Surgical approach of weight regain after bariatric surgery

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Abstract: Bariatric surgery is the most effective treatment for obesity. A significant long-term complication of bariatric surgery is weight regain. Weight regain is associated with the return of several obesity-related comorbidities and increased economic burden. Surgical complications from the index procedure, such as sleeve and pouch dilatation, expansion of the gastrojejunostomy, "neofundus" formation, or gastro-gastric fistulas, play a major role in the pathophysiology of weight regain. The most frequent mechanisms are the loss of restriction and insufficient malabsorption. Poor adherence to nutritional recommendations, the lack of physical activity and mental disease are also important. Percent of maximum weight loss seems to be the most clinically relevant tool to measure and follow weight regain in the postoperative period. Ten to forty percent of patients will experience significant weight regain after the first 12 to 18 months of sleeve gastrectomy or laparoscopic Roux-en-Y gastric bypass. The evaluation of weight regain is multidisciplinary. Contrasted studies such as an upper gastrointestinal series and upper endoscopy are mandatory. An effective treatment option for weight regain is revisional surgery. However, revisional surgery is technically challenging and is often associated with increased risk of complications. Technical factors from the index surgery and a thorough preoperative evaluation are central to the selection of the appropriate revisional procedure. Endoscopic and robotic platforms are being employed to address revisional surgery.

Keywords: Roux-en-Y gastric bypass; sleeve gastrectomy (SG); weight regain (WR); revision; robotics

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Introduction

Obesity is a rapidly growing disease with significant health burden (1,2). Bariatric surgery has become the most effective treatment for obesity and related comorbidities by decreasing the usage of medications (3,4), promoting diabetes remission (5), improving cardiovascular risk, and reducing mortality (6-10). Furthermore, the advantages of bariatric surgery extend to obese non-diabetic patients (11,12), adolescents, the elderly population, and it may also be beneficial for type 1 diabetics (13-15).

Despite the wide acceptance of bariatric surgery, weight regain (WR) remains an important concern. WR is associated with economic burden, major postoperative morbidity, and poor quality of life (16-23). Moreover, WR is an extremely frequent issue; it is estimated that WR will affect 10–75% of all bariatric patients in the long term (24,25). Still, the

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management of WR remains controversial (26).

Although continuous dietary counseling and psychological support effectively counter WR, surgical complications from index procedures are a common cause of WR that, most frequently, can only be addressed by revisional intervention. Thus, technical proficiency in primary procedures and revisional alternatives to resolve postoperative complications are especially relevant in WR discussion (24,25). In the following chapter we address WR from a technical standpoint. We highlight several pitfalls surgeons should avoid in index procedures and then focus in the revisional options for the two most commonly performed bariatric interventions, sleeve gastrectomy (SG) and Roux-en-Y-gastric bypass (RYGB).

Understanding WR

When significant weight loss occurs, multiple metabolic mechanisms to defend adiposity are activated (27,28). The resting metabolic rate is suppressed, thyroid hormone secretion is reduced, fatty acid conversion to ATP is diminished, and skