions from a prior surgery. Once pneumoperitoneum is accomplished, adhesions between the stomach, liver, Roux limb, and omentum are taken down by blunt and sharp dissection. The Nathanson retractor is used to retract the liver. Meticulous dissection is needed to separate the afferent and efferent Roux limb. The blood supply to the Roux limb should be maintained as most of the time just resecting the redundant blind loop will correct the anatomy and does not require to create a new anastomosis. If after mobilization of the Roux limb, there is a question about the viability of the anastomosis then the anastomosis has to be taken down and new anastomosis will have to be created. The use of a fluorescent camera after injecting the tracer dye called ICG can be very beneficial to confirm the vascularity of the tissue. Once the mobilization is completed and the anatomy is defined, the endoscope is advanced to the Roux limb. The scope in the Roux limb acts as a stent and guides the resection and also prevents stenosis. Endo GIA 60 mm staples are used to resect the redundant small bowel. Many times when there is excessive dilatation of the Roux limb and the anastomosis, the stapling can start on the Roux limb marching upward toward the anastomosis and gently tapering at the pouch. The endoscope in place will guide in the dissection.

Once the resection is completed, the endoscope is withdrawn to the pouch to visualize the anatomy and confirm that there is no active bleeding in the lumen. The gastrojejunostomy is then submerged under water to test the anastomosis for air leak. Fibrin glue can be placed over the anastomosis at this time to help in hemostasis.

On postoperative day 1 (POD 1), the patient undergoes an upper gastrointestinal gastrografin study to delineate the reconstructed anatomy and rule out leak or obstruction. The patient is started on a bariatric clear liquid diet if the study is normal and is discharged with a proton pump inhibitor for the immediate 6–8 weeks postoperatively.

### Prevention

It is our belief that the development of candy cane after gastric bypass is usually due to some faulty techniques while creating the gastrojejunostomy at the time of initial operation. If good surgical principles are applied while creating the anastomosis, the occurrence of candy cane can be prevented. The anastomosis should be performed at the most dependent portion of the gastric pouch. Depending on the orientation of the pouch, the gastrostomy should be made usually on the posterior wall of the stomach. Occasionally the anterior wall at the base may be the preferred site. The anastomosis should appear as a functional end-to-end connection. If after the anastomosis there appears as a redundant blind loop, then every effort should be made to excise this redundant small bowel by using an endo GIA stapler, endoscope, or bougie as a stent. The stomach pouch and jejunum should be aligned in such a way that there is no twisting of the anastomosis. The correct orientation of the anastomosis will prevent preferential passage of food into the potential blind loop.

## Internal Hernia

### Introduction

Internal hernia is the herniation of the small bowel due to the mesenteric defects created while doing a Roux-en-Y gastric bypass. Mesenteric defects that are created during a Roux-en-Y gastric bypass include (Fig. 8.8):

- A mesenteric defect at the jejunojejunostomy
- A space between the transverse mesocolon and Roux-limb mesentery (Petersen's defect)
- A defect in the transverse mesocolon in patients with a retro colic Roux-limb

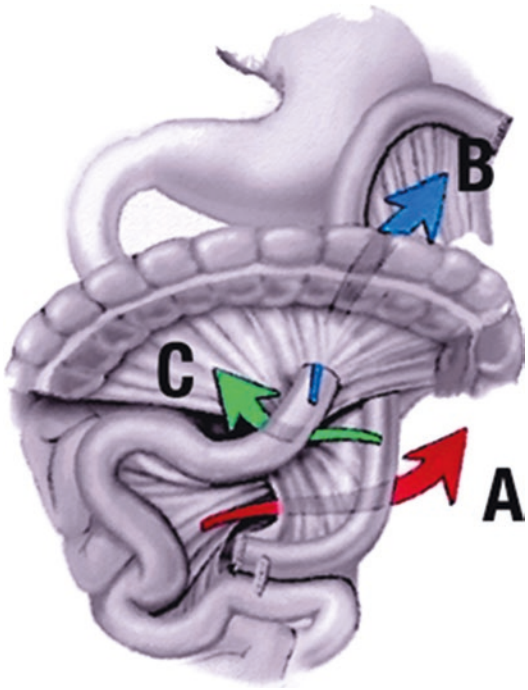


**Fig. 8.8** Mesenteric defects that are created during a Roux-en-Y gastric bypass

Internal hernias have been described in 0–5% of patients after laparoscopic gastric bypass [7, 17]. The majority of internal hernias after laparoscopic gastric bypass occurred through the transverse mesocolon defect (44 of 66 in one study) [18].

Internal hernia is seen more commonly in patients who have lost a significant weight after surgery. Excessive loss of the mesenteric fat can potentially create the defects in the mesentery. Most internal hernias are reported a few years after the surgery.

## Workup and Diagnosis

The patient usually has a history of episodes of severe colicky pain of sudden onset followed by abdominal distension and vomiting. These symptoms may resolve in a few hours to a few days.

Internal hernias can be difficult to detect radiographically because they are intermittent. CT scan of the abdomen with contrast is the diagnostic test of choice. Several studies have shown that the "mesenteric swirl" sign on

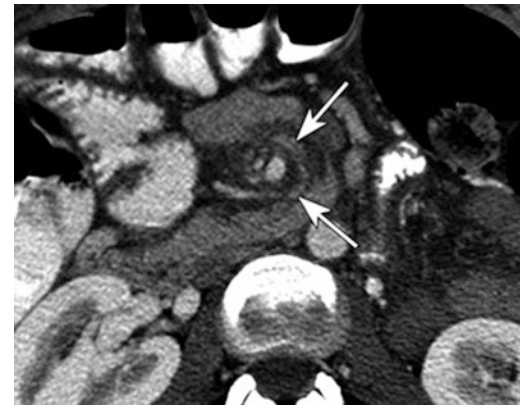

**Fig. 8.9** CT scan findings of internal hernia

CT scan is the best indicator of an internal hernia following gastric bypass [19]. The mesenteric swirl sign shows a swirled appearance of the mesenteric vessels or fat at the root of the mesentery (Fig. 8.9). The mesenteric swirl sign has high sensitivity (78–100%) and specificity (80–90%) and can be easily recognized by experienced radiologists. The presence of a small-bowel obstruction, engorged mesenteric nodes, and edema of the mesentery also supports the diagnosis of internal hernia.

## Surgical Management

Patients with a classic history of intermittent obstruction with CT scan findings should be planned for surgical exploration. Delay in surgical intervention can cause bowel ischemia and may increase the morbidity and mortality. Patients with acute obstruction should be considered for nasogastric decompression using the tube. The NGT can be placed under fluoroscopic guidance. The patient should be aggressively hydrated and electrolyte imbalance should be corrected. If the small bowel is grossly dilated and there is a concern for ischemia, then quick exploratory laparotomy using a midline incision may be preferred over the laparoscopic approach. The bowel viability should be quickly assessed and attempts should be made to quickly reduce the hernia. The anatomy can be confusing at times so a systematic approach should be adhered. The three common internal hernia

sites should be identified. A space between the transverse mesocolon and Roux-limb mesentery (Petersen's defect) can be easily identified by tracing the Roux limb proximally. If there is no herniation at this site then the inter mesenteric defect can be easily identified by lifting the jejuno jejunal anastomosis. If the patient had a retro colic Roux limb then look at the transverse mesocolon defect. Once you have identified the site of the hernia defect, the small bowel should be traced in a systematic way. We use the ileocecal junction to identify the terminal ileum. From here you can trace the bowel proximally to reduce the hernia. Sometimes you can trace the bowel from DJ and march distally. Once the bowel is completely reduced, check for the viability of the bowel. If there is a concern for ischemia of the bowel, then that segment needs to be resected. The defect is then closed with a non-absorbable suture. All the three potential sites should be closed to minimize the recurrence of hernia.

In a stable patient with a suggestive history of internal hernia but no obstruction, the approach can be laparoscopic using the same principle.

### Prevention

The use of an ante colic Roux limb can, in theory, reduce the risk of internal hernia formation by eliminating the transverse mesocolic defect. A 2016 meta-analysis found that the use of an antecolic Roux limb, as opposed to a retrocolic Roux limb, was associated with lower rates of postoperative internal hernia (1.3% versus 2.3%) and small bowel obstruction (1.4% versus 5.2%) [20]. To reduce the incidence of internal hernias, all mesenteric defects should be closed with nonabsorbable sutures [18]. In a multicenter trial, 2507 patients were randomly assigned to undergo laparoscopic Roux-en-Y gastric bypass with or without mesenteric defect closure [21]. Compared with no closure, mesenteric closure significantly decreased the incidence of reoperation due to small bowel obstruction.

## Marginal Ulceration

### Introduction

Marginal ulceration is a challenging problem, which can cause significant morbidity in the postoperative bariatric patient. Marginal or anastomotic ulcers represent as many as 52% of the postoperative complications after gastric bypass [22]. There is a wide range of incidence of marginal ulcers after gastric bypass surgery that ranges from 0.6% to 16% of patients [23]. Marginal ulcers occur near the gastrojejunostomy and precisely on the jejunal site. The ulcer is usually caused by the acid produced in the stomach and injury in the adjoining jejunum adjacent to the gastrojejunal anastomosis. Many times the damage to mucosa by smoking, infection, or certain medications is the cause for ulceration. The etiology of marginal ulcers remains elusive. There are perhaps multifactorial etiologies including both exogenous and intrinsic or technical factors. Smoking is perhaps the strongest risk factor for marginal ulcers followed by the consumption of NSAIDS and steroids. *H. pylori* infection is also linked with a higher incidence of marginal ulcers. These bacteria infect the superficial mucosa and disrupt the mucous layer, making the mucosa more susceptible to acid damage. Technical factors during the surgical procedure also play an important role. Poor tissue perfusion due to tension or ischemia at the anastomosis can certainly lead to ulceration. Chronic irritation produced by the presence of foreign materials, such as staples or nonabsorbable sutures, is definitely associated with ulceration. Higher acid production under conditions like the retained fundus in the pouch or the presence of gastro-gastric fistula can damage the mucosa of the jejunum leading to marginal ulcers.

### Diagnosis and Workup

Patients with marginal ulcers typically present with abdominal pain, nausea, and vomiting, as well as in more extreme cases, hematemesis, sto-

mal obstruction, or even perforation. Abdominal pain is the most common cause of intractability for surgical intervention [24]. Patients who present with vague abdominal symptoms require a focused and thorough investigation.

Endoscopy is the diagnostic study of choice [22]. The upper GI contrast study using gastrografin or barium is not very sensitive and can easily miss the lesion. For symptomatic patients after gastric bypass, EGD is accurate, safe, and effective for the management of postgastric bypass complications. Endoscopy will clearly demonstrate the presence of marginal ulcer on the jejunal side of the anastomosis. Typically, a large pale ischemic ulcer will be seen. After endoscopy (Fig. 8.10), biopsies should be performed for the gastric pouch to evaluate *H. pylori* infection. Effort should be made to look for gastro-gastric fistula and many times complementing with an upper gastrointestinal series may help in diagnosis. Occasionally recurrent ulcer can form a stricture at the anastomosis and may require dilatation using a balloon or bougie to negotiate the scope into the jejunum to evaluate the jejunum.

## Management of Marginal Ulcer

Medical treatment is the initial treatment to manage marginal ulcers. Treatment for a marginal ulcer is dependent on its etiology. The contributing risk factors should be eliminated in order to have a successful medical treatment. Immediate smoking cessation is imperative for smokers. Patients on NSAIDS and steroids should discontinue their medications. For a documented marginal ulcer either by symptoms or endoscopy, initial treatment involves starting a proton pump inhibitor and sucralfate suspension (1 g oral liquid every 6 hrs) for a period of 3–6 months. For comprehensive therapy, a breath or serology test should be performed for *H. pylori*, if biopsy and culture were not performed at the time of initial endoscopy. Endoscopy is also useful for removal of foreign bodies, such as sutures or staples, which prevent the ulcers from healing. Medical eradication of *H. pylori* infection includes two antibiotics and a proton pump inhibitor [16]. It is essential to optimize the nutritional status of the patient undergoing medical treatment to help in healing of these ulcers. Low iron levels or hemoglobin or malnutrition should be addressed appropriately. The patient is clinically monitored for the changing symptoms. Marginal ulcer if left untreated or persists despite appropriate medical treatment can lead to stricture formation and ultimately gastric outlet obstruction, which requires numerous endoscopic dilatations [25]. Thus, it is imperative to assess whether the ulcer responds to medical therapy and has evidence of healing on repeat endoscopy. The initial treatment is given for a period of 3 months followed by a repeat endoscopy. If the symptoms improve and the endoscopic findings are consistent with healing of ulcer, then medical treatment is continued for another 3 months followed by repeat endoscopy. If there is worsening of symptoms and the endoscopy shows no signs of healing, then we consider these patients for surgical intervention. In addition to medical intractability, surgical indications include patients with gastro-gastric fistula and a marginal ulcer, patients with chronic anemia secondary to slow blood loss from the gastrointestinal tract, and patients with massive bleeding from the marginal ulcer.

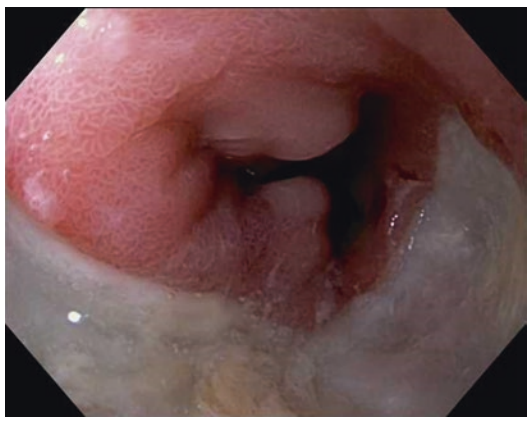

**Fig. 8.10** Endoscopic findings of marginal ulcer

## Surgical Treatment

Although marginal ulcers have traditionally been thought of as relatively rare complications following RYGB and those requiring revision even more uncommon, recent data reveal that the reoperation rate is greater than initially believed [22]. For medical intractability, the standard surgical treatment involves resection of the entire ulcer bed at the gastrojejunostomy and reconstructing the anatomy with a new gastrojejunostomy [16]. The presence of a marginal ulcer and a nonhealing gastro-gastric fistula typically mandate immediate surgical management. For a simple marginal ulcer, surgery is indicated when ulcer symptoms persist despite maximum proton pump inhibitor therapy and sucralfate for 3 months without healing, risk factors such as smoking and NSAIDS are eliminated, and the patient's nutritional status is optimized.

## Surgical Management Options

Revision of a gastric bypass for marginal ulcer management can be performed either through an open, laparoscopic or robotic approach. This largely depends on the surgeon's experience with bariatric surgery revisions and advanced laparoscopic skills, as well as the approach of the patient's initial operation. Revisional surgery for marginal ulcers typically involves resection of the gastrojejunostomy containing the ulcer and reconstruction. The laparoscopic or robotic approach is favored, if technically possible, due to its benefits of decreased postoperative pain, faster recovery, and less wound complications [16]. The technique involves placement of five trocars. The initial access can be made by a Verres needle or an Optiview port as there may be underlying adhesions from a prior surgery. Once pneumoperitoneum is accomplished, adhesions between stomach and liver are taken down and liver is retracted using the Nathanson retractor. Using blunt and sharp dissection the anatomy is revealed by meticulously dissecting the gastric pouch out from the gastric remnant, mobilizing the Roux limb and the gastric pouch. Our initial approach to the lesser sac is the pars flaccida approach. The pars flaccida technique involves entering and dividing the often transparent lesser omentum that drapes over the caudate lobe of the liver. The vessels in the lesser omentum are divided with care to preserve the left hepatic artery. This window to the lesser sac allows retro gastric tunneling to the gastroesophageal junction, exposing the angle of His [26, 27]. For revisions, if the window to the lesser curve of the stomach is obliterated from previous dissection, the lesser sac can be approached from the greater curve using a retrograde tunneling maneuver with care not to injure the lesser curve vessels. The articulating instruments are very beneficial in this dissection. If the gastric remnant has not been divided from the gastric pouch in the original operation, a linear endoscopic stapler is used to transect the stomach and a new pouch is created such that it is small in size and excludes the fundus. At this point the pouch should be evaluated for its size orientation and if it has a large retained fundus. The crural muscles should be well identified and assessment should be made of any existing hiatal hernia.

At this point, the flexible endoscope is introduced. The anatomy, including the gastric pouch, gastrojejunostomy, and the distal jejunum is confirmed. The pouch is transacted about 1–2 cm above GJ anastomosis. A green or black linear stapler is preferred as the tissues are relatively thick. The endoscope is withdrawn before placing the stapler to ensure that the stapler is positioned on healthy tissues and complete ulcer is included in the specimen. The mobilized Roux limb is inspected and transitioned using the linear stapler through a healthy portion with good blood supply. The use of a fluorescent camera after injecting the tracer dye called ICG can be very beneficial to confirm the vascularity of the tissue. Once the specimen is free after transecting the small bowel, the reconstruction can be performed using the stapler or the handsewn technique. If the circular stapler is used, a 25 mm anvil is introduced via the transoral route into the gastric pouch. The circular stapler is introduced trans-abdominally and placed through the opening in the Roux limb. The gastrojejunostomy is

constructed by approximating the anvil in the pouch to the circular stapler in the Roux limb. The enterotomy left in the jejunum is closed with a linear stapler. Alternately, the linear stapler can be used to create the anastomosis and then the enterotomy is closed using an absorbable suture like 2-0 Vicryl and reenforced with a nonabsorbable suture. The use of linear stapler or hand sewn anastomosis has been found to have a lower rate of stricture formation and is our preferred method [28].

Once the anastomosis is completed, the endoscope is advanced into the jejunum to visualize the patency of connection. Occasionally a flap can be created in the wall of the stomach creating a false lumen during dissection. This can easily be prevented by visualization using the endoscope. Also, endoscopic visualization will confirm that there is no active bleeding in the lumen. The gastrojejunostomy is then submerged under water to test the anastomosis for air leak. Fibrin glue can be placed over the anastomosis at this time to help in hemostasis.

If on initial exploration a significant hiatal hernia is noted then the hiatal anatomy needs to be corrected at this time. This usually entails adequate mobilization of the esophagus and closure of the crural defect using the nonabsorbable suture. If a large retained fundus is noted in the gastric pouch, then every attempt should be made to excise the fundus using a linear stapler. This will reduce the acid production and healing of the ulcer. Some surgeons advocate performing a truncal vagotomy to address the potential high parietal cell distribution in the gastric pouch [29]. Most bariatric surgeons, however, do not advocate truncal vagotomy.

For perforated marginal ulcer, diagnostic laparoscopy with repair has been found to be safe and successful [30], particularly in the first 24 hours of diagnosis and for patients without evidence of sepsis or hemodynamic instability. The first step is to perform a thorough investigation by mobilizing the remnant stomach, duodenum, and Roux limb to identify the source of perforation. Once identified, repair is performed by over sewing the perforation with a jejunal and omental patch [19]. Others advocate primary closure with absorbable sutures, reinforcement with a gastrosplenic ligament patch and a fibrin sealant, and closed-suction drain placement [31]. If laparoscopic repair cannot be performed safely, an operative plan should be carried out in an open fashion. If primary closure is not possible, irrigation and drainage is the next appropriate approach [30]. If ischemia is suspected as the cause of the perforated marginal ulcer, then complete reconstruction of the gastrojejunostomy is indicated [13]. In addition, if excess parietal cell mass is presumed to be the source of the ulcer, a truncal vagotomy with or without gastric pouch revision is recommended [30].

On Postoperative Day 1 (POD 1), the patient undergoes an upper gastrointestinal gastrografin study to delineate the reconstructed anatomy and rule out leak or obstruction. The patient is started on a bariatric clear liquid diet if the study is normal and is discharged on POD 2 with a proton pump inhibitor for the immediate 6–8 weeks postoperatively.

## Prevention

Prevention is the best treatment for marginal ulcers after gastric bypass. Recommendations include smoking cessation and elimination of NSAIDS and steroids. Alternatively, for patients who are dependent on agents such as NSAIDS or steroids, a laparoscopic sleeve gastrectomy could be offered instead of the RYGB which has a lower incidence of marginal ulcers. Further, prophylactic measures can be taken to prevent the occurrence of marginal ulcers. Routinely treating all RYGB patients with proton pump inhibitors for 3 months postoperatively decreases the incidence of marginal ulcers after surgery [32].

We also recommend routine upper endoscopy as a precautionary measure. Preoperative esophagogastroduodenoscopy (EGD) with biopsies for *H. pylori* should be performed. The patients showing positive for infection should be treated prior to bariatric surgery.

A number of technical aspects can also be considered from a prevention standpoint. To

minimize anastomotic ischemia, performing the gastrojejunostomy with a proper surgical technique is critical; the elements include approximating the tissue without tension, performing a meticulous dissection, and ensuring that the blood supply to the stomach and jejunum remains unaltered. With respect to the gastric pouch, its construction should exclude the fundus such that the remaining parietal cell mass and the potential for acid production is minimized. Nonabsorbable sutures should be avoided in the inner layer of the gastrojejunal anastomosis as they are often associated with a higher incidence of marginal ulcers [33].

## Gastro-gastric Fistula

### Introduction

A gastro-gastric fistula (GGF) is a rare complication following RYGB where the gastric pouch has abnormal communication with the gastric remnant. GGF was a very common complication before the divided RYGB, however with modern RYGB techniques GGF occurs in 1–6% of patients [34]. The true GGF rate is likely higher, however, as many GGFs are asymptomatic and thus go undiagnosed. The exact cause of GGF is unclear although it is believed that most of them occur due to poor surgical techniques where the gastric pouch and gastric remnant are not fully separated. When a surgical error is not the cause of the GGF, major causative factors include staple line leak, ulceration, stapler malfunction, and natural gastric migration [35, 36].

### Diagnosis and Workup

Patients can present with GGF anywhere from <2 months following surgery to over 7 years following RYGB. Patients typically present with epigastric pain, nausea, and weight regain. These may also be accompanied by gastrointestinal bleeding, vomiting, diabetes recurrence, GERD, diarrhea, and bloating. GGF can also be associated with marginal ulcers and occur simultaneously [34, 35, 37].

The diagnostic tests of choice are the UGI (Fig. 8.11) and EGD (Fig. 8.12). Oral enhanced CT is also an option although more expensive for the patients. As GGF can be symptomatic when the fistula is smaller than 1 cm, they can be easily overlooked upon EGD inspection. In most cases the GGF will be located on the left side of the pouch along the gastro-gastric staple line and the entire staple line should be carefully inspected as it is the most common area for fistulas to occur. An UGI is indicative of GGF, even in an asymptomatic patient, when contrast fluid can be seen filling the remnant stomach. The UGI can be useful to perform before the EGD to confirm the presence of the GGF and possibly determine a location that can be confirmed with the EGD [35].

UGI barium swallow shows contrast filling both gastric pouch and gastric remnant indicative of a GGF.

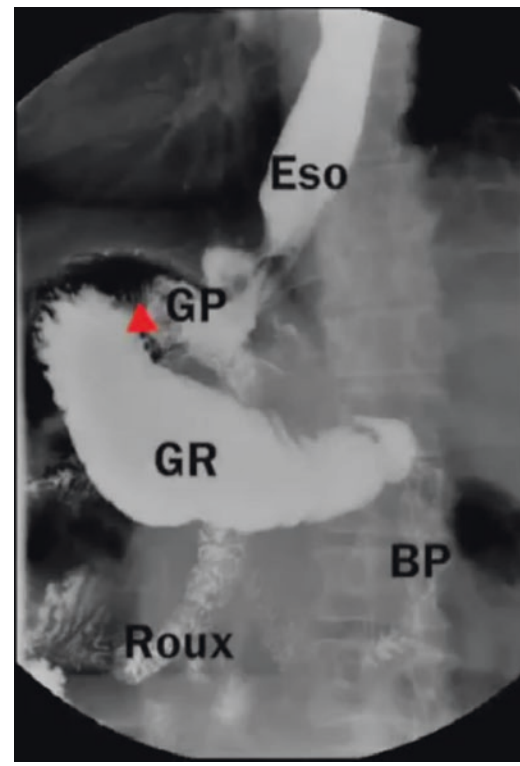


**Fig. 8.11** Upper GI showing gastro-gastric fistula

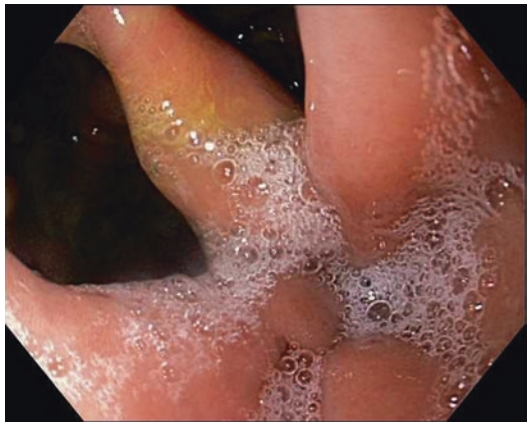

**Fig. 8.12** Endoscopic findings of gastro-gastric fistula

### Medical Management of Gastro-gastric Fistula

Medical management of GGF is similar to the treatment of marginal ulcers. The aim is to reduce gastric acid secretion to allow the GGF to close spontaneously. This treatment is best when GGF occurs with marginal ulcers.

### Operative Management

There are two types of GGFs that occur following the RYGB. When the fistula is close to the gastrojejunal anastomosis, en bloc resection of the gastrojejunal anastomosis is necessary. Then a new side-to-side gastrojejunal anastomosis should be created and closed using absorbable sutures [37].

When the GGF is more than 1–2 cm from the gastrojejunal anastomosis, a simple resection of the gastric pouch tract can be performed using a linear stapler and a 36-French calibration tube. Resection of the other end of the fistula along the gastric remnant is also advisable to avoid gastric antrum syndrome. Further omentoplasty can also be performed to maintain separation of the pouch and the remnant [37].

For sufficiently small fistulas, usually less than 1 cm I diameter with the best results <10 mm, EGD repairs are possible using a variety of different methods. These include endoclips, fibrin sealants, covered esophageal stents, and EGD suturing systems. These techniques are safe but may have a higher rate of recurrence than the previously described surgical techniques which remain the standard of care [35].

### Prevention

As many GGFs are caused by incomplete gastric division, great care should be taken to divide the proximal stomach completely. Other preventative measures include the complete removal of all foreign objects if the procedure is revisional, smoking cessation, and techniques similar to ulcer prevention as marginal ulcers are associated with GGFs.

## Intussusception

### Introduction

Small bowel intussusception is a very rare complication associated with the gastric bypass. Intussusception is the process where one part of the small bowel slides into an adjacent part of the bowel. Although intussusception typically occurs in children and is most often antegrade following gastric bypass, its presentation is much different and most often occurs retrograde. Following gastric bypass most retrograde intussusception occurs near the jejunojejunostomy with the common channel sliding into the jejunojejunostomy being the most common type following RYGB. Intussusception is thought to be a motility disorder following the RYGB. It lacks the common "lead point" that is present in most cases of adult intussusception. Due to the new anatomy of the Roux limb, normal small bowel motility is obstructed and may be the cause of intussusception [38].

### Diagnosis and Workup

Intussusception occurs in about 1% of RYGB patients and typically occurs years after surgery with reports of Intussusception more than 20 years after RYGB but can occur in as little as 5 months after surgery. Patients often present with

abdominal pain and nausea/vomiting. However, they can also present with a tender mass, elevated blood count, and peritoneal irritation. Fever is almost never present even with the elevated white blood count [38, 39].

CT scans are the radiographic tests of choice. Most often a "target sign" is found that is indicative of intussusception (Fig. 8.13). Although this is not always present, signs include dilated small bowel, wall thickening, vascular compromise if there is an obstruction, and ischemia. While CT is the best test, some intussusceptions may not be found on CT scan especially if they are small and intermittent. Exploratory laparotomy is the most reliable test if symptoms are severe [38].

CT scan showing a typical target sign, together with dilated and thickened jejunal loops, suggest edema and ischemia [38].

## Operative Management

There is no consensus on the best operative technique for repairing small bowel intussusception. As it is likely caused by the RYGB anatomy, there is always a risk of recurrence. The most conservative route is a simple reduction of the Intussusception with plication sutures to hold the small bowel in place. As there is a paucity of published cases there is a conflict as to the recurrence rate following this reduction. Some have reported little to no recurrences following reduction while other groups have reported 100% recurrence rate following this approach [39, 40].

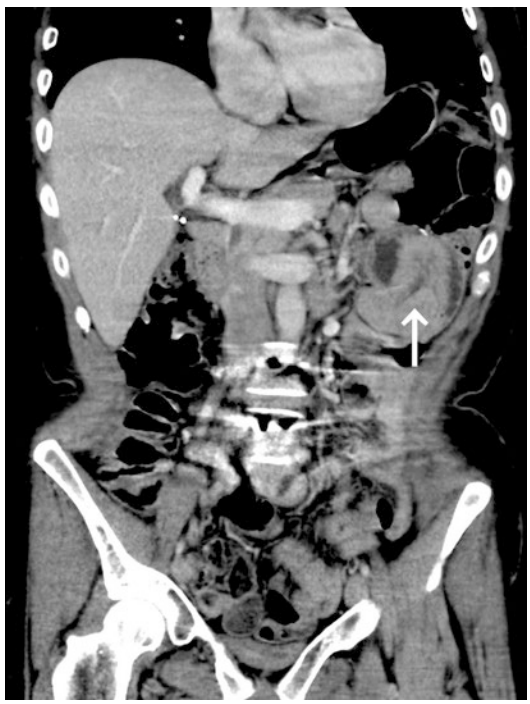

**Fig. 8.13** CT scan findings of intussusception

The other surgical option is reduction of the bowel where the intussusception occurs. This has a higher complication rate and is a more difficult procedure but has a low recurrence rate in all studies. If the intussusception includes the jejunojejunostomy, this should be reconstructed after the reduction [38].

Another surgical option is reversal of the gastric bypass. If the cause is a motility disorder as believed this reversal to normal anatomy with a reduction of the intussusception should fix the problem. This can be done concurrently with a sleeve gastrectomy to help reduce weight regain [41].

The decision on the best approach to use should be made on a case-by-case basis using a surgeon's experience. However, as Intussusception can lead to ischemia and necrosis, if the bowel is necrotic, reduction is the only viable option.

## Prevention

As there are relatively few patients who present with intussusception and the etiology of the complication is not well understood, there is no proven technique to prevent or reduce intussusception rates.

# Leak

## Introduction

A gastrointestinal leak is a known complication after the RYGB and is a significant cause of the

overall morbidity and mortality if not treated correctly. Leaks can happen at any of the staple lines following RYGB although they are most commonly found at the gastrojejunal anastomosis, gastric pouch staple line, jejunojejunostomy, and gastric remnant staple line. Leaks typically occur soon after surgery and can be very serious complications and should be treated as quickly as possible [42].

### Diagnosis and Workup

Typical signs of a leak are tachycardia, fever, abdominal pain (typically radiating to the left shoulder or the scapular region), and respiratory distress. Lab work is rarely useful in diagnosing a leak and could be normal. UGI and CT with oral contrast are typical tests for a leak. UGI is cheaper and is highly specific; however, its sensitivity is low (<50%) and for this reason some surgeons prefer a CT scan which is still highly specific but also very sensitive. The CT scan can also find other problems which could cause the same symptoms such as pulmonary embolism, pneumonia, and effusion [42, 43].

If the patient is unstable they should immediately be taken back to the operating room and an exploratory laparotomy should be performed looking for leaks or any other cause of the symptoms. When the patient is unstable, radiologic tests can worsen the condition and the extra time can increase the morbidity and mortality of the leak.

### Medical Management

Surgery is the preferred method for repairing a leak, and nonsurgical methods should only be considered if the patient is stable and for carefully selected patients. Treatment options include bowel rest, antimicrobial agents, and total parental nutrition. Patients should be monitored closely with drains left in to assess drain outputs and repeated radiological tests to assess if the leak is healing. A low reoperation threshold should be maintained for patient safety [42].

### Operative Management

Reintervention is typically done laparoscopically. All staple lines should be inspected for damage and the leak identified and oversewn to close. The area should then be tested either using a methylene blue or air leak test to confirm that the leak is closed and no other leak exists at the present time.

### Prevention

Although there are no proven safeguards against leaks, many surgeons employ one or more different safeguards in their surgical techniques. The most common of these is testing different anastomosis using either an air leak or methylene blue test at the time of surgery. While this has not been shown to reduce leak rates, any leak discovered should be fixed before closing. Another common technique is reinforcing the different staple lines by over sewing or overlaying biologic or synthetic materials. Although this technique is widely performed, it has no definitive evidence of a lower leak rate [42].

## Malnutrition

### Introduction

As the RYGB is a malabsorptive procedure which shortens the small intestine, there is always a higher risk of developing malnutrition. Deficiencies of micronutrients following bariatric surgery can arise from several mechanisms that include preoperative deficiency, reduced dietary intake, malabsorption, and inadequate supplementation. After gastric bypass, there is a high chance of micronutrient deficiencies of vitamin D, calcium, copper, and iron as these are all mainly absorbed in the proximal bowel. Since obesity is a risk factor for malnutrition and micronutrient deficiencies, all patients should be screened, and deficiencies corrected prior to surgery. RYGB leads to a very reduced food intake especially in the first few postoperative months.

This decreased intake with decreased absorption is primarily responsible for new nutritional deficiencies following surgery. Nutrient deficiencies can take time to present after surgery and can occur years following surgery. The most common nutrients that become low following bariatric surgery are protein levels, vitamin D, iron levels, and vitamin B12 levels [44].

## Diagnosis and Workup

Protein malnutrition is the most severe form of malnutrition following RYGB and can occur in up to 13% of patients. The symptoms include edema, hearing loss, and low blood serum albumin. This should be watched for especially in the early postoperative phase as patients are adjusting to their new diet and may begin to eat less protein. Typically, patients should consume at least 1.1 g/kg of protein based on an ideal body weight.

Iron deficiency typically presents anemic with fatigue, weakness, headache, hair loss, poor nail condition, PICA, and SOB. Iron deficiencies can be serious, and they may not be resolvable with dietary changes alone. Vitamin B12 deficiency usually presents with paresthesia and macrocytic anemia. Vitamin B1 deficiency typically presents with burning feet, neuropathy, visual loss, ataxia, and chronic vomiting. Vitamin D presents with decreased bone density and secondary hyperparathyroidism [45].

All nutrients have some chance of being deficient following bariatric procedures and blood tests should be done if any vitamin or nutrient is suspected to be low [44, 46]. These blood tests are the diagnostic gold standards for diagnosing any vitamin or protein deficiency.

**Presurgical Screening** The American Society for Metabolic and Bariatric Surgery (ASMBS) intergraded health nutritional guides for the surgical weight loss patient recommend routine baseline presurgical screening for levels of thiamin, vitamin B12, folate, iron, vitamin D and calcium, fat-soluble vitamins (A, E, K), zinc, and copper [47]. These screening laboratory tests can be performed as an integral part of the preoperative clinical nutrition evaluation by a registered dietitian.

**Postsurgical Screening** ASMBS guidelines further recommend nutrient assessments every 3–6 month in the first year after bariatric surgery, and annually thereafter with laboratory tests [47]. During each follow-up visit, clinicians should perform a review of systems to help identify symptoms of micronutrient malnutrition. Some of these symptoms may be subtle, such as loss of night vision, memory issues, or impaired learning (Table 8.1). The routine panel of laboratory tests is determined by individual programs.

## Medical Management

The best solution for malnutrition following RYGB is changing the patient's diet and adding multivitamin supplements. Patients should talk with a dietary specialist about their current eating habits and determine how to properly eat enough protein and vitamins with their daily intake and supplement their vitamin intake when necessary. All patients should be advised to supplement their dietary intake with oral supplements from the time of surgery to decrease the likelihood of vitamin deficiency. Following are the guidelines for supplementation after gastric bypass [49, 50]. The patients should be clinically monitored for symptoms of deficiency and should have yearly blood work for assessment (Table 8.2).

## Operative Management

After medical intervention if no change occurs and the deficiency appropriately endangers the patient's health there are surgical options. These

**Table 8.1** Micronutrient deficiency and symptoms after gastric bypass

| Micronutrient | Postoperative prevalence | Symptoms of deficiency |
|---|---|---|
| Vitamin A [47, 48] | 8–11% after RYGB | Night blindness, Bitot's spots hyperkeratinization of skin, loss of taste<br>Advanced signs: corneal damage and blindness |
| Vitamin D | 25–80% | Hypocalcemia, tetany, tingling, cramping, metabolic bone disease, muscle pain, rickets, osteomalacia, and rachitic rosary |
| Vitamin B1 (thiamine) | 1–49% | Beriberi – congestive heart failure (wet beriberi), aphonia, peripheral neuropathy,<br>Wernicke encephalopathy (nystagmus, ophthalmoplegia, and ataxia), confusion, or coma |
| Vitamin B12 | 33% after RYGB; | Macrocytic (megaloblastic) anemia, mild pancytopenia, and neuropsychiatric findings (e.g., depression and neuropathy) |
| Folate | Up to 65% after RYGB | Macrocytic (megaloblastic) anemia, mild pancytopenia, and neural tube defects |
| Iron | 20–55%, after RYGB | Anemia, pica, and impaired learning |
| Zinc | 40% after RYGB | Growth retardation, delayed sexual maturity, impotence, and impaired immune function |
| Copper | 10–20% after RYGB | Anemia, neutropenia, and ataxia |
| Selenium | 14–22% after RYGB | Skeletal muscle dysfunction and cardiomyopathy, mood disorder, impaired immune function, and macrocytosis |
| Calcium | 1.9% after RYGB | Bone disease and secondary hyperparathyroidism |

**Table 8.2** Micronutrient management after gastric bypass

| Micronutrients | Supplementation | Repletion |
|---|---|---|
| Vitamin A | 10,000 IU daily | 50,000 IU for 2 weeks |
| Vitamin D | 3000 IU D3 daily from all sources | 3000–6000 IU of D3 daily (preferred) or 50,000 IU of D2 1–3 times per week |
| Vitamin B1 (thiamine) | 50–100 mg daily from a B-complex | Oral: 100 mg three times daily until symptoms resolve<br>Intravenous: 200 mg three times daily to 500 mg once or twice daily for 3–5 days, followed by 250 mg daily for 3–5 days, and subsequent oral maintenance |
| Vitamin B12 | Oral dose of 350–500 mcg daily | 1000–2000 mcg daily until the level is normalized |
| Folate | 800 mcg daily | 1000 mcg daily until the level is normalized, and then resume the maintenance dose |
| Iron | 60 mg of elemental iron daily | Oral: 150–300 mg 2–3 times a day<br>Parenteral iron for those who do not respond to oral supplementation |
| Zinc | RYGB: 8–22 mg (100–200% RDA) | Optimal repletion dose unknown<br>Overdose can be associated with toxicity or copper deficiency |
| Copper | 2 mg daily (200% RDA) | Mild-to-moderate deficiency: 3–8 mg copper orally until levels normalize<br>Severe deficiency: 2–4 mg intravenous copper for 6 days |
| Selenium | Unknown but likely higher than 100 mcg/day [4] | 2 mcg/kg/day in patients who develop cardiomyopathy [5] |
| Calcium | 1200 mg daily in divided doses | 1500 mg daily in divided doses |

include RYGB reversal to the normal anatomy to increase absorption to the presurgical levels or lengthening of the common channel. Both are associated with less weight loss or weight regain. The RYGB reversal can be paired with a sleeve gastrectomy to avoid weight regain.

### Prevention

The best way to prevent malnutrition is through patient education. Patients should know about the risk and rates of malnutrition and be taught how much protein they should eat each day to absorb enough proteins in their diet. They should also be advised to use multivitamins to supplement their vitamin intake following the surgery.

## Closed-Loop Bowel Obstruction

### Introduction

A closed-loop small bowel obstruction (CLBO) occurs when a segment of the small bowel is obstructed on both ends. Closed-loop obstruction is also known as gastric remnant distension and refers to a segment of the bowel without proximal or distal outlets for decompression. Closed-loop obstruction is also known as gastric remnant distension after gastric bypass but can also occur after internal hernia. It is a rare but lethal complication following gastric bypass. The remnant stomach is a blind pouch and can cause closed-loop obstruction if there occurs a mechanical blockage in the biliopancreatic limb. Paralytic ileus or impaired emptying of bypass can also lead to massive distension. Progressive massive distension can ultimately lead to rupture of stomach with spillage of gastric content leading to peritonitis [51]. The remnant stomach in closed-loop obstruction can accumulate many liters of injurious contents like gastric acid, pancreatic enzyme, bile, and bacteria, and leakage of these contents can cause severe sepsis with high mortality. Following gastric bypass CLBO is most likely to occur as an obstruction in the biliopancreatic limb as the remnant stomach constitutes the other side of the obstruction, if a CLBO is not properly diagnosed soon after the symptoms begin. CLBO is a very rare complication and is reported rarely in the literature [52].

### Workup and Diagnosis

The diagnosis can be suspected based on the history and physical examination. This complication can occur in the early postoperative period and can also occur many years after the surgery. The patient will present with progressive distention of the abdomen with severe spasmodic abdominal pain, severe nausea, retching, shoulder pain, or hiccup with insignificant vomiting. Often the patient will complain of a progressive shortness of breath. On examination you will typically find upper abdominal distension with left upper quadrant tympany. Most patients will have tachycardia, tachypnoea, and dehydration. Plain x ray of the abdomen will show a large gastric air bubble. CT scan of the abdomen will reveal the anatomy and confirm the diagnosis (Fig. 8.14). CLBO typically appears with a U-shaped distended bowel loop and might show a distended gastric remnant. There is some evidence that elevated plasma pancreatic enzymes may be indicative of a closed-

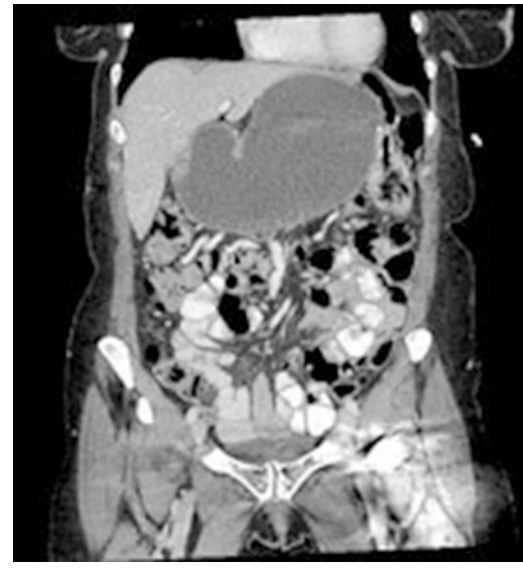

**Fig. 8.14** CT closed loop obstruction

loop obstruction following gastric bypass and a high level of suspicion should be maintained in order to correctly diagnose CLBO [53, 54].

## Operative Management

Urgent surgical intervention is required once the diagnosis is established. If there is no evidence of perforation or sepsis, then surgical treatment consists of emergent operative decompression with a gastrostomy tube, or percutaneous gastrostomy can be performed under radiologic guidance [55]. Immediate operative exploration and decompression are required if percutaneous drainage is not feasible, or if perforation is suspected. Commonly, CLBO is the symptom of something else that happens and not the problem on its own. CLBO can be caused by adhesions and internal hernias. The root cause of the obstruction should be fixed in the manner presented elsewhere in this chapter and all necrotic bowel should be removed [54].

## Prevention

Although gastrostomy is not performed routinely by most surgeons in the initial gastric bypass operation, drainage of the gastric remnant can prevent this rare but sometimes fatal complication. Routine gastrostomy should be considered in the elderly, super-obese patients, patients with diabetic gastropathy, and as part of revisional surgeries where gastric emptying may be delayed.

Video 8.1 shows endoscopic findings of gastro-gastric fistula showing communication of the pouch to the remnant stomach. Video 8.2 shows the upper GI contrast study showing filling of the remnant stomach through a fistula.

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# Part III

# Revisional Anti-reflux and Gastric Procedures

# 9 Reoperative Anti-Reflux Surgery and Revisional Paraesophageal Hernias

Frank J. Borao, Brian J. Shea, Shabiah C. Martin, Jonathan M. Decker, and Anthony J. Squillaro

## Introduction

Gastroesophageal reflux disease (GERD) is a very common problem among adults in the United States, with approximately 20–40% of adults affected by symptoms of reflux disease in their lifetime [1]. According to a report by the National Institute of Diabetes and Digestive and Kidney Diseases, GERD was the most frequently first listed digestive system diagnosis, accounting for 17.5% of all digestive system diagnoses [2]. With the increasing utilization of proton pump inhibitor therapy, surgery for gastroesophageal reflux decreased in the early 2000s. However, recent studies have demonstrated side effects of prolonged use of proton pump inhibitors (PPIs), including a strong association with gastric polyps and weak associations with dementia, community-acquired pneumonia, nutritional deficiencies, bone fractures, interference with other drug metabolism, and clostridium difficile infection [3–7]. Daily use of PPIs also comes at a significant cost to the patient and fails to address regurgitation encountered with an incompetent lower esophageal sphincter. When examining medical therapy versus surgery, previous comparisons of the two approaches have demonstrated superiority of surgical therapy when compared to medical therapy for GERD [8–10]. These issues with PPIs coupled with increasing utilization of the laparoscopic approach to anti-reflux surgery [11, 12] have led to a resurgence in the surgical management of gastroesophageal reflux disease.

Long-term follow-up of patients that have undergone fundoplication demonstrate reoperation rates of approximately 5.2% at 5 years and 6.9% at 10 years for failure, according to a population-based study of the California Office of Statewide Health Planning and Development database [13]. This rate appears to be slightly higher if a paraesophageal hernia was repaired at the index operation. Fundoplication failure is suspected in patients that develop new or recurrent symptoms after surgery. These symptoms most often include heartburn, regurgitation, and/or dysphagia. In this patient population, there are a significant proportion of patients that have an identifiable mechanical failure and ultimately require reoperation [14–16]. This chapter will review the initial evaluation of a patient with a suspected fundoplication failure and recurrent paraesophageal hernia, as well as identifiable patterns of failure, reoperative techniques and commonly encountered intraoperative issues, and postoperative care.

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## Initial Evaluation

Patients who have undergone fundoplication procedures may have a degree of dysphagia or abdominal discomfort postoperatively and are kept on a modified diet for the first few weeks after an operation. This results from the edema surrounding the wrap causing narrowing of the distal esophagus. Dietary modification allows this area to heal without subsequent stricture or cicatrix formation caused by the trauma of passing solid or bulky foods. This period of initial discomfort should resolve after approximately 4–8 weeks. Non-resolution of symptoms after this period or the development of new symptoms should raise suspicion of failure.

When failure is suspected in a patient that previously underwent fundoplication, a thorough history and physical examination should be obtained. History should focus on duration and timing of symptoms, as well as any exacerbating or alleviating factors. If the operation was performed elsewhere, efforts should be made to obtain the operative reports from the patient's previous operation and the report examined for description of essential elements of the procedure, including complete dissection of the hernia sac if a paraesophageal hernia present, restoration of normal anatomy, length of intra-abdominal esophagus obtained, crural reapproximation, the presence or absence of mesh reinforcement, division of short gastric vessels, and type and length of fundoplication.

After this information is obtained, workup can be initiated and should include some or all of the studies discussed below.

## Upper Gastrointestinal Series

An upper GI series is likely the most useful investigation in the workup of a patient with recurrent reflux or dysphagia following an antireflux operation. It is especially useful in the event of a previously corrected paraesophageal hernia. This study can identify the position of the wrap and the position of the GE junction relative to the diaphragm, as well as suggest the possibility of a short esophagus. Comparison to a previous upper GI study can be helpful in determining the mechanism of failure. Abnormal findings can include a herniated wrap, a slipped fundoplication, or a recurrent paraesophageal hernia. Upper GI series appears to most reliably predict a hiatal or paraesophageal hernia, though the sensitivity of detection of a hernia increases when combined with some or all of the studies below [17] (Figs. 9.1, 9.2, 9.3, 9.4, and 9.5).

## Esophagogastroduodenoscopy (EGD)

An EGD is useful in the evaluation of a patient with reflux to determine the degree of esophagitis and the presence or absence of Barrett's metapla-

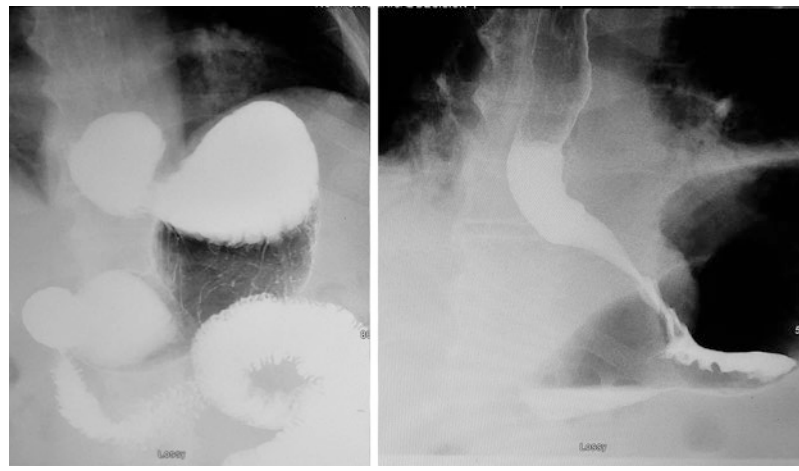

**Fig. 9.1** Upper GI demonstrating a hiatal hernia that was subsequently repaired with Nissen fundoplication

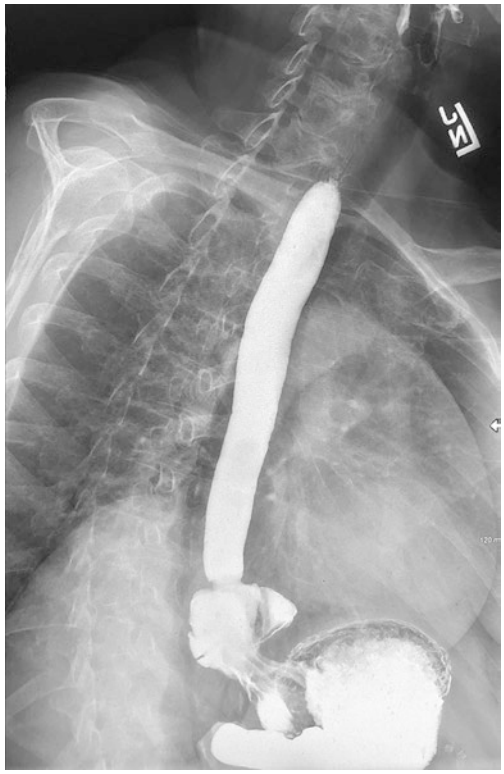

**Fig. 9.2** Upper GI of transhiatal herniation of Nissen fundoplication

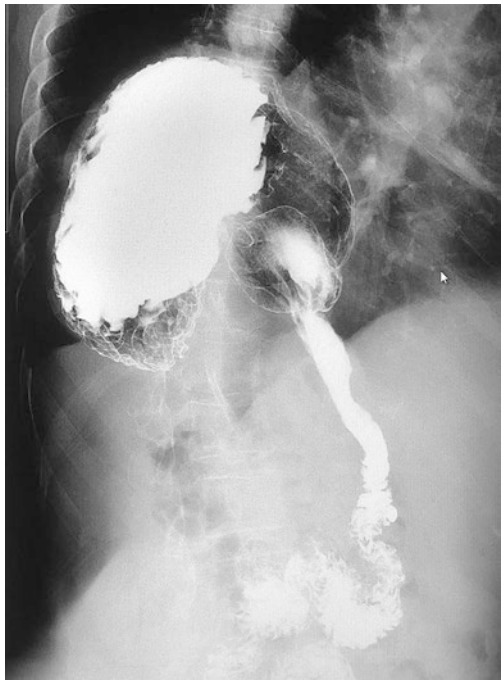

**Fig. 9.3** Upper GI demonstrating a large paraesophageal hernia with organoaxial volvulus

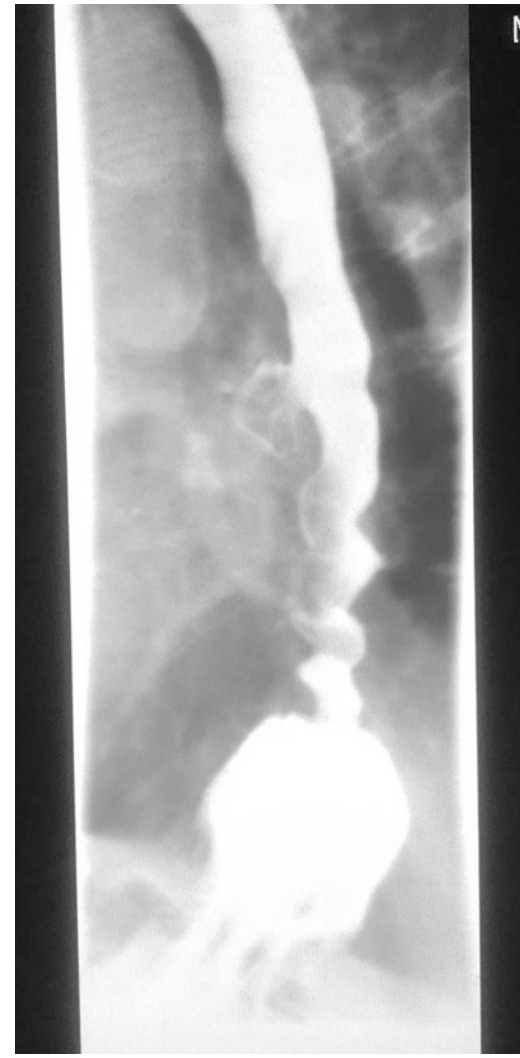


**Fig. 9.4** Upper GI demonstrating herniated wrap causing chronic back pressure into the esophagus resulting in tertiary esophageal contractions and a mid-esophageal diverticulum

sia of the esophagus. An EGD also may identify other diagnoses not possible with other studies, such as malignancy. An EGD can also assess the tightness of the wrap, the integrity of the wrap, and suggest the presence of a paraesophageal hernia. The EGD alone, however, should not be utilized for the purposes of identifying a paraesophageal hernia, as the presence or absence of a paraesophageal hernia or the size of the hernia is not accurately predicted in the authors' experience (Fig. 9.6).

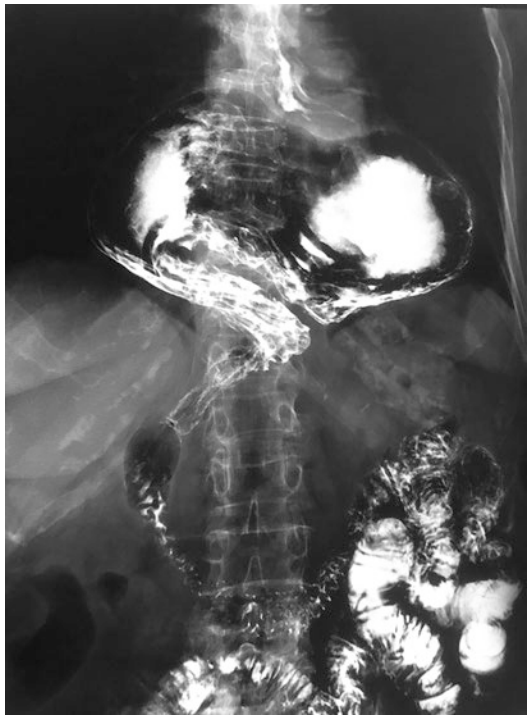

**Fig. 9.5** Upper GI of large paraesophageal hernia demonstrating cardiac compression on CT scan

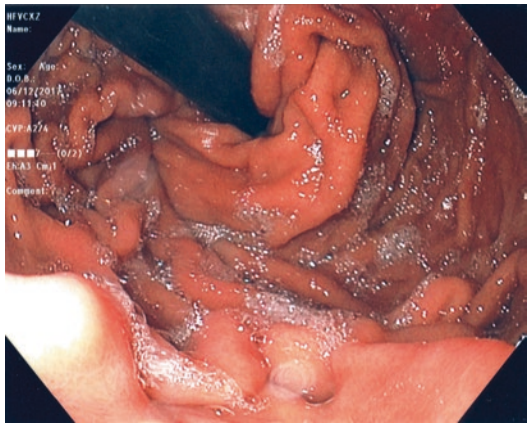

**Fig. 9.6** View on endoscopy of completed and intact Nissen fundoplication

## Esophageal Manometry

Many experts in the field advocate for the use of routine preoperative manometry in patients undergoing reoperative anti-reflux surgery. Manometry allows for understanding of motility of the esophagus and may identify patients with achalasia that were misdiagnosed prior to their first operation. Manometry may demonstrate patients with an outlet obstruction that may benefit from an endoscopic dilation procedure [18]. Some surgeons advocate for tailoring of the fundoplication to fit manometry findings, as some patients may have manometry findings considered contraindications to a Nissen fundoplication [19–21]. However, this practice has been refuted in previous studies examining the impact on tailoring a fundoplication to manometry findings [22]. Furthermore, a subsequent study demonstrated that performing a Nissen fundoplication may normalize motility in patients with preoperative hypomotility [23].

Paraesophageal hernias can also make manometry a difficult test to perform and their results difficult to interpret. A study by Roman et al. highlighted the difficulties with manometry in patients with large paraesophageal hernias. In this study, intubation of the stomach below the diaphragm was not possible in 49% of patients due to the large hernia, making measurement of intra-abdominal pressure not possible. Additionally, there were several patients that had manometry findings consistent with an esophagogastric junction obstruction, likely secondary to the angulation of the esophagus at this level due to the altered anatomy related to the hernia [24]. Needless to say, the use of routine manometry remains controversial.

## 24-Hour pH Testing

Twenty four-hour pH testing is often utilized in the preoperative workup for anti-reflux surgery. This is accomplished by placing a BRAVO wireless capsule in the esophagus approximately 5 cm from the squamocolumnar junction, which tracks reflux events. Alternatively, a transnasal catheter can be placed for this purpose. Newer technology has allowed for impedance testing, detecting all reflux events not just those related to acid. A normal pH study may indicate that more investigations need to be performed to determine an etiology for the patient's symptoms.

Preoperative pH testing can be an indicator for how a patient will respond to surgery. Previous studies have demonstrated that patients who have reflux symptoms with evidence of GERD on pH testing have improved outcomes to reflux therapy, especially when compared to patients that undergo reflux therapy without evidence of reflux on pH testing [25]. Therefore, pH testing is often recommended to confirm reflux, and cessation of medications has been recommended to increase the predictive value of the test [26, 27].

## Gastric Emptying Study

A gastric emptying study typically is not part of the initial workup for patients being evaluated for anti-reflux surgery or for paraesophageal hernias. However, a gastric emptying may be considered in patients undergoing reoperative surgery. This may especially be of use in patients undergoing multiple reoperations. A previous study by van Rijn et al. demonstrated that vagus nerve injury was present in up to 20% of patients undergoing anti-reflux procedures, and while reflux control was not affected by the presence or absence of vagus nerve injury at 6 months, long-term follow-up demonstrated increased rates of reoperation and lower rates of symptom control in patients with vagus nerve injury. Postoperative gastric emptying was delayed significantly in patients with a nerve injury [28]. The impact of this issue can be significant, as a study by Yolsuriyanwong et al. demonstrated that the identification of a vagus nerve injury preoperatively altered the surgical plan in a significant number of patients [29]. Though not routinely recommended as an initial test for revisional anti-reflux procedures, the authors of this chapter suggest that it may be useful in patients having persistent symptoms after multiple anti-reflux procedures.

Once workup with the above studies is complete, a determination should be made as to whether or not the patient would benefit from reoperation. Some issues encountered in the above workup may be amenable to medical management or endoscopic dilation procedures. However, many patients with persistent or new symptoms and abnormal testing will need reoperation (Figs. 9.7 and 9.8).

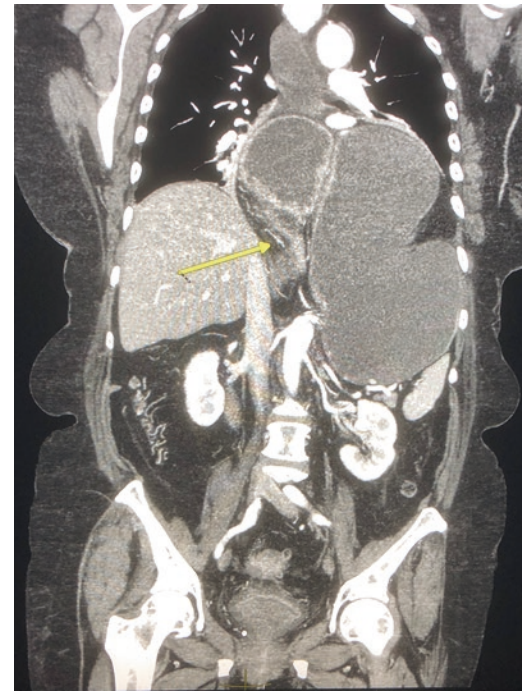

**Fig. 9.7** CT scan of large paraesophageal hernia causing gastric outlet obstruction with arrow indicating area of obstruction

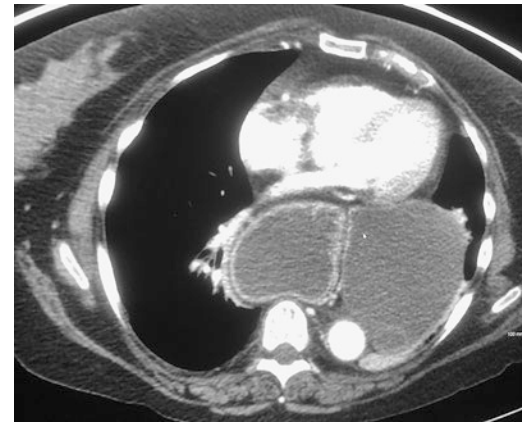

**Fig. 9.8** Axial CT scan of the chest demonstrating cardiac compression from a large paraesophageal hernia

## Patterns of Failure

Several previous classification systems have been created to describe patterns of failure associated with fundoplication. Important elements of these patterns of failure include the integrity, construction, and position of the wrap [30–32]. Issues with

fundoplication can include complete disruption of the fundoplication, a slipped fundoplication, transhiatal herniation, or malconstruction of the wrap utilizing the body of the stomach (Figs. 9.9, 9.10, 9.11, 9.12, and 9.13). Issues with transhiatal herniation of the wrap can have varying degrees of complexity depending on the integrity of the crural repair. At times the wrap can simply slip above a widened anterior hiatus with an intact crural repair (Fig. 9.14), while at other times disruption of the posterior cruroplasty can lead to a recurrent large paraesophageal hernia. Some failures can be visualized on the preoperative workup with the UGI or endoscopy, and patients with suspected failure of their primary operation should be evaluated with the above studies. A recognized pattern of failure helps with intraoperative decision-making, especially when it comes to hiatal reapproximation. It is important to note that previous studies have demonstrated that a patient's symptoms do not necessarily predict wrap position and that patterns of failure are difficult to predict based on symptoms alone [33].

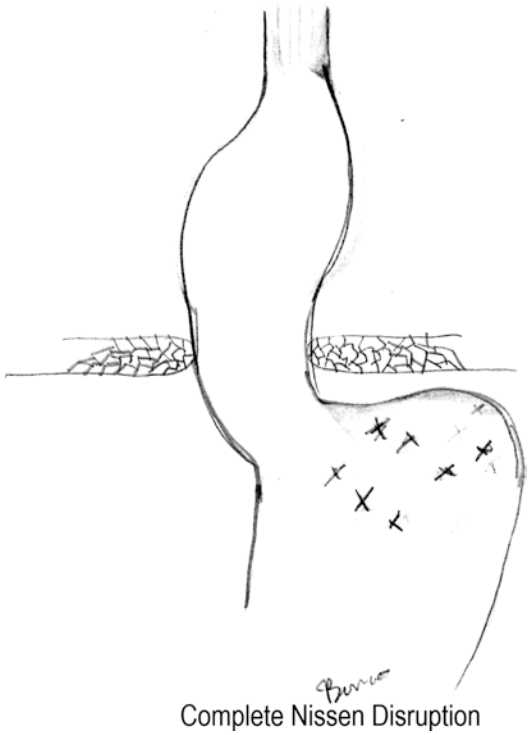


**Fig. 9.9** Illustration demonstrating complete Nissen disruption

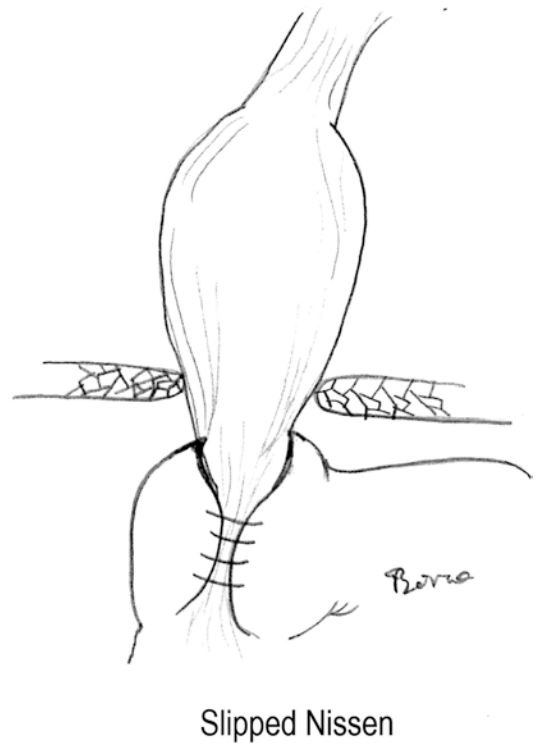


**Fig. 9.10** Illustration demonstrating slipped Nissen fundoplication

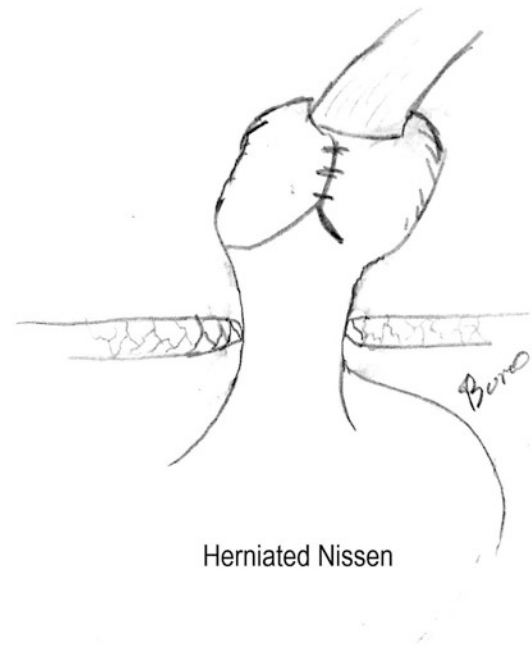


**Fig. 9.11** Illustration demonstrating herniated Nissen fundoplication

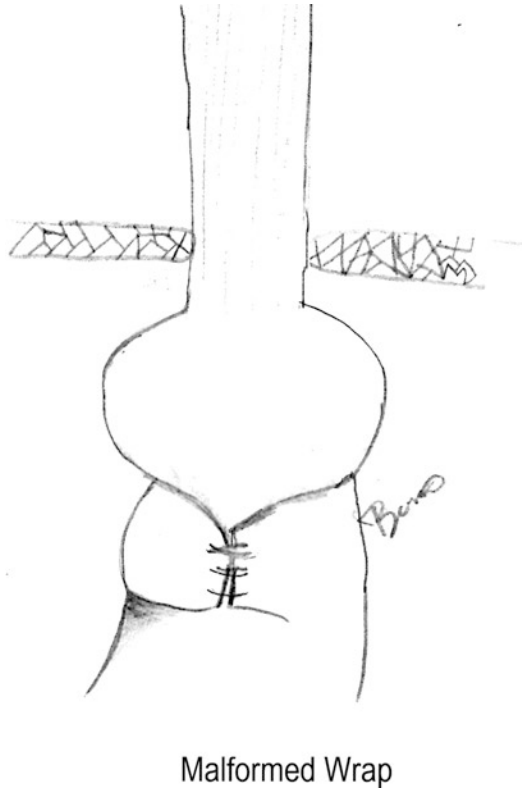


**Fig. 9.12** Illustration demonstrating malformed Nissen fundoplication

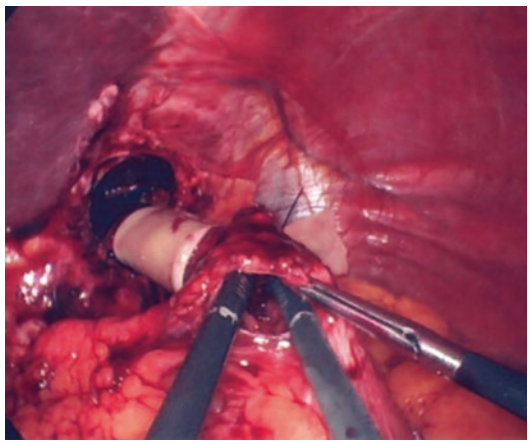

**Fig. 9.13** Image demonstrates a Nissen fundoplication that was performed with the body of the stomach

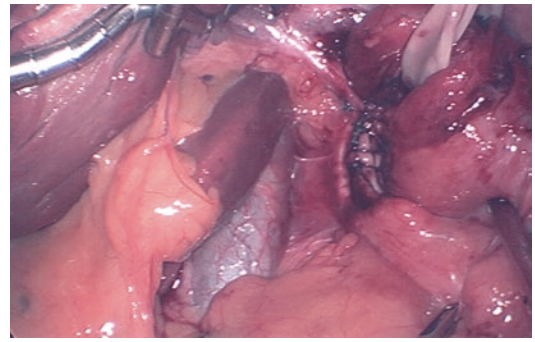

**Fig. 9.14** Intact posterior cruroplasty, slightly widened superior hiatus after reduced mediastinal migration of Nissen fundoplication

## Operative Approach and Technical Considerations

When the decision is made to take the patient to the operating room, typically a laparoscopic approach is utilized. In reoperative foregut surgery, several series have demonstrated an increased risk of conversion to open procedure for reoperative cases [34–37]. With this in mind, the surgeon should be willing to convert to an open procedure if necessary. The procedure starts with sharp dissection along the left lateral segment of the liver to lyse adhesions between the liver and the stomach from the previous operation. Adhesions in this area can be particularly dense if the previous operation was performed open or if the patient suffered complications with their last procedure. Once the left lateral segment of the liver is free, it can be retracted with a liver retractor. The gastrohepatic ligament should then be taken down, with care taken to identify an accessory or replaced left hepatic artery in this area, if present. There is typically significant fibrotic reaction around the edge of the crus, especially if a prior mesh was implanted. Typically, it is not possible to simply evert an attenuated phrenoesophageal ligament due to the dense scarring present. Careful sharp dissection must be performed to free the diaphragm and attempt entry into the posterior mediastinum.

The mediastinal pleura at times is violated during dissection, which can cause a capnothorax. Surgeons should therefore be in constant communications with their anesthesia colleagues, looking for difficulties ventilating the patient. If the patient becomes unstable, the mediastinal pleura should be opened or a red rubber catheter inserted through the defect created, to equilibrate pressures between cavities. As a last resort, tension capnothorax may necessitate insertion of a pigtail chest tube.

Dissection should continue to the right crus of the diaphragm, and what remains of the anterior phrenoesophageal ligament divided continuing anteriorly right to left until the left crus of the diaphragm is encountered. Once the right and left crus of the diaphragm are dissected, blunt dissection posterior to the stomach and esophagus intra-abdominally can be performed, and a Penrose drain is placed to encircle the stomach and esophagus in this position for additional traction.

At this point, steps should be undertaken to restore normal anatomy. If a paraesophageal hernia is present, the hernia sac should be completely dissected from the mediastinum, reduced into the abdominal cavity and excised. Complete reduction of the hernia sac has been demonstrated to ensure adequate dissection, and excision of the hernia sac eliminates one of the possible causes of early failure of repair after the operation [38, 39]. The esophagus should be dissected circumferentially as high as feasible, ideally to the level of the aortic arch, with care taken to identify and preserve the vagus nerves.

At completion of this step, adequate intra-abdominal esophagus versus a short esophagus should be identified. If a short esophagus is identified in the setting of complete esophageal mediastinal dissection, the patient will require an esophageal lengthening procedure, which will be described below. Next, the previous repair should be taken down. Several studies recommend complete takedown of the fundoplication with or without takedown of the crural closure [34–36, 40, 41]. An additional study recommends takedown of the fundoplication if noted to be too tight, malformed, or twisted [42]. This can be accomplished with sharp dissection, taking care to cut all sutures utilized in the previous repair to restore normal anatomy. If a Nissen fundoplication was previously constructed, this can also be accomplished by creating a plane between the esophagus and stomach and firing a linear cutting stapler to divide the wings of the fundoplication. If using a stapler, care should be taken to ensure that the stapler is not leaving a very small section of excluded stomach (Fig. 9.15).

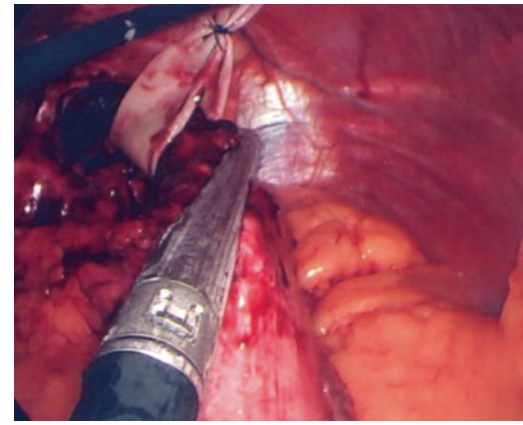

**Fig. 9.15** Takedown of malformed Nissen fundoplication using a linear cutting stapler to divide the wings of the Nissen fundoplication

At this point in the procedure, reconstruction of the anti-reflux valve and crural reconstruction should begin.

## Crural Reconstruction

During the dissection of the right and left crus of the diaphragm, the overlying peritoneum should be preserved as much as possible. This adds an additional layer to give strength to the repair and prevents the muscle from shredding. The crura should be reapproximated with nonabsorbable sutures in a tension-free manner posteriorly. This is typically accomplished using interrupted sutures in horizontal mattress, figure of eight, or simple fashion with or without pledgets (Fig. 9.16). A posterior hiatoplasty is preferred among most surgeons to minimize angulation of the esophagus and is recommended by the authors of this chapter. It is important to note,

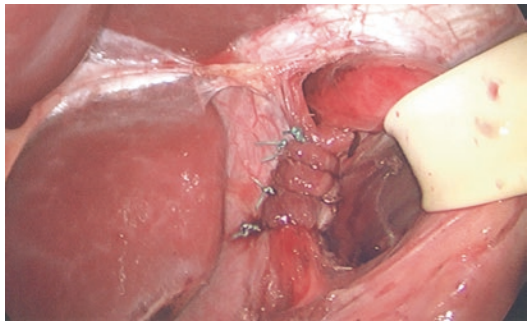

**Fig. 9.16** Posterior cruroplasty with interrupted nonabsorbable braided suture

however, that a previous randomized controlled trial of posterior vs. anterior crural closure demonstrated that at short term, 5-year and 10-year intervals, there was no significant difference in patient satisfaction, symptoms, or reoperation rates between the two groups [43–45].

Reapproximation of the crura can be especially difficult in reoperative surgery. Being that one of the most common causes of failure stems from transhiatal migration of the wrap, the crura are often further apart and more difficult to bring together than in the index operation, and simple suture reconstruction of the hiatus often cannot be accomplished in a tension-free fashion.

Techniques have been described in order to close a wide hiatus in a tension-free manner. One technique involves creating an iatrogenic pneumothorax via left pleurotomy which causes the diaphragm to billow and flatten, bringing one crus closer to the other to allow a more tension-free repair [46]. Another technique that has been well described is the creation of relaxing incisions in the diaphragm. Incising the diaphragm lateral to the crus on either the right or left side allows the crura to be brought together in the midline with little or no tension. The diaphragm can then be closed with a prosthetic mesh in a lateral position away from the esophagus if necessary or covered with extension of the biologic mesh used to reinforce the hiatoplasty. Incisions can either be made on one or both sides [47–49]. If incision on just one side is enough to reapproximate the crura, the right side is preferred, as the liver provides a natural barrier against a future incisional diaphragmatic hernia.

If the hiatus is difficult to bring together, reinforcement of the closure has been recommended. This can be accomplished with the utilization of nearby tissue for autologous transfer or biologic mesh prosthesis. Utilization of synthetic mesh near the hiatus is not recommended due to the risk of erosion of the mesh into the esophagus or stomach [50, 51]. Techniques for autologous tissue transfer have been described for reinforcement. The falciform ligament may be mobilized using an energy device from the anterior abdominal wall and then stitched to the right and left crus of the diaphragm. Preferably this is used to buttress a repair rather than bridge the hiatal opening, and bridging techniques often have a higher rate of failure [52, 53]. In a similar fashion, the left triangular ligament of the liver can be mobilized and sutured anteriorly to the right and left crus after completing a posterior hiatoplasty [54].

Buttress of the posterior hiatoplasty with a biologic mesh has been recommended in previous studies, demonstrating a lower recurrence rate [55–57]. This benefit, however, does not seem to hold true when examining patients 5 years after surgery, as a trial comparing biologic mesh reinforcement to no reinforcement demonstrated comparable recurrence rates at 5 years [58]. These data apply to primary paraesophageal hernia repairs. For recurrent hernias or a difficult hiatal closure during reoperative anti-reflux surgery, biologic mesh use has been recommended. The use of a biologic mesh not only reinforces the posterior hiatoplasty by incorporating into the tissues but also may serve as a sturdier tissue for reapproximation in a future operation in the event of a recurrent paraesophageal hernia. Additional information regarding the use of biologic mesh will be discussed in another section of this chapter.

## Evaluation of Esophagus

After complete mobilization of the esophagus as high as possible (preferably to the level of the aortic arch), the intra-abdominal esophageal length should be assessed. Adequate intra-abdominal esophageal length is considered to be 2–3 cm,

and obtaining adequate intra-abdominal length decreases the risk of a recurrent paraesophageal hernia. A study by Puri et al. identified large paraesophageal hernias, the presence of Barrett's esophagus, and reoperative surgery all as risk factors for the presence of a short esophagus [59].

If a short esophagus is identified, an esophageal lengthening procedure is recommended to create adequate intra-abdominal length around which a wrap can be performed. Several methods for performing a Collis gastroplasty have been described. One method includes the utilization of an EEA stapler to create a gastric window and fire a stapler along an esophageal dilator placed into the stomach. This technique was first detailed by Félicien Steichen in the 1980s [60]. An EEA stapler can be utilized laparoscopically as well, inserted through the abdominal wall. The preferred method of a Collis gastroplasty by the authors of this chapter is a stapled wedge gastroplasty, similar to the method described by Terry et al. [61]. An esophageal dilator is placed through the esophagus into the stomach. The assistant brings the fundus onto the stapler, and the stomach in this area is transected transversely to an area approximately 3 cm below the angle of His. Then, a vertical staple line is created parallel to the esophageal dilator to remove a wedge of stomach, creating increased intra-abdominal length around which a wrap can be created.

A method that has been described as an alternative to a Collis gastroplasty is a hybrid Hill-Nissen procedure. This technique has been described by Bellevue et al. [62] to have equivalent outcomes to the Collis-Nissen procedure. This technique entails placing two Hill sutures of nonabsorbable material through the anterior and posterior sling musculature of the gastroesophageal junction, anchoring this area to the preaortic fascia. The hiatus can be closed posteriorly and anteriorly in cases of a large opening. A Nissen fundoplication is then performed over an esophageal dilator. A short esophagus presents a challenge when performing anti-reflux surgery and/or paraesophageal hernia repair, and the most important step to preventing issues related to a short esophagus is the recognition of the problem intraoperatively.

## Fundoplication

The type of fundoplication performed during an anti-reflux procedure has been a topic of constant debate, especially in the setting of a paraesophageal hernia. Classically, a Nissen fundoplication has been used to create a 360° wrap to create an anti-reflux wrap. There has been some concern that creation of a Nissen fundoplication creates a valve whose baseline pressure is difficult for the esophagus to overcome in the presence of an underlying esophageal motility issue, as can be the case with a long-standing paraesophageal hernia.

Esophageal motility disorders can be difficult to discern preoperatively as outlined in the above section on the preoperative workup. Some studies have demonstrated that a partial fundoplication in the setting of a paraesophageal hernia repair can be advantageous, as a posterior 270° wrap (Toupet fundoplication) offers the same benefits of reflux symptom control as a Nissen fundoplication with a lower risk of postoperative dysphagia due to poor esophageal motility. The concern with this procedure, however, is that while it may decrease the incidence of postoperative dysphagia, it may have a lower rate of symptom control.

There have been several previous studies meant to examine the optimal approach for fundoplication for an anti-reflux procedure. Bell et al. examined clinical and manometric results of 22 patients undergoing Rossetti-Nissen or Toupet fundoplication and found that the two approaches were equivalent in symptom control. Patients undergoing a Rossetti-Nissen more often complained of persistent dysphagia, gas bloat, or odynophagia and had a higher lower esophageal sphincter pressure on manometry [63]. A prospective randomized study of Nissen vs. Toupet fundoplication by Zornig et al. randomized 200 patients with and without documented esophageal dysmotility to receive a Nissen fundoplication or a Toupet fundoplication, and symptom control was assessed at a 4-month follow-up interval. While interviews showed comparable subjective outcomes between the two groups, there was a statistically significant difference in

dysphagia rates, with dysphagia being a more common complaint in patients that underwent a Nissen fundoplication and did not correlate with preoperative dysmotility [64]. A 2-year follow-up study of this patient population demonstrates comparable satisfaction rates between the procedures and shows dysphagia was more common in those that underwent Nissen fundoplication and did not correlate to preoperative dysmotility [65]. An additional prospective randomized comparison of the two approaches was performed by Lundell et al. in 137 patients randomized to receive a Toupet or Nissen-Rosseti fundoplication. Findings of this study concluded that the two approaches are equivalent in their control of GERD symptoms, but symptoms of gas bloat were more prevalent in the full fundoplication group [66]. There have also been meta-analyses and a systematic review aimed at determining the better approach for fundoplication in anti-reflux surgery, which have concluded that symptom control between Nissen and Toupet appears similar, with increased rates of dysphagia and gas-related symptoms for patients who underwent a Nissen [67, 68].

While there is evidence to support the Toupet procedure, no level one evidence exists to suggest replacing a Nissen with a Toupet fundoplication. The practice of the authors of this chapter is to perform a Nissen fundoplication for reflux in patients with or without a paraesophageal hernia. A previous study by Rydberg et al. helped to demonstrate that tailoring the fundoplication to the preoperative esophageal function is not helpful [22]. Persistent dysphagia has been demonstrated to be a rare complication of a Nissen fundoplication [69]. If a patient does have persistent dysphagia following a Nissen fundoplication, the patient may benefit from a revision procedure to revise the Nissen fundoplication to a Toupet fundoplication. A previous study by Schwameis et al. demonstrated that revision from a Nissen fundoplication to a Toupet fundoplication effectively relieved symptoms of dysphagia and bloating [70].

The use of a bougie during fundoplication has been recommended. The practice of the authors is to perform a floppy Nissen fundoplication without a bougie in place and to perform an intraoperative endoscopy to assure that the fundoplication is in good position and not too tight. This avoids the potential issues with passing a bougie blindly into the stomach and potentially perforating the esophagus. Several previous studies have examined bougie use. A prospective, blinded, randomized clinical trial performed by Patterson et al. demonstrated that performing a fundoplication without a bougie led to increased rates of postoperative dysphagia [71]. However, follow-up studies by Novitsky et al. and Somasekar et al. found no such association and suggested that a Nissen fundoplication can be safely performed without the use of a bougie [72, 73]. It is the opinion of the authors that as long as the wrap can be interrogated with intraoperative endoscopy for satisfactory position and length and assuring that the wrap is not too tight, performing a fundoplication without a bougie is safe.

## Considerations for Bariatric Patients

According to the American Society for Metabolic and Bariatric Surgery (ASMBS), the number of bariatric procedures performed per year has been steadily increasing from 2011 to 2017, and laparoscopic sleeve gastrectomy is now the most frequently performed bariatric procedure [74]. While Roux-en-Y gastric bypass has been demonstrated to be an effective procedure for both reflux disease and obesity, the effect on reflux of other bariatric procedures is still being studied. It is important to evaluate the relationship between a bariatric procedure and its postoperative effect on gastroesophageal reflux when evaluating patients with preoperative gastroesophageal reflux disease and obesity.

With the rise in the number of bariatric procedures performed per year, certain trends have begun to develop. The number of laparoscopic sleeve gastrectomies performed per year has increased by over 40% since 2011, and the number of laparoscopic gastric band placements has decreased by over 33% [74]. With a simultaneous rise in the number of laparoscopic gastric sleeve

procedures and a high prevalence of gastroesophageal reflux disease, it stands to reason that there are many patients who have preoperative symptoms of gastroesophageal reflux who are being evaluated for a laparoscopic sleeve gastrectomy. A retrospective study of 110 patients was performed by Genco et al. evaluating the incidence of erosive esophagitis and Barrett's esophagus after patients underwent a laparoscopic sleeve gastrectomy. In this study, 17.2% of patients were diagnosed with Barrett's esophagus postoperatively. Additionally, incidence of GERD symptoms and proton pump inhibitor (PPI) intake increased significantly compared to preoperative values (68.1% versus 33.6% and 57.2% versus 19.1%) [75]. This study would suggest that performing a laparoscopic sleeve gastrectomy could actually worsen sequela of gastroesophageal reflux disease. Other studies such as a recent systematic review and meta-analysis performed by Oor et al. in 2016 were unable to come to a consensus regarding the effect of a laparoscopic sleeve gastrectomy on a patient with GERD; this ultimately leaves the surgeon to make a decision based on the individual patient [76]. The Fifth International Consensus Conference on sleeve gastrectomies concluded that average reported weight loss outcomes 5 years postoperatively were significantly higher for expert surgeons. Furthermore, patients with GERD should have pH and manometry study prior to laparoscopic sleeve gastrectomy. They also felt, however, that Barrett's esophagus, GERD, and hiatal hernias were contraindications to performing laparoscopic sleeve gastrectomies [77].

Another procedure frequently considered for patients with morbid obesity is the laparoscopic Roux-en-Y gastric bypass. Multiple studies have shown that laparoscopic Roux-en-Y gastric bypass procedures are effective for weight loss and the reduction of gastroesophageal reflux symptoms [78, 79]. These studies were corroborated by Tai et al. who describe 150 patients with decreased reflux symptoms and erosive esophagitis after Roux-en-Y gastric bypass at a 12-month follow-up compared to a control group with reflux symptoms who did not undergo Roux-en-Y gastric bypass [80]. The theory behind the effectiveness of the Roux-en-Y gastric bypass to reduce gastroesophageal reflux is multifactorial. It is thought that reflux symptoms decrease secondary to a smaller gastric pouch which secretes less gastric acid, the diversion of biliary reflux secondary to the Roux-en-Y reconstruction, and decreasing intra-abdominal pressure secondary to a large amount of weight loss.

Obesity increases the risk of recurrence of hiatal hernia, and in obese patients, it may be appropriate to perform a procedure that simultaneously treats the hiatal hernia and can improve weight loss [81]. Shada et al. performed a database review of over 76,000 patients who underwent paraesophageal hernia repair concurrently with bariatric surgery. The most common combination was a paraesophageal hernia repair with laparoscopic sleeve gastrectomy. After cohort-matching the paraesophageal hernia and non-paraesophageal hernia patients, there was no significant difference in outcomes [82]. Performing a concomitant paraesophageal hernia repair with bariatric surgery appears to be a safe technique [82, 83]. Dakour et al. describe their retrospective review of 165 patients who underwent either a laparoscopic sleeve gastrectomy with concomitant hiatal hernia repair or a laparoscopic sleeve gastrectomy only. In this study, GERD remission was seen in 21.3% of patient who underwent simultaneous HHR and 29.7% in those who did not. New-onset GERD symptoms were reported in 41.4% of patients who underwent hiatal hernia repair in addition to laparoscopic sleeve gastrectomy and 46.2% of patients who underwent only a laparoscopic sleeve gastrectomy. They concluded that performing a HHR in addition to the LSG does not significantly reduce postoperative GERD symptoms [84].

Patients that undergo bariatric surgery are at risk for herniation of the gastric sleeve, gastric pouch, or gastric band. A case presented by Al-Sanea et al. details a 23-year-old male who underwent a laparoscopic sleeve gastrectomy complicated by postoperative intrathoracic migration of part of the sleeve after nausea and vomiting necessitating re-operation [85]. Amor et al.

provide a case report of a 57-year-old female who underwent a laparoscopic sleeve gastrectomy who developed a de novo hiatal hernia 2 years postoperatively. She underwent a conversion to Roux-en-Y gastric bypass without complication [86].

There is currently debate as to whether bariatric procedures cause hiatal hernias or postoperative hiatal hernias are a result of a missed hiatal hernia. In gastric band patients, there is evidence to suggest that hernias may develop as a result of band placement. A retrospective review published by Azagury et al. of over 690 patients with gastric bands from the years 2005–2009 demonstrated a 1.7% rate of significant hiatal hernia development within 2 years of placement. This study suggests that the herniation of the band may result from chronic back pressure [87]. Given the findings of this study and from our experience, the authors recommend evaluation of the hiatus when removing a gastric band.

Regardless of the cause of a postoperative hernia, postoperative intrathoracic migration of a gastric sleeve has been demonstrated to be problematic (Figs. 9.17 and 9.18). Saber et al. detailed the problem of intrathoracic sleeve migration in a recent study. He identified 19 patients who had previously undergone laparoscopic sleeve gastrectomy diagnosed with sleeve migration based on imaging findings of the staple line above the hiatal opening. Of these 19 patients, 9 had undergone hiatal hernia repair during their index procedure. Clinical suspicion of intrathoracic sleeve migration may arise with postoperative symptoms of GERD, epigastric pain, persistent nausea and/or vomiting, and dysphagia. Risk factors suggested by this study included central obesity, chronic constipation, and postoperative GERD symptoms [88]. The results of this study and previous reports suggest that intrathoracic sleeve migration may pose a problem for patients undergoing bariatric surgery. The authors of this chapter recommend that patients undergoing bariatric surgery be evaluated for the presence of a hiatal hernia preoperatively, or at least intraoperatively. Preoperative endoscopy can suggest the presence or absence of a hiatal hernia in patients being evaluated for bariatric surgery. However, in our experience this method of diagnosis has been notoriously inaccurate. In our practice, all patients at time of surgery undergo careful evaluation of the hiatus, with careful dissection to determine the presence or absence of a hernia. If a hernia is present, it is repaired at the time of the operation with a posterior cruroplasty with or without biologic mesh reinforcement.

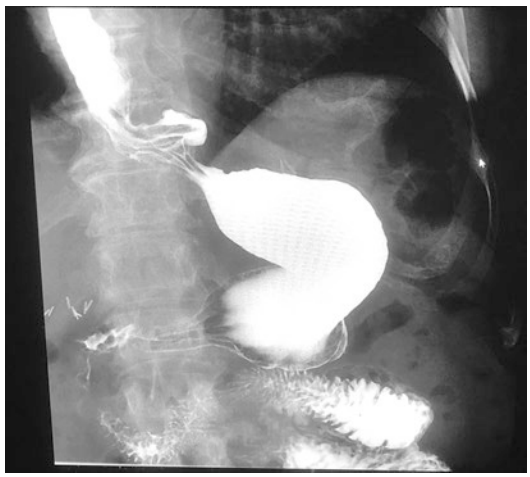

**Fig. 9.17** Upper GI demonstrating intrathoracic migration after a sleeve and hiatal hernia repair 10 years prior

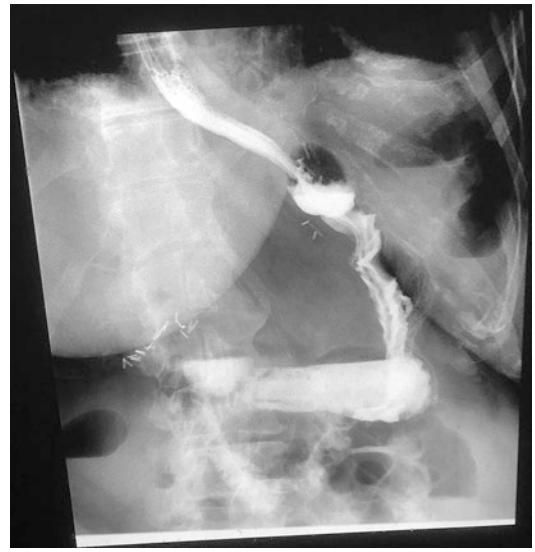

**Fig. 9.18** Upper GI after repair of intrathoracic migration after a sleeve and hiatal hernia repair 10 years prior

## The Use of Mesh

Laparoscopic Paraesophageal hernia repair may present various challenges. Encountering a large paraesophageal hernia, extremely thin crural tissue, and increased tension during surgery may lead to a difficult repair with increased rates of hernia recurrence (Fig. 9.19). High recurrence rates after laparoscopic paraesophageal hernia repair has led to the interest and use of mesh reinforcement in addition to cruroplasty in attempts to reduce recurrence rates. Generally, mesh reinforcement is used with large paraesophageal hernias greater than 5cm. The use of mesh reinforcement as a part of a paraesophageal hernia repair has been demonstrated in some studies to lower recurrence rates after laparoscopic paraesophageal hernia repair compared to cruroplasty alone. A meta-analysis performed by Müller-Stitch et al. of 3 randomized controlled trials and 9 observational clinical studies showed a recurrence rate of 12.1% vs. 20.5% when comparing laparoscopic mesh augmented repair vs. laparoscopic mesh free repair [89] (Fig. 9.20).

When discussing mesh reinforcement, the type of mesh used is of importance. Although permanent mesh provides better tensile strength, it may cause an increased inflammatory response and loss of elasticity, and potential complications including dysphagia from scarring, erosion into the esophagus or stomach, and esophageal stenosis [50, 90]. Most surgeons would recommend the use of biologic mesh implants owing to reduced complications when compared to nonabsorbable mesh.

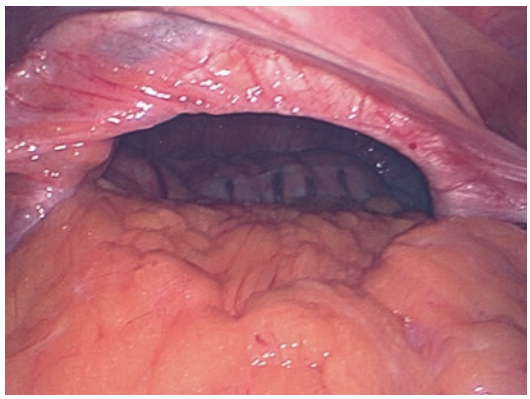

**Fig. 9.19** Image demonstrating a very large paraesophageal hernia with a very wide hiatus

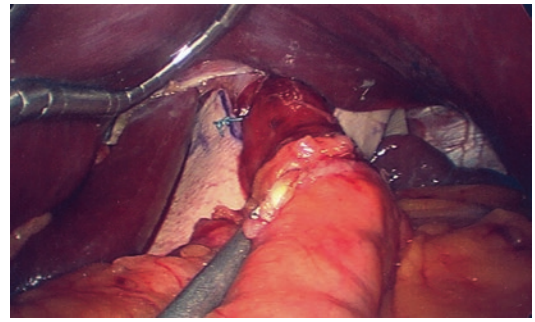

**Fig. 9.20** Completed posterior cruroplasty with biologic mesh

Biologic mesh can be derived from human, bovine, and porcine tissue. The mesh acts as a regenerative framework aiding in remodeling and tissue ingrowth [90]. Mesh integration with the host tissues is important for a durable long-term repair. Inflammation and healing are areas for concern whenever mesh is implanted. After mesh implantation, there is an inflammatory response to the implanted foreign body which includes protein absorption, platelet adherence with subsequent releasing of chemoattractants, which cause other cells including polymorphonucleocytes, fibroblasts, smooth muscle cells, and macrophages to migrate to the area. After the acute inflammatory response, a chronic inflammatory response is seen. In relation to foreign bodies, this inflammatory response will lead the way to a foreign-body reaction phase. This is a complex defense reaction involving foreign body giant cells, macrophages, infiltration of fibroblasts, and neovascularization [91]. The fibroblast is responsible for creation of the extracellular matrix and collagen to maintain the integrity of connective tissue [92] (Fig. 9.21).

Biologic mesh has been studied to evaluate its use in paraesophageal hernia repair to determine if it reduces recurrence rates without the concomitant complications that were seen in nonabsorbable mesh. A long-term follow-up from a multicenter prospective, randomized trial by Oelschlager et al. demonstrated no significant difference with recurrence rates between two

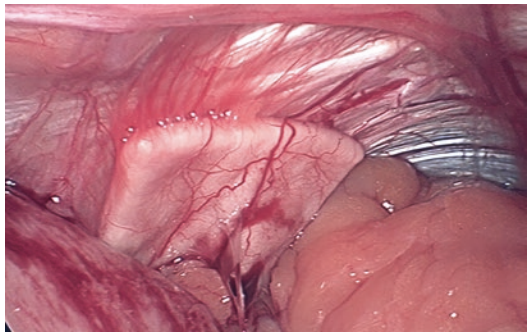

**Fig. 9.21** Image demonstrates strong integration, advanced tissue formation, and neovascularization of the porcine hepatic-derived biologic mesh 26 months after implantation. Notice the lack of adhesions over the exposed surface

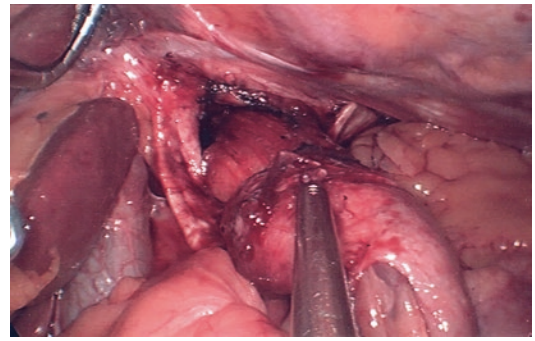

**Fig. 9.22** Reduced Nissen fundoplication from mediastinal position with intact well-integrated biologic mesh posteriorly

groups of patients, those who had primary cruroplasty and those who were closed primarily and reinforced with mesh. From the original 6-month follow-up period, recurrence rates were 9% vs. 24% in the group closed primarily and reinforced with biologic mesh compared to the primary closure-alone group [57]. However at the 5-year follow-up, recurrence rate in the group reinforced with mesh vs. the primary closure alone was 54% vs. 59%, respectively, showing no significant difference [58].

In our experience of patients who present with recurrence after a paraesophageal hernia repair with biologic mesh reinforcement, we have noticed findings of improved tissue quality. The tissue remodeling due to the prior implanted graft provides a better quality of tissue which helps to perform a more durable repair. The biologic mesh that has incorporated into the tissues near the hiatus can cause some scar tissue formation in this area, making initial hiatal dissection difficult. However, once hiatal dissection is complete, the biologic mesh can be utilized for repair of the hernia (Fig. 9.22). Where flimsy crural tissue may have existed before, making reapproximation all but impossible, a stronger material that can hold suture now exists, facilitating closure. Although many surgeons do not routinely utilize mesh at the index operation for a paraesophageal hernia, the presence of a biologic mesh may aid in repair of a recurrence if one were to develop.

## Outcomes After Reoperative Anti-reflux Surgery

When determining the overall success of a procedure, the term success should be defined. When discussing anti-reflux surgery, success can be defined as freedom from symptoms of reflux, freedom from medication use, and overall patient satisfaction. When determining success in repair of paraesophageal hernias, the decision of whether the patient needs a further intervention often depends on the presence or absence of symptoms. Although large paraesophageal hernias often have a high radiographic recurrence rate, patients typically report improved symptoms [93–95]. A study by Jones et al. followed 209 patients who underwent repair of a paraesophageal hernia with absorbable mesh. Recurrence was 16% at 1 year and increased to 39% at 5 years. However, heartburn and regurgitation symptoms had significantly improved, and there was no significant difference in postoperative symptoms between patients who were identified to have a radiographic recurrence and those who did not [93]. This indicates that the measure of success of paraesophageal hernia repair should depend on patients' symptoms and not a radiographic finding.

In terms of reoperative surgery for gastroesophageal reflux overall, symptom improvement and patient satisfaction are not as high as it is for primary surgery. Many patients do report improvement of symptoms, but not quite at the

rates that they did with the first operation. A study by Signhal et al. demonstrated that patient satisfaction decreased with each subsequent intervention after initial anti-reflux surgery [96]. While patients may not be as satisfied as those that need no subsequent intervention, revisional anti-reflux surgery still provides patients with relief, especially those with persistent gastroesophageal reflux symptoms, gas-bloat syndrome, or regurgitation. Outcomes are not as favorable in patients with a short esophagus that require Collis gastroplasty [97–99].

## Conclusion

Laparoscopic reoperative anti-reflux surgery can be challenging. In patients that present with persistent symptoms after an anti-reflux procedure, a mechanical cause of failure should be sought out as outlined in this chapter. If a cause of failure is identified, patients benefit from undergoing reoperation to fix the identified problem. This can very often be accomplished laparoscopically, but conversion rates are higher for reoperative surgery than they are for primary anti-reflux procedures. The tenets of primary anti-reflux surgery hold true in reoperative surgery, with tension-free repair of a paraesophageal hernia if one is present, and correct construction of the wrap. Patients that require reoperative surgery should be evaluated by an experienced surgeon at a high-volume center, as reoperative anti-reflux surgery can be challenging.

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# Postgastrectomy Syndromes

10

Melissa M. Beitner and Subhash Kini

## Introduction

The indications for gastric resection are a myriad and range from the less common peptic ulcer disease and gastric malignancy to the increasingly prevalent morbid obesity.

Partial or total gastrectomies are being performed less commonly in the USA. This is because of effective medical therapy for peptic ulcer disease and the decreasing incidence of gastric cancer. However, the number of bariatric operations has increased substantially.

Resection of the pylorus (which changes the way the stomach empties) and vagal denervation (which changes gastric motility and bile secretion) are the two key mechanisms implicated in postgastrectomy syndromes [2].

## Types of Gastrectomy

Classic postgastrectomy syndromes are constellations of signs and symptoms related to late postoperative complications following gastric surgery. The sequelae of gastric surgery depend on the extent of resection (be it total, subtotal/distal, or central gastrectomy or bariatric procedures such as the sleeve gastrectomy or non-resectional procedures as in the gastric bypass), reconstruction technique (typically, Billroth I, Billroth II, or Roux-en-Y or any form of pyloric ablation), and the effects of vagotomy. Sleeve gastrectomy and wedge resections do not lead to the classic postgastrectomy syndromes whereas vagotomy with/without drainage can lead to postgastrectomy syndromes.

Billroth I reconstruction is at risk for the development of dumping syndrome and alkaline reflux gastritis. Billroth II reconstruction is also at risk for the development of dumping syndrome and alkaline reflux gastritis in addition to the duodenal stump leak, obstruction of the afferent loop, and malabsorption [1, 3].

While the mechanisms underlying most postgastrectomy syndromes remain to be fully elucidated, bypass, ablation, or destruction of the pylorus is the most important mechanical factor responsible [4].

Most postgastrectomy syndromes improve with time and can be managed with dietary and behavioral modifications [2]. Attempts should always be made to avoid reoperation, particularly in patients whose symptoms defy classification into one of the commonly recognized clinical patterns and until an adequate period of time has passed.

Postgastrectomy syndromes may be broadly grouped into complications of form or complications of function. This chapter will review classic

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**Table 10.1** A summary of the presentation, workup, and treatment for several syndromes

| Complication | Presentation | Management strategy |
|---|---|---|
| Afferent loop syndrome | Immediate postprandial pain and cramping followed by vomiting without food | Surgical – Braun enteroenterostomy or conversion to Roux-en-Y<br>Possible stent in a palliative setting |
| Efferent loop syndrome | Nausea, vomiting (sometimes bilious), distension | Surgical – lysis of adhesions, reduction of internal hernias, possible resection of stricture of intussusception, marginal ulcer, or recurrent cancer |
| Roux stasis syndrome | Chronic abdominal pain, early satiety, epigastric fullness, nausea, vomiting | Exclude obstruction<br>Dietary modification<br>Metoclopramide, erythromycin<br>Gastric resection with Roux-en-Y |
| Small pouch | Weight loss, malnutrition, anemia, dumping syndrome | Dietary modification<br>Pouch reconstruction |
| Dumping syndrome | Diaphoresis, weakness, lightheadedness, palpitations, abdominal pain, cramps followed by diarrhea, possibly hypotension and syncope. Follows a carbohydrate-rich meal | Dietary modification<br>Octreotide<br>Convert Billroth II to Billroth I<br>Narrow the gastrojejunal stoma<br>Pouch construction to increase the reservoir (Hunt-Lawrence J pouch)<br>Reversing the gastrojejunostomy |
| Alkaline reflux gastritis | Pain, nausea, bilious emesis | Trial of medical management<br>Creation of Roux-en-Y |
| Delayed gastric emptying | Epigastric fullness, pain, nausea after eating, vomiting undigested food, intolerance of solids | Rule out mechanical obstruction<br>Metoclopramide or erythromycin<br>Reducing the pouch size with Roux-en-Y reconstruction |
| Postvagotomy diarrhea | Diarrhea that is self-limited postoperatively, occurs immediately but does not resolve, episodic or intermittent without warning | Exclude other causes<br>Distinguish from dumping syndrome<br>Dietary measures, antidiarrheals, antispasmodics, cholestyramine<br>Limit use of vagotomy when possible<br>Pyloric reconstruction and reversed antiperistaltic jejunal segment interposition |

postgastrectomy syndromes as they relate to gastric resection with reconstruction. As we straddle general surgery, surgical oncology, and bariatric surgery, we define the gastric remnant as it is typically referred to in a gastric bypass the excluded stomach, while the resulting stomach forming the gastroenterostomy is referred to as the pouch. A summary of the presentation, workup, and treatment for several syndromes is presented in Table 10.1.

## Complications of Form

### Afferent Loop Syndrome

This uncommon syndrome results from acute or chronic obstruction of the afferent loop. Obstruction may result from several etiologies including gastroparesis, hernias, volvulus, kinking at the anastomosis, marginal ulceration, adhesions, recurrent cancer, and intussusception [1].

Obstruction of the afferent limb leads to distension and increases intraluminal pressure in the proximal jejunum, duodenum, and also biliary-pancreatic ducts. If this dilatation is marked and backpressure is very high, perfusion to the bowel may be impaired leading to perforation; backpressure within the biliary pancreatic ducts can present as acute pancreatitis [5, 6].

Afferent loop syndrome classically manifests with symptoms of immediate postprandial pain and cramping, followed by vomiting which relieves symptoms. The vomitus does not contain foodstuff. Diagnosis is made on symptoms and confirmed on CT, which will show a dilated afferent limb.

Management of this rare complication is primarily surgical. In the acute setting, duodenal stump or gastric remnant blowout or necrosis is possible and surgical intervention is emergent. If the afferent limb is viable, a Braun-type enteroenterostomy will decompress the afferent limb. Alternatively, conversion to a Roux-en-Y gastrojejunostomy is an option for management. In the rare event that the duodenum is completely necrosed, pancreaticoduodenectomy is required.

Endoscopy is rarely useful for diagnosis but may be useful in a palliative setting to place a self-expanding metal stent in the obstructed limb [1].

## Efferent Loop Syndrome

Efferent loop syndrome refers to partial or complete mechanical obstruction of the efferent limb at or near the gastrojejunostomy following Billroth II. It occurs less commonly than afferent loop syndrome and may present in an acute or chronic form. Symptoms depend on the level of obstruction, and presentation is similar to a small bowel obstruction with emesis (sometimes bilious), nausea, and distension [1]. Chronic obstruction is partial and often intermittent.

It is often due to retroanastomotic hernias through the mesocolon but other causes include adhesive disease, anastomotic strictures, jejunogastric intussusception, marginal ulceration, and recurrent cancer or carcinomatosis.

Evaluation and diagnosis are made by CT and endoscopy. A HIDA scan may be useful to differentiate efferent loop syndrome from bile reflux gastritis in the case of chronic symptoms [1].

Surgical management is required. This may consist of lysis of adhesions, reduction of internal hernias with closure of mesenteric defects, and possibly revision of the anastomosis. Operative findings may dictate the need for conversion to Billroth I or Roux-en-Y gastrojejunostomy [2]. In the case of malignant obstruction, an endoscopically placed self-expanding metal stent may be used.

## Roux Stasis Syndrome

Roux stasis syndrome occurs after Roux-en-Y gastrojejunostomy and is characterized by chronic abdominal pain, early satiety, epigastric fullness, nausea, and vomiting. Symptoms may lead to malnutrition and weight loss. Gastric bezoars may develop.

The cause of this entity is unclear but several physiologic changes may contribute to what is likely a functional obstruction, particularly changes pertaining to the vagotomized gastric pouch and the motility of the Roux limb. It is thought that vagotomy decreases the tone of the gastric remnant. Additionally, transit through the Roux limb is slowed due to disruption of the forward spread of pacesetter potentials generated in the duodenum with division of the jejunum and the subsequent appearance of ectopic pacemakers that drive the potentials retrograde [3].

In the early postoperative period, obstruction must be ruled out. In the late postoperative period, internal hernia, recurrent malignancy, adhesive diseases, and anastomotic stricture may cause mechanical obstruction. These must be ruled out as Roux stasis syndrome is a diagnosis of exclusion [1].

Radionuclide scanning can measure gastric emptying and Roux transit and is most useful for diagnosis.

Treatment is initially medical with dietary modification (small, frequent meals) and a trial of metoclopramide and erythromycin (though these drugs tend not to provide long-term control). Surgical management may involve extensive gastric resection or completion gastrectomy with Roux-en-Y reconstruction. The Roux limb should be kept to <50 cm as longer lengths may predispose to stasis. Alternatively, if complete gastrectomy has already been performed, a jejunostomy feeding tube may need to be placed.

## Pouch Problems

A small gastric pouch results in early satiety and epigastric pain after eating, with or without postprandial vomiting. Symptoms are more

prevalent when more than 80% of the stomach is removed. This results from loss of the reservoir function of the stomach due to decreased capacity and loss of receptive relaxation and accommodation with vagotomy rather than from rapid gastric emptying [2].

A small gastric pouch can result in weight loss, malnutrition, and anemia. These patients may have dumping symptoms. Although this contributes to weight loss in bariatric patients undergoing gastric bypass [7], this is not desirable in other patient populations undergoing gastric surgery.

Medical management is generally successful. Small, frequent meals supplemented by vitamins, iron, pancreatic enzymes, and antispasmodic agents are recommended.

In intractable cases following a Billroth II anastomosis, several procedures to restore the capacity of the pouch have been utilized. The Hunter-Lawrence pouch and the Tanner Roux-19 pouch have been described for this purpose [2]. Pouch reconstruction after total gastrectomy is beneficial for patients with expected long-term survival [3]. Patients report a lower incidence of dumping and reflux and higher Gastrointestinal Quality of Life scores though weight is unchanged.

## Complications of Function

### Nutritional and Metabolic Consequences

Vagotomy, gastric resection, and bariatric surgery involve major changes in the anatomy and function of the gastrointestinal tract with significant nutritional and metabolic complications.

Preoperative nutritional assessment and rigorous postoperative follow-up with administration of nutritional supplements are key to avoiding and treating such complications [8].

The American Society for Metabolic and Bariatric Surgery recommends monitoring multiple nutritional components including vitamins B1, B6, B12, A, D, E, and K, folate, iron, zinc, and protein after bariatric surgery [1, 9].

Given that iron absorption takes place primarily in the proximal gastrointestinal tract and is facilitated by an acidic environment, iron deficiency resulting in anemia occurs in 50% of patients. Decreased acid production, decreased intrinsic factor production, and bypass of the duodenum all contribute. Iron deficiency is exacerbated by vitamin C deficiency. Iron deficiency anemia is the most common metabolic side effect of gastric bypass for morbid obesity [10]. Vitamin B12 and folate deficiency also occur. Vitamin B12 deficiency does not depend on the type of reconstruction but rather the loss of gastric intrinsic factor.

Malabsorption may play a role in weight loss post gastric bypass and other gastrectomy procedures; however fecal fat is much unchanged [9]. Protein deficiencies are common and is attributed to food intolerance to protein-rich foods [8].

Abnormalities of calcium and vitamin D can contribute to metabolic bone disease. Calcium absorption occurs in the duodenum. Fat malabsorption due to bacterial overgrowth or inefficient digestion can affect vitamin D absorption. This can lead to pain or fractures years after gastrectomy. It may be necessary to screen high risk patients with skeletal monitoring to initiate appropriate treatment [11].

### Dumping Syndrome

It is postulated that dumping syndrome arises from the rapid delivery of a hyperosmolar load to the small bowel. Loss of pyloric regulation, impaired accommodation and capacity of the pouch with accelerated gastric emptying, and loss of duodenal feedback are thought to be the causative mechanisms.

Early dumping occurs around 30 minutes after a meal and is characterized by vasomotor and gastrointestinal symptoms. Patients complain of diaphoresis, weakness, light-headedness, and palpitations with abdominal pain or cramps that is frequently followed by diarrhea. The pathophysiology is thought to involve reduced gastric volume, bypass or removal of the barrier function of the pylorus, and/or rapid transit secondary to

vagotomy and impaired duodenal feedback inhibition (in bypass procedures) and results in entry of undigested food to the small bowel [2]. Hyperosmolar nutrients in the small bowel draw fluid into the small bowel leading to symptoms of hypovolemia – tachycardia and even syncope. Fluid shifts also cause distension and contribute to cramping abdominal pain, bloating, and diarrhea. Increased release of multiple gastrointestinal hormones including vasoactive agents (neurotensin, vasoactive intestinal peptide), incretins (gastric inhibitory polypeptide and GLP-1), and glucose modulators (insulin and glucagon) are also implicated. These hormones may result in uncoordinated gastrointestinal motility and inhibit secretion and result in hemodynamic effects [12]. Vasomotor symptoms include flushing, palpitations, diaphoresis, tachycardia, syncope, and hypotension [1].

The second phase, the less common, late dumping, occurs 2–3 hours after a meal and likely represents postprandial hypoglycemia with its attendant symptoms. Symptoms include hypoglycemia and vasomotor symptoms including flushing, palpitations diaphoresis, tremulousness, and hunger [1].

Patients react by limiting oral intake leading to weight loss and malnutrition.

Diagnosis is usually clinical, and empiric treatment based on symptoms usually establishes the diagnosis. However, an oral challenge with 50 g glucose can be used to correlate symptoms and objectively diagnose the problem. Assessment of gastric emptying can be a helpful adjunct. Symptom-based questionnaires are also used to identify clinically significant symptoms. Endoscopy and fluoroscopic imaging can serve to define the anatomy and rule out other differentials.

Management consists initially of dietary modification. Patients are advised to take six small meals a day, avoiding liquids and solids at the same time limiting simple sugars, and concentrate on a diet high in protein and fat [1]. Others also recommend a high-fiber diet [12]. Attempts to slow gastric emptying by increasing food viscosity using guar gum or pectin are not well tolerated. Others have used acarbose to limit carbohydrate absorption or diazoxide to inhibit insulin release in the management of late dumping [12, 13]. Symptoms refractory to dietary modification may be managed with somatostatin analogues. These slow gastric emptying impede intestinal transit and inhibit GI hormone release. Common side effects of somatostatin analogues include diarrhea, nausea, steatorrhea, gallstone formation, pain at the injection site, and weight gain.

Symptoms often resolve with time. Surgical treatment is warranted infrequently. Outcomes with a variety of surgical procedures are variable and unpredictable. Surgical options depend on the preceding type of gastric resection. Primary prevention of dumping syndrome with use of a pylorus-preserving central gastrectomy (PPG) for early mid-body gastric cancer has been studied in Japan with success [14].

Operations to restore duodenal transit by converting Billroth II to Billroth I or narrowing the stoma of the gastroenterostomy have been proposed. Other options include reconstruction of a previously ablated pylorus and interposition of an antiperistaltic jejunal segment have been described [1]. Other options include pouch construction (Hunt-Lawrence J pouch) to increase the capacity of the functional reservoir after a total gastrectomy [3, 14].

## Alkaline Reflux Gastritis

Bile reflux occurs when the pylorus is resected, bypassed,or destroyed, allowing intestinal contents to reflux into the pouch and esophagus. It occurs most frequently after Billroth II gastrectomy and less so after Billroth I and pyloroplasty as the intestinal contents flow past the anastomosis. It is rare after Roux-en-Y. Patients present with pain, nausea, and bilious emesis several years after gastrectomy. The intestinal contents injure the gastric mucosa though which component of this contributes most is unclear.

Patients may be diagnosed on endoscopy which shows bile reflux as evidenced by erythema, bile in the stomach, thickened gastric folds, atrophy, and petechiae [1]. HIDA scan may

show pooling of bile in the stomach. Patients typically do not respond to maximal acid suppression and multichannel intraluminal impedance and pH testing show a refluxate with a pH >4. Scintigraphy may be used to identify delayed gastric emptying because delayed bile clearance may be involved and can be problematic post revision.

Medical treatment is usually ineffective. Though none have been consistently proven effective, antacids, anticholinergics, cholestyramine, ursodeoxycolic acid, sucralfate, and metoclopramide may be trialed [1, 4].

Surgical treatment usually involves creation of a Roux-en-Y which diverts biliopancreatic secretions away from the pouch. The Roux limb should be at least 45–60 cm in length. The pouch may also require revision to a small caliber depending on preexisting gastroparesis. Additionally, a vagotomy should be performed if not done initially to prevent marginal ulcer development.

Despite the Roux-en-Y configuration, some patients still experience reflux. Other options for managing bile reflux include Braun enteroenterostomy (45–60 cm distal to the gastrojejunostomy), the Henley jejunal interposition (typically 40 cm), and the duodenal switch (when reflux occurs with an intact pylorus).

## Delayed Gastric Emptying

Delayed gastric emptying occurs after gastric resection for cancer in up to 30% of cases (though clinically much less). Food retention after distal/subtotal gastrectomy for cancer is seen commonly on postoperative endoscopy but is not correlated with symptoms. A decrease in gastric motor tone can result from gastric surgery and lead to delayed gastric emptying [2]. Symptoms may include epigastric fullness, pain, nausea after eating, and vomiting of undigested foods with intolerance of a solid diet. Bezoars may form. This occurs after vagal disruption to the proximal stomach. Underlying conditions that increase the risk include preoperative gastric outlet obstruction, diabetes mellitus, hypothyroidism, and autonomic neurologic disorders [2]. It seems to be more frequent after Billroth I than Billroth II or Roux-en-Y.

It is important to determine if obstruction to outflow is mechanical or functional. Typically, a distended gastric pouch without mechanical obstruction will be evident on CT and endoscopy. Delayed gastric emptying is confirmed on scintingraphy, which objectively evaluates the emptying of solids.

Most patients respond to conservative management. Management is initially medical with prokinetic agents such as metoclopramide or erythromycin. When this fails, operative therapy aimed at decreasing the reservoir capacity of the pouch, including complete resection of the pouch, with Roux-en-Y reconstruction to prevent bile reflux. By removing the atonic pouch, esophageal peristalsis will propel food directly into the remaining pouch and small bowel. The disordered motility in the Roux limb will slow the transit of liquids and solids making the Roux limb a type of reservoir for the meal [15].

## Postvagotomy Diarrhea

All types of gastric surgery may result in postoperative diarrhea with the incidence highest after truncal vagotomy. Diarrhea develops in 20% after truncal vagotomy, 3% after selective vagotomy, and 1% after proximal vagotomy [2, 4]. Four patterns have been described – self-limited postoperative, immediate postoperative that does not resolve, episodic diarrhea, and an intermittent diarrhea that occurs without warning [4]. It can usually be distinguished from dumping syndrome on symptomatology.

Although the exact pathogenesis is unclear, several mechanisms have been proposed. These include vagal denervation of the small bowel and biliary tree with decreased receptive relaxation and rapid gastric emptying leading to rapid transit of bile salts into the colon and changes in the rate and pathway of the enteric flow of chyme which may lead to relative malabsorption of nutrients normally digested by mucosal enzymes [2, 4].

Diagnosis is made on symptoms, and other causes of diarrhea should be ruled out.

Management consists of dietary measures such as small frequent meals, addition of fiber, limiting liquids and lactose-containing foods, antidiarrheals, antispasmodics, and cholestyramine.

The best treatment is prevention by utilizing the proximal vagotomy when possible. In the few patients with disabling symptoms refractory to the above interventions, several remedial surgical options designed to slow small bowel transit have been described [4]. Pyloric reconstruction (reversal of pyloroplasty) and reversed antiperistaltic jejunal segment interposition 90–100 cm distal to the ligament of Treitz and 10 cm in length have been described [4].

## Summary

Gastric surgery can result in classic syndromes due to late complications of form or function. A thorough history is essential to distinguish between syndromes and differentials. Often symptoms can be managed with lifestyle and dietary modification. Reoperation is usually not necessary except in cases of afferent and efferent obstruction and recalcitrant cases of alkaline reflux gastritis.

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# Part IV

# Revisional Endoscopic Procedures

# 11 Intraoperative Endoscopy During Revisional Foregut Surgery: Who to Scope?

Erin M. Thompson, Georgios Orthopoulos, and John R. Romanelli

Endoscopy plays an important role in the operative planning prior to any surgical interventions in the upper gastrointestinal tract [1]. However, endoscopic techniques can also provide extremely useful information in the evaluation and management of postoperative upper gastrointestinal symptoms and complications following foregut surgery, including antireflux and bariatric procedures [2–6]. Commonly encountered symptoms include abdominal pain, nausea, emesis, and dysphagia, while weight regain, heartburn, regurgitation, hematemesis, and melena are less common.

The etiology of these symptoms can be multifactorial, and an endoscopic evaluation is frequently required in order to identify a source and exclude intraluminal structural complications in patients who present with the abovementioned symptoms that persist despite counseling and behavior modification [6–8]. Also, failure of antireflux surgery has been reported in multiple studies, and pathologic acid reflux tests can be observed in 5–15% of patients with gastroesophageal reflux disease. This can occur after Nissen as well as after Toupet fundoplication [5].

Evaluation is particularly important in patients who present within the first one to three postoperative months, since this is when the majority of postoperative complications occur [4, 7]. This is usually performed as part of planning prior to revisional surgical intervention, but it can frequently provide useful information intraoperatively, especially in sick patients who have potentially suffered leaks or strictures following the index procedure.

## Management of Leaks

Postoperative leak in the upper gastrointestinal tract can be associated with dreadful consequences. This usually involves postoperative complications of bariatric and antireflux procedures and can be associated with significant morbidity. Usually a conservative approach results in successful management of these complications, but occasionally a more invasive approach is required. Traditionally this included surgical and interventional radiology techniques, but recently endoscopic therapies have been introduced as a valid, alternate, minimally invasive approach to postoperative complications.

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Leaks after foregut surgery are usually associated with bariatric procedures and are most commonly found along staple lines. Leak after sleeve gastrectomy can occur with an incidence of approximately 2.4% and is frequently located at or near the gastroesophageal junction, whereas for patients who undergo Roux-en-Y gastric bypass, the anastomotic leak incidence ranges between 0.1% and 5.6% and usually occurs at the gastrojejunostomy [9]. The different types of endoscopic intervention for postoperative anastomotic leak include endoscopic stents, endoscopic clips, endoluminal vacuum therapy, and endoscopic suturing.

## Endoscopic Stent Placement for Leaks

This is considered to be the most commonly used approach for management of endoluminal leaks. Self-expandable endoscopic stents (SEES) can be placed to decrease the intraluminal pressure which has been associated with the development of leaks, especially after sleeve gastrectomy. Also, placement of SEES can exclude the tissue defect from the gastrointestinal fluid and thus prevent peritoneal contamination while allowing oral nutrition to be resumed [10].

There are two major types of SEES available: metal (SEMS) and polyester (SEPS). Metal stents can be further subdivided into partially covered (PCSEMS) and fully covered (FCSEMS) stents. The main difference between these two types of stents is the silicone coating that is completely covering the FCSEMS, acting as a barrier between the stent and the mucosa [8]. The advantage is the easy removal of the stent; however there is a higher trend towards migration. In contrast, PCSEMS have uncovered ends that can induce tissue hyperplasia, which serves to prevent migration, but also can make removal of the stent more difficult and can potentially increase the risk of bleeding and perforation. Currently there are no randomized control trials evaluating the efficacy of one type of stent versus the other.

Most studies regarding the effect of SEES in the management of leaks have been published in patients that have undergone bariatric surgery. In these studies, the rates of leak closure and complication ranged from 65% to 100% and 14% to 86%, respectively. The most commonly encountered complication was migration of the stent which has been reported with a rate of 5–67% [8]. The wide range of numbers reported in across studies can be attributed to the heterogeneity of the studies with variable measuring characteristics such as the size of the wall defect, the timing of stenting after surgery, and different types of stent placement, as well as the fact that in some studies the success of leak closure is due to combination of stent placement with other endoscopic techniques.

Chang et al. reported their experience in the management of anastomotic complications after foregut surgery using endoscopic stent placement. In their retrospective review study, 47 patients underwent endoscopic SEMS placement for anastomotic complications, including sleeve gastrectomy leaks, gastrojejunal and pouch staple line leaks after Roux-en-Y gastric bypass, and enterocutaneous fistulas, following upper gastrointestinal surgery. 70.9% of the study population achieved improvement of their symptoms and 57% of the subjects who had suffered anastomotic or staple line leaks were able to initiate oral nutrition within 48 h of stent placement [11]. In a recent meta-analysis, Puli et al. reported a successful leak closure rate of 87.7% with only 9% of patients requiring revisional surgery for persistent anastomotic leak. Also the reported proportion of successful endoscopic stent removal was 92.6% with a 16.9% rate of stent migration [12]. As reported before, stent migration after stent placement remains a major consideration that can lead to morbid conditions such as bleeding and perforation. There are no specific guidelines regarding the exact timing of stent removal, but most experts recommend removal of the stent after 6–8 weeks following placement. This provides enough time for leak closure but also avoids developing excessive tissue hyperplasia. Until stent removal, weekly endoscopic evaluations are highly advised in order to detect possible stent dislodgement [8].

## Endoscopic Clip Placement

Endoscopic closure of full-thickness defects in the gastrointestinal wall can be performed utilizing endoscopic clips. There is limited data evaluating the role of this endoscopic technique for the management of anastomotic or staple line leaks. Most promising data derive from the use of the over-the-scope clip (OTSC®, Ovesco Endoscopy GmbH, Tübingen, Germany), a clipping device made of nitinol and loaded at the tip of the endoscope. This clip allows for full-thickness apposition of less than 3 cm wall defects [8]. As with other endoscopic techniques, appropriate drainage of leaked material/abscess needs to occur as a separate procedure. Also, in cases where fistula has already formed, it is highly recommended to proceed with de-epithelialization of the fistula edges (e.g., argon plasma coagulation, cytology brush) before placing the OTSC® in order to promote healthy tissue granulation.

The OTSC® has been almost exclusively used in post-sleeve gastrectomy leaks. A recent systematic review [13] revealed the overall success rate of 86% in the management of laparoscopic sleeve gastrectomy-related leaks/fistula with a clinical success rate ranging between 57% and 100%. Despite the fact that the systematic review included a small amount of associated studies, it is a general conclusion that OTSC® is a safe endoscopic closure device and that its success rate is associated with early endoscopic intervention. Christophorou et al. demonstrated in their multicenter retrospective study that no previous gastric banding, smaller leak/fistula (≤1 cm), a short interval between laparoscopic sleeve gastrectomy and fistula (≤3 days), and an interval of ≤21 days between fistula diagnosis and the first endoscopy are related to most successful outcome [14]. Of course, one must recognize the potential downside of a large metal clip such as the OTSC® when placed—that is if eventual surgical revision is needed, the clip is large, bulky, and hard to dislodge from the tissue, which could complicate surgical techniques utilized to address failed endoscopic leaks.

## Endoluminal Vacuum Therapy

The use of negative pressure wound therapy within the gastrointestinal tract after previous surgery is a novel approach. Endoluminal vacuum therapy ("E-Vac") has been used successfully to treat anastomotic leaks after colorectal surgery [15, 16]. A brief description of the procedure in the upper gastrointestinal tract includes induction of general anesthesia and the use of a standard diagnostic gastroscope. After initial endoscopic assessment, a nasogastric tube is passed through the nose and out through the patient's mouth. An appropriate size piece from a standard sponge (V.A.C.® GranuFoam™ Small Dressing Kit, KCI, San Antonio, TX) is applied, large enough to cover all the holes at the distal end of the nasogastric tube. The foam is wrapped around the end of the nasogastric tube and secured in place with sutures, the most distal of which is left slightly long to create a loop. This is grasped with endoscopic biopsy forceps through the working channel of the gastroscope and withdrawn into the working channel so that the E-Vac device sits side-by-side with the gastroscope. Subsequently, the two together are then manipulated under vision into the pharynx and through the cricopharyngeal muscle down to the defect. The biopsy forceps are used to advance the sponge into the defect, and after that, the external end of the nasogastric tube is connected to a suction pump applying negative pressure. The procedure can be repeated every 48–72 h depending on the clinical response [17].

To date, there has been a number of published case reports and series of patients that show effective management of upper gastrointestinal leaks utilizing E-Vac therapy [17, 18]. Pournaras et al. evaluated 21 patients that had developed leak after gastric or esophageal surgery. Bariatric cases were excluded 95% of the study population completed the treatment successfully with healing of the defect and/or resolution of the abscess cavity. No major complications were noted besides bleeding in two patients [17]. Leeds et al. evaluated the use of E-Vac therapy in patients who developed staple leaks after sleeve gastrectomy. In their paper, they report success rate of

89% in obtaining and maintaining source control with no complications, concluding that the E-Vac therapy is a safe and viable option in that patient population [18]. Our own anecdotal data has shown that E-Vac can help reduce the size of an abscess cavity external to the leak, but keeping the sponge at the level of the leak can be quite a challenge.

### Endoscopic Suturing

Endoscopic suturing systems have gained popularity in the management of bariatric complications such as gastric pouch dilation and weight recidivism. Besides these uses, there are two suturing systems that have been successfully used in bariatric fistula cases: the StomaphyX™ system (EndoGastric Solutions, Inc. Redmond, WA) and the OverStitch™ system (Apollo Endosurgery, Austin, TX). StomaphyX™ was utilized to successfully repair leaks that had developed in two high-risk patients who underwent revisional bariatric surgery [19]. The OverStitch™ device allows for full-thickness suturing achieving tissue approximation in the gastrointestinal tract and has also been used to successfully repair bariatric fistulas [20].

## Management of Strictures

The development of strictures after bariatric surgery is usually considered a late complication and their incidence varies depending on the type of the bariatric operation that had been performed. The estimated incidence rate of post-laparoscopic Roux-en-Y gastric bypass (RYGB) strictures ranges between 3% and 28% [7], whereas post-laparoscopic gastric sleeve stenosis can occur in 0.1–3.9% of cases [21]. This complication is more often located at the gastrojejunal anastomosis after RYGB and less frequently at the jejunojejunal anastomosis, whereas after sleeve gastrectomy is usually located in the proximal sleeve or distally at the angularis incisura. The cause of stricture formation is likely multifactorial and includes tissue ischemia caused by the stapler, edema, or tension during the formation of the anastomosis. The use of a circular stapler in order to perform anastomoses in RYGB patients has been associated with higher stricture rate than those performed with a linear stapler or hand-sewn techniques [22]. Patients usually present with nausea, emesis, dysphagia, and early satiety that can result in malnutrition and weight loss. Besides its use in the diagnosis of stricture, endoscopy has been proven an extremely useful tool in the therapeutic management of the strictures.

### Endoscopic Balloon Dilation

Endoscopic balloon dilation is the most commonly performed endoscopic approach for the management of strictures post-laparoscopic RYGB [23]. These balloons are designed to advance through the working channel of the endoscope with or without a guidewire and are designed from polymers that have the ability to expand to the desired diameter. The size of the stricture is estimated by the ability of the scope to traverse it. Based on that, the appropriate balloon size can be decided. The balloon is positioned at the site of maximum luminal stenosis and then inflated slowly to its maximum diameter. Usually dilation to 15 mm in the first session is safe, and it should be held under tension for 1 min. However, typically, several dilations are required with gradually increasing balloon diameters up to 20 mm in order to achieve resolution of the symptoms. A plethora of recent studies in the literature have demonstrated that endoscopic balloon dilations to treat post-RYGB anastomotic strictures are safe and can achieve a success rate that exceeds 90% [8]. It is worth mentioning that the timing of balloon dilation in patients with gastrojejunal strictures after RYGB might be important in their successful management. Yimcharoen et al. showed that late gastrojejunal anastomotic strictures (>90 days after RYGB) are less amenable to endoscopic balloon dilations, often require multiple endoscopic therapies, and are less likely to resolve without revisional surgery [24].

In patients who have undergone laparoscopic sleeve gastrectomy and developed stenosis, different methods to dilate the stenosis have been used including a Savary bougie and the through-the-scope (TTS) balloon dilatation system (esophageal wire-guided balloon dilatation catheter; Boston Scientific, Natick, MA, USA). Shnell et al. reported a success rate of 44% in patients who underwent TTS balloon dilation under fluoroscopic or endoscopic guidance in order to treat post-laparoscopic sleeve gastrectomy stenosis. Up to three dilatation sessions were required in most of the study patient in order to achieve a maximum and consistent improvement of their symptoms. The study concludes that sequential dilatations are indicated in patients who can demonstrate at least some symptomatic relief after the first treatment and that balloon dilation is a safe procedure that should be considered as an alternative to major surgical intervention [25].

## Endoscopic Stent Placement for Strictures

Besides the previously described use of stents in the management of endoluminal leaks, stenting may also be used in the management of strictures. Eubanks et al. report a success rate of 83% in managing refractory to repeated balloon dilation strictures in six patients that had undergone bariatric procedures (laparoscopic RYGB and laparoscopic sleeve gastrectomy). Following stent placement, 100% of these patients had immediate oral nutrition and all but one were tolerating solid bariatric diet in follow-up of 2.3 months [26]. Aburajab et al. reported long-term resolution of obstructive symptoms in 100% of sleeve gastrectomy patients with stricture after undergoing endoscopic stenting with FCSEMS [27].

As previously mentioned, a common complication after stent application is stent migration which has been reported to occur in up to 66% of stents placed [7]. Another drawback is the need for surveillance with multiple endoscopies to evaluate the correct position and possible reposition of the stent. Moon et al. reported that double stenting or use of OTSC can be utilized to prevent migration of the stents, achieving a 19.5% migration rate. However, 3.4% of the patient population required early removal of the stent due to intolerance and 13.8% developed stenosis after stent placement and removal [28].

## POEM (Per-oral Endoscopic Myotomy) Procedure for Recurrent Symptoms After Previous Myotomy for Achalasia

Heller myotomy (HM) has long been considered the gold standard for the treatment of achalasia. Recurrence of symptoms after HM for treatment of achalasia occurs in 10–20% of patients [29–32]. Historically, these failures have been treated with endoscopic therapies such as pneumatic dilation or with often difficult repeat surgical myotomy. First reported in 2010, Per-oral endoscopic myotomy (POEM) has emerged as less-invasive option for primary treatment of achalasia [33]. POEM has more recently been advocated as a salvage therapy for symptom recurrence in these patients for whom prior surgical myotomy has failed.

Published experience to date has demonstrated the safety and efficacy of POEM in patients with previous surgical myotomy, including those with fundoplication and those with previous thoracic myotomy, in the short and long term [34–42]. Although some data show POEM after HM may be less effective than primary HM, others report clinical response rates similar to primary POEM, with similar complication rates. A large retrospective cohort study comparing patients undergoing POEM with and without prior HM showed a significant difference in success rates between the groups, with 81% clinical effectiveness (defined as Eckardt score $\leq 3$) in the prior HM group and 94% in the group without prior HM at a median 8.5-month follow-up. There was no significant difference in adverse events between the groups [39]. However, Tyberg et al. [41] presented their international experience of 51 patients, with 96% clinical success post-HM POEM, which is similar

to primary POEM. All patients in this study completed at least 1 year follow-up, and mean follow-up was 24.4 months. Similarly, Zhang et al. [40] found no significant difference in clinical success rates between primary and post-HM POEM (95.7 vs. 95.1%). Technical success rates for post-HM POEM in the preceding studies were 98%, 100%, and 100%, respectively. Clearly the data show that in properly selected patients POEM is technically feasible and clinically effective as salvage therapy for recurrent symptoms after failed HM. One important difference to note in POEM performed for recurrent achalasia after HM is that the myotomy is typically performed posteriorly, to avoid the site of the prior myotomy. This has the advantage of being away from the pericardium and without the need to consider leaving the longitudinal (i.e., outer) layer of muscle intact, but the disadvantage of the spine pushing the endoscope laterally and away from the most posterior part of the esophageal wall.

Similar to surgical myotomy, a 10–20% failure rate has been described in patients undergoing POEM [32, 43–45]. Repeat POEM has been advocated as a salvage therapy in patients with recurrent symptoms after previous endoscopic myotomy. The so-called re-POEM has been described with less frequency than POEM for failed surgical myotomy but thus far has been shown to be an effective rescue therapy. Fumagalli et al. [38] presented their experience with re-POEM in 15 patients with recurrent or persistent symptoms after previous POEM. Re-POEM was performed after a mean of 13.5 months (range 4–37 months) following initial POEM, and technical success was achieved in 100% of patients. Only one patient experienced a clinically significant procedure-related adverse event, and 100% clinical success (Eckardt ≤3) was seen at a mean follow-up of 11.3 months. More recently, Tyberg et al. [41] detailed their multicenter, international experience with 46 patients undergoing re-POEM for persistent or recurrent symptoms after initial POEM. Technical success was achieved in 100% of patients. There was 17% adverse event rate, with all adverse events being peri-procedural bleeding managed endoscopically at the time of the procedure. Clinical success (Eckardt ≤3 at 3 months) was achieved in 85% of patients, although it is unclear if this success will persist in the long-term. In both studies, myotomy during re-POEM was made in the opposite orientation from the initial myotomy, most often in the posterior position, as described prior with POEM following HM. Overall, repeat POEM for persistent or recurrent symptoms after initial POEM appears to be a safe and efficacious therapy, but long-term follow-up is needed. Whether repeat failure is due to technical concerns, or that the aperistaltic esophagus simply will no longer empty even with the aid of gravity remains an area of investigation.

Pre-procedure workup and inclusion criteria for POEM after prior myotomy should be similar to primary POEM and should generally include upper endoscopy, upper GI contrast exam, and high-resolution manometry if the diagnosis of achalasia is in question. Alternative causes for symptoms such as GERD or peptic strictures should be ruled out. A diligent review of the medical record should be performed to ascertain the location of the previous myotomy and the presence and type of fundoplication. Attempts should be made to avoid the area of the previous myotomy during POEM, in general utilizing either the posterior or right lateral position for the new myotomy in patients with previous HM and either anterior or posterior position in patients with previous POEM. For patients who have undergone previous HM, Orenstein et al. suggest positioning the patient in near-left lateral decubitus position, rotating the esophagus 60°, and allowing easy access to the 2 o'clock position for the new myotomy [37].

Regardless of previous therapy, POEM after prior myotomy (HM or POEM) should be performed only in experienced centers. It is recommended that practitioners perform at least 30 cases of standard POEM before attempting salvage POEM [35].

## Endoscopic Treatment for Weight Regain After Roux-en-Y Gastric Bypass

Although no longer the most commonly performed bariatric procedure in the United States, Roux-en-Y gastric bypass (RYGB) is still considered by many to be the gold standard in weight

loss surgery, producing excellent weight loss, resolution of comorbidities, and improved quality of life [46, 47]. Long-term studies, however, have shown a trend of weight regain over time, with inadequate weight loss or clinically significant weight regain occurring in up to 35% of patients [48–52]. There is no universally accepted definition for what constitutes clinically significant weight regain, and definitions vary among studies. In a recent survey of 460 bariatric surgeons worldwide, only a minority (31%) of respondents use a fixed definition of significant weight regain, and these definitions were so varied that a common theme could not be identified [53]. Although weight regain after RYGB is certainly multifactorial, anatomic abnormalities such as dilation of the gastric pouch and gastrojejunal (GJ) stoma have been implicated as contributing factors [54–57]. As such, several endoscopic techniques reducing the size of the gastric stoma and pouch have been developed, including sclerotherapy or thermal ablation of the GJ stoma, the ROSE (Restorative Obesity Surgery Endolumenal) procedure, and endoscopic gastric plication utilizing novel devices such as StomaphyX™ (EndoGastric Solutions, Redmond, WA) and OverStitch™ (Apollo Endosurgery, Austin, TX).

Endoscopic injection of sodium morrhuate as a sclerosing agent was first described in the literature in 2003 as a method for inducing scarring and subsequently reducing the diameter of the GJ stoma [58]. However, this has now been largely abandoned as a primary procedure due to marginal weight loss in the long term as well as the tendency toward requiring several sessions to be maximally effective [59–61].

The ROSE procedure is a technique utilizing the Incisionless Operating Platform™ (USGI Medical, San Clemente, CA) and tissue anchors to plicate gastric tissue, thereby decreasing the size of the gastric pouch and GJ stoma. Early experience with ROSE suggested its safety and effectiveness in halting weight regain [62, 63]. Horgan et al. [64] presented data on 112 patients who underwent ROSE for treatment of weight regain. With 86% follow-up at 6 months, an average of 18% excess weight loss (EWL) was seen, which correlated to an average absolute weight loss of 6.5 kg. Similarly, Raman et al. [65] presented a retrospective review of 37 patients with an average EWL of 23.5% at almost 5 months, which correlated to weight loss of 4.2 kg. Whether this meager amount of excess weight loss will be considered acceptable and whether the effectiveness will persist in the long-term remains to be seen. Furthermore, in the two aforementioned studies, the final observed GJ stomal diameter averaged 11.5 mm and 10.3 mm, respectively, which may be too large to see maximal benefit from this procedure.

While initial studies with StomaphyX™ appear promising, longer-term studies have produced mixed results [66, 67]. Goyal et al. [68] performed a retrospective chart review of 59 patients who underwent endoscopic gastric plication (EGP) and reduction of the GJ stoma using the StomaphyX™ device. Of the 53 patients included in the final analysis, the average EWL was only 4.3% at >2 years' follow-up, and 35.8% of patients had actually gained weight compared to their pre-procedure weight. Furthermore, 12 patients underwent endoscopy at an average of 18 months post-procedure and were found to have average GJ stoma diameters of 22.6 mm at that time, compared with 12.3 mm immediately post-procedure, bringing into question the durability of the procedure. In 2014, Eid et al. [69] published a randomized clinical trial comparing endoscopic gastric pouch and GJ stoma reduction using StomaphyX™ to a sham endoscopic procedure. The primary end point was defined as post-procedure reduction in excess BMI of 15% or greater and BMI of 35 or less at 12 months post-procedure. Enrollment was closed early due to preliminary data indicating failure to achieve the primary end point in at least 50% of treated patients. 10 of 45 (22.2%) patients did reach the primary efficacy endpoint at month 12, but similar to the previous study, there was a trend toward decreasing efficacy over time.

More recent studies have focused on full-thickness endoscopic suturing (FTS) using devices such as Overstitch™ alone or in combination with GJ stoma mucosal ablation. A 2017 meta-analysis by Burnaldi et al. included 19 studies with a total of 823 patients who underwent FTS alone, as well as seven studies with 320 patients who underwent FTS combined with GJ

mucosal ablation using argon plasma coagulation (APC). Mean EWL after revision in the long term (≥12 months) was 11% in the FTS-only group, compared with 25% in the FTS + APC group. To date, no randomized controlled trails have been performed evaluating the efficacy of FTS with or without APC, and therefore this meta-analysis is limited to observational studies. Nevertheless, the authors conclude that FTS with the aim to reduce GJ stoma size is an effective treatment for weight regain after RYGB, with greater weight loss seen with the addition of APC.

A 2018 retrospective review was subsequently published of a cohort of 45 patients who underwent FTS using Overstitch™ as well as APC [70]. Fourteen patients who met criteria for intervention but did not undergo the procedure were included in the analysis as a control group. %EWL was significantly higher in the revision group at 6 months, 1 year, and 2 years, with approximately 16% higher EWL in the revision group at 2 years. Maximal %EWL from pre-bariatric surgery weight approached 50%, which was maintained at 2-year follow-up. Interestingly, for each 1mm increase in GJ stoma size after revision, %EWL decreased by about 2%, supporting the hypothesis that GJ stoma size plays a critical role in achieving successful weight loss post-bariatric surgery.

Although clearly an important factor in success after RYGB, there are no current universally accepted GJ stoma size criteria for optimal weight loss. Thompson et al. [71] found that GJ stoma diameter of <10 mm correlated to more than double the excess weight loss (EWL) compared to the remainder of the cohort in patients undergoing endoscopic suturing for stoma reduction. Similarly, Riva et al. [72] saw a statistically significant difference in weight loss between the group with final GJ stoma diameter ≤10 mm and GJ stoma diameter >10 mm. Patel et al. [73] defined technical success of endoscopic suturing for gastric stoma reduction to be a final GJ stoma diameter of 4–10 mm. The recently updated 2nd edition of The SAGES Manual of Bariatric Surgery recommends a final GJ stoma diameter of 10–14 mm and defines a "dilated" stoma to be ≥15 mm [74].

While changes in anatomy can certainly play a role in weight regain, perhaps a more common reason for weight regain is the failure of patients to adhere to nutritional and lifestyle recommendations post-bariatric surgery. Therefore, a consensus of the literature recommends a thorough multidisciplinary evaluation of patients presenting with weight regain, including surgical, dietary, and behavioral health evaluation. Optimization of diet and lifestyle modifications should occur as a primary intervention, and it is advisable to institute a trial period of several months with close dietary and behavioral health follow-up for patients presenting with weight regain after RYGB, prior to performing more invasive investigational studies. If the patient remains resistant to further weight loss after appropriate dietary and lifestyle modifications, further evaluation should be performed. Prior to considering a therapeutic endoscopic procedure, workup with both diagnostic upper endoscopy and upper GI contrast study is prudent to evaluate surgical anatomy as well as to rule out an occult process causing weight regain, such as gastrogastric fistula. Furthermore, many authors would not consider performing endoscopic intervention prior to 2 years from index operation [62, 64, 67, 69, 71–75].

## Novel Endoscopic Therapies for Reflux After Foregut Surgery

Several novel endoscopic therapies for treatment of gastroesophageal reflux disease (GERD) have been developed in recent years, including Stretta® (Mederi RF, Houston, TX) and EsophyX™ (EndoGastric Solutions, Redmond, WA). As both of these have been proven to be effective in treatment of primary GERD, these devices are now being explored as possible treatment options in patients experiencing de novo or refractory GERD after foregut surgery.

Stretta® was the first device approved by the United States Food and Drug Administration for the treatment of medically refractory GERD. It delivers radiofrequency energy to the muscle of the lower esophageal sphincter (LES), which

serves to increase muscle fibers in both size and number, thereby strengthening and lengthening the LES. A 2016 meta-analysis of over 2000 patients showed Stretta® to be a safe and effective therapy for the treatment of GERD [76]. In recent years, Stretta® use has also been described in patients with a history of prior foregut surgery, such as previous antireflux or bariatric surgery. Noar et al. [77] described their experience with 18 patients who underwent Stretta® as therapy for recurrent symptoms after previous laparoscopic Nissen fundoplication. Patient satisfaction at 10 years was 86%, with significant improvements in all categories of GERD-HRQL questionnaire, although 50% of patients remained on daily PPI therapy. Less success has been seen with Stretta® for treatment of GERD post-sleeve gastrectomy. In one group of 15 patients, Stretta® failed to improve symptoms at 6 months, with one complication (6.7%), and a majority of patients were dissatisfied with the procedure [78]. Matter et al. [79] had better success with Stretta in patients with GERD post-RYGB, with five out of six patients having complete resolution of symptoms and discontinuation of medications at 20 ± 2 months (range 15–28 months).

EsophyX™ is a novel device for use in the Transoral Incisionless Fundoplication (TIF) procedure, which attempts to enhance the antireflux valve for treatment of GERD by using polypropylene anchors to plicate fundal tissue to the distal esophagus at the Angle of His. This has historically been described for use as an alternative to surgical fundoplication, but more recently has been suggested for use in post-POEM GERD. Initially described in 2015 in a video case presentation, Tyberg et al. [80] have now detailed their experience with TIF in five patients with post-POEM GERD. At a mean 27 months' follow-up, 5 out of 5 patients were able to discontinue PPIs, and all 3 patients with esophagitis on pre-procedure EGD showed resolution at 3 months' follow-up. A more recent publication detailed a series of 44 patients who underwent TIF [81]. After a median follow-up of 59 months, median GERD-HQRL scores improved significantly from 27 (range 2–45) to 4 (0–26) ($p < 0.001$). 32 of the 44 patients (72.7%) were no longer on PPIs, and these patients were all symptom-free. A 5-year follow-up study on a cohort of 60 patients, 44 of whom were followed up for the full 5-year period [82], was done on the second iteration of the EsophyX™ device [82], which demonstrated GERD-HQRL score reduction from 22.2 to 6.8 at 5 years, a reduction from 100% to 34% PPI usage at 5 years, and resolution of regurgitation seen in 86% at 5 years, indicating reasonable long-term durability of the procedure.

Newer devices such as the MUSE device (Medigus, Ltd., Omer, Israel) and the GERDX system (G-SURG GmbH, Seeon-Seebruck, Germany) lack significant long-term data but are discussed in a recent review [83]. These devices have undergone several iterations to achieve an increase in the lower esophageal pressure, and as such, may not be widely commercially available as of yet. Certainly, early case reports and then long-term data will be needed to determine the future of such products and their role in GERD therapy. From the number of devices coming to market for the treatment of GERD, one can surmise an appetite for an endoluminal treatment that is less invasive than traditional fundoplication, but is more efficacious than PPIs alone.

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# 12 Revisional Foregut Surgery in the Pediatric Patient

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## Repair of Tracheoesophageal Fistula

First described in 1670 by English physician William Durston, esophageal atresia (EA), with or without tracheoesophageal fistula (TEF), is a relatively common congenital anomaly occurring in 1/2500–1/4500 live births, with an overall survival rate greater than 90% [1]. Despite significant improvements in surgical technique since the first successful one-step correction of congenital EA with distal TEF by Dr. Cameron Haight in 1941, postoperative complications with resultant morbidity are not entirely rare, and those warranting operative intervention continue to present a challenge.

Severe anastomotic stenosis (AS), anastomotic leak (AL), and recurrent TEF (RTEF) are all significant indications for reoperation; however, reoperation is not the first line of management for postoperative AS and AL cases [2]. At present, nonoperative management with chest-tube drainage, parenteral nutrition, and broad-spectrum antibiotics is recommended and effective for most cases of AL [3]. Similarly, first-line management for postoperative AS remains to be endoscopic esophageal dilatation and stenting combined with steroid injection to avoid reentry into an adhesed thoracic cavity. While reoperation is required in the setting of AS or AL only for those patients who fail to experience relief of symptoms, it is often mandated by the presence of a RTEF or TEF which remained undiagnosed during the primary repair.

A fistulous communication recurs in up to 5–10% of cases after repair of EA with a TEF [3]. Patients in whom the fistulous communication recurs often present with respiratory complaints, including choking, persistent cough, and recurrent pneumonia, which can result in bronchiectasis and tracheitis with subsequent tracheomalacia [4]. The time to identification of the recurrence may vary from 5 days to over a decade, and the diagnosis can be overlooked as routine contrast studies often do not show the recurrent fistula. The majority of these recurrences are associated with a postoperative esophageal leak and/or stricture requiring subsequent esophageal dilatations following the index operation [4].

Repair of a recurrent TEF poses several technical challenges for the surgeon, an even higher risk of re-recurrence, and postoperative complications including esophageal stricturing and anastomotic leaks. Difficulties in localizing the new fistulous connection further compound the challenges faced in the reoperative setting.

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Evaluation of a patient suspected to have a postoperative TEF should include an esophagram and rigid and flexible bronchoscopy with esophagoscopy [4]. Dual diagnostic imaging allows for localization of the fistula and adequate planning of the operative approach. Repair in the open surgical approach is conducted via either thoracotomy or cervicotomy, depending on the anatomic location of the fistula, followed by lysis of adhesions with completion mobilization of the lung [4]. Esophageal mobilization should be initiated in the less scarred distal esophagus and then proceed with non-cautery sharp dissection of the remainder of the trachea and esophagus to prevent ischemic injury [5]. Following division of the fistula, a simple suture closure of the esophageal defect may be performed in a transverse orientation if no stricture exists. Stricturoplasty or segmental stricture resection is performed in cases of significant stricturing. In the event of a long segment of stricture precluding primary repair, a staged repair for traction-induced esophageal growth or a cervical esophagostomy with subsequent jejunal interposition is recommended [4]. Rotational pexy of the esophagus and/or trachea should be employed to increase suture line separation and thus minimize the risk of re-recurrence [4]. For persistent close apposition of suture lines, tissue interposition consisting of local small flaps of scar, pleural or pericardial tissue, and rarely muscle may prevent re-recurrent fistulization, even in the setting of a postoperative anastomotic leak [5].

Anastomotic complications and recurrence after repair of TEF remain a technical challenge for even the most experienced surgeons making a customized approach to each case essential.

## Pediatric Achalasia

Pediatric achalasia is a rare esophageal motility disorder characterized by the absence of relaxation of the lower esophageal sphincter (LES) as well as absence of peristalsis of the esophageal body [6]. Present in only .01 to .11 cases per 100,000 live births, most data on achalasia management in children is extrapolated from adult experience. Children often present with difficulty eating, nocturnal cough, and progressive weight loss and are treated for failure to thrive, gastroesophageal reflux, and recurrent respiratory infections [7–9]. Surgical repair in the form of a laparoscopic esophagomyotomy with or without partial fundoplication is the preferred management for the pediatric population, with symptomatic relief seen in 77–93% of patients [9]. Surgical failure requiring redo myotomy in 7% of patients might be underestimated as postoperative follow-up is limited to date [10].

## Gastric Fundoplication

Gastroesophageal reflux (GER) is a relatively common condition of infancy and early childhood, with management aimed primarily at reducing symptoms and preventing complications. The majority of cases (>65%) will resolve spontaneously with maturation of the lower esophageal sphincter (LES) around 2 years of age. Those patients who do not experience resolution or who develop complications of the condition—including failure to thrive, respiratory disease, laryngospasm, and esophageal strictures—are considered to have gastroesophageal reflux disease (GERD) [11]. Children at particular risk for severe reflux include those with neurological impairment, repaired esophageal atresia, congenital diaphragmatic hernia, and chronic lung disease [12].

The mainstay of treatment for GERD in the pediatric population consists of dietary and behavioral modifications and medical management. Those patients who remain symptomatic after an adequate trial of conservative management, or who develop significant complications of GERD, may benefit from surgical management of the disease. Antireflux surgery remains relatively prevalent among surgical procedures performed in the pediatric population, with 48,665 such procedures recorded among children in the United States between 1996 and 2003 [13]. As with other types of abdominal procedures, the laparoscopic method has increased in popularity, and robotic-assisted

fundoplication procedures in children have been described [14].

Fundoplication is the primary surgical treatment for GERD in the pediatric population, and both full 360° wraps (Nissen) and partial wraps (Thal and Toupet, among others) have been described. Partial wrap procedures may be particularly useful in patients with a comorbid esophageal motility disorder, to prevent dysphagia resulting from a full wrap. The basic steps of the procedure are equivalent to those used in the adult population: mobilization of the gastroesophageal junction, hiatal dissection and creation of a retroesophageal window, division of short gastric vessels, crural approximation, and creation of a fundal wrap [11].

Long-term outcomes, especially in the era of more predominant laparoscopic surgery, are mixed regarding the efficacy of full and partial wraps. In 2006, Esposito et al. demonstrated similar outcomes between laparoscopic full and partial wraps among neurologically intact children [15]. A prospective, randomized study comparing laparoscopic Nissen and Thal fundoplication noted a higher absolute failure rate (recurrence of reflux symptoms requiring redo fundoplication) among the partial wrap group compared to the full wrap group (5.9% vs. 15.9%) but a significantly higher incidence of postoperative dysphagia requiring dilation in the Nissen group (11.8% vs. 2.4%) [16]. Unfortunately, symptoms of reflux or other complications may persist after antireflux operations, with a higher prevalence of intractable symptoms in neurologically impaired children. One review from a large children's hospital notes that 63% of children who received an antireflux procedure continued to require evaluation for GERD and medical therapy at 2 months postoperatively [17].

Surgical revision may become necessary due to herniation of the wrap through the diaphragmatic hiatus, wrap disruption or "slippage," adhesive bowel obstruction, and excessive tightness of the wrap leading to dysphagia. Data on revisional fundoplication surgery remains slim due to the low requirement for these procedures (generally <10% in pediatric patients), but some reviews suggest around a 70% success rate for revisional fundoplication in children, with a further 70% success rate among those who require a third operation [18]. Revisional fundoplication is a technically challenging undertaking in any population, but reports suggest it can be undertaken with a minimally invasive approach in many patients [19]. Failure past a second revision is often treated with jejunostomy feedings or additional surgery to address underlying gastric dysmotility.

## Gastrostomy Tube Insertion

Farrelly's comprehensive review of pediatric enteral and vascular access provides an excellent segue into a discussion of the indications for revisional surgery after gastrostomy [20]. Gastrostomy tube may be indicated in neonates, infants, and children requiring enteral access for feeding or decompression for greater than 4 weeks duration. Tube insertion may be achieved surgically, endoscopically, or radiologically [21]. For what should be a relatively simple procedure, there is a disproportionately high complication rate, with 30-day emergency department visits at 8.6% and readmission rates at 3.9% [22].

The Stamm gastrostomy, first described in the 1890s, remains the preferred open procedure, and the technique is familiar to most pediatric surgeons. It is carried out through a small upper midline or transverse left upper quadrant incision and includes placement of 2 concentric purse-string sutures around the tube, followed by suture fixation of the gastric serosa to the anterior abdominal. The gastrostomy tube is then brought out through the abdominal wall via a separate stab incision. In recent years, laparoscopic gastrostomy has become increasingly more popular, as has percutaneous endoscopic gastrostomy (PEG) placement [23, 24].

Excluding the wound complication rate, early complications are similar between the open and laparoscopic technique for tube insertion [25]. Tube dislodgement is very common, occurring in up to 65% of patients within the first 5 years [25]. Dislodgement within the first few days of placement (or within the first 2 weeks if positioning

cannot be confirmed radiographically) mandates immediate surgical revision. As children grow, approximately 6% require tube revision for pain or leakage, and that risk is highest in those who underwent tube placement prior to 18 months of age [26].

The introduction of PEG tube placement into the management of the pediatric patient population has brought with it unique complications. Major complications after PEG tube placement are documented in 10–15% of patients between the ages of 1 and 5 years, and many of these require urgent surgical revision [27]. Unrecognized intraperitoneal placement of a PEG tube may result in near-fatal peritonitis requiring urgent laparotomy and subsequent revision. Gastrocolocutaneous fistulae can occur in 1.7–12.5% of patients, resulting in failure-to-thrive and diarrhea, and ultimately require surgical revision [28]. Furthermore, "buried bumper syndrome" has been described with PEG gastrostomies due to excessive pressure or tension and may necessitate surgical revision. In all gastrostomies, but particularly after PEG gastrostomy, tract disruption associated with tube changes may warrant emergent abdominal exploration [26]. Lastly, after elective removal of any gastrostomy tube, the resultant gastrocutaneous fistula may require surgical closure should it persist [29].

## Pyloromyotomy

Idiopathic hypertrophic pyloric stenosis (IHPS) is a commonly treated surgical condition in children, occurring in 2–4 of every 1000 live births [30]. It presents within the first 2–12 weeks of life with a peak incidence occurring during the fifth week of age [31]. There is a higher prevalence among males, preterm births, multiple births, and first-born children [32]. Though it has been hypothesized that a deficiency of nitric oxide synthase in the pyloric muscle causes pylorospasm and hypertrophy of the muscle, the etiology of IHPS is ultimately unknown [31]. Patients classically present with nonbilious projectile emesis with a possible association of a right upper quadrant "olive-like" mass on physical examination. In addition, dependent on the degree of emesis, patients may present with a hypochloremic, hypokalemic metabolic alkalosis on routine laboratory analysis. While it is recognized that IHPS is not a surgical emergency, the mainstay of treatment is highly dependent on fluid and electrolyte resuscitation and balance followed by operative correction of the hypertrophic pylorus [33].

The pyloromyotomy has remained the mainstay of treatment for IHPS over the past century, with an excellent prognosis and low morbidity and mortality [32]. The procedure, as described by Ramstedt, is typically performed by making either a transverse right upper quadrant, vertical, or circumumbilical skin crease incision and delivering the pylorus through the incision. A longitudinal incision is made in the hypertrophied pyloric muscle and the circular muscle must be carefully divided from the stomach to the junction of the proximal duodenum, until bulging of the submucosa is visualized. In recent years, several centers have adopted the laparoscopic approach, utilizing a 3–5 mm trocar at the level of the umbilicus and a stab incision of instrument entry in bilateral lower quadrants.

The incidence of postsurgical failure of pyloromyotomies is reported to be approximately 4% [34]. Such failure exists in the form of an incomplete pyloromyotomy or, rarely, a recurrent pyloric stenosis [35]. Strategies to ensure adequacy of muscle division at index operation include creating a myotomy of approximately 2 cm in length, passage of a 14F catheter through the pylorus into the duodenum, or removal of a section of pyloric muscle from the myotomy edge [36]. While emesis is frequently observed for several days in the postoperative period as a result of pyloric edema, gastroparesis, and gastroesophageal reflux, it usually resolves spontaneously. In the face of early persistent postoperative emesis, an upper GI series should be obtained to rule out duodenal perforation, GERD, or incomplete pyloromyotomy, with the latter being the most likely cause of an early failed pyloromyotomy [35]. While endoscopy-guided balloon dilatation has been successfully

performed, a diagnosis of incomplete myotomy is typically followed by a redo laparotomy to complete the myotomy [36, 37].

Mucosal perforation noted at the time of the index operation may be managed with a muscular and mucosal re-approximation, 180° pyloric rotation, and repeat myotomy, or simply a primary mucosal repair [38, 39]. Such perforation is described in 1–2% of cases in the literature and can be detected intraoperatively with the appearance of bile in the operative field or bubbling noted upon gastric air insufflation [40]. The missed duodenal perforation presents a greater challenge with respect to management and carries with it a higher morbidity. The infant with a missed enterotomy presents with pain, fevers, abdominal distention, and peritonitis. If the enteric leak remains unrecognized, sepsis, shock, and death may ensue; thus, a perforation that is suspected postoperatively requires immediate reexploration with mucosal repair. The incidence of missed perforations after pyloromyotomy is not quoted in the literature and may largely go underreported.

## Repair of Duodenal Atresia

Duodenal atresia and stenosis are surgical diseases of the pediatric population, typically managed with duodenoduodenostomy when technically possible. Both open and laparoscopic techniques have been described, though the technical challenge of intracorporeal suturing and higher associated risk of leak limits the laparoscopic approach to relatively high-volume centers [41]. Regardless of approach, the steps of the operation remain similar: Kocher maneuver to mobilize the duodenum, locating the area of obstruction with an orogastric tube if not visually obvious, mobilization of the distal duodenum if required, exploration of the distal duodenum for any additional obstruction or web, and performance of a side-to-side or diamond-shaped duodenoduodenostomy.

Revisional surgery after repair of duodenal atresia is not common, but a tapering duodenoplasty may be needed to address a persistently dilated and dysfunctional proximal duodenum [42]. One long-term study identified that 9% of children required revisional surgery over a 30-year follow-up period: the most commonly required operation was a tapering duodenoplasty or duodenal plication, but others included conversion of jejuno- or gastroduodenostomy to duodenoduodenostomy and revision of the duodenoduodenostomy [43]. Additionally, 11.8% of the children required abdominal operations for related conditions, including adhesiolysis, fundoplication, and operation for complicated peptic ulcer disease [43].

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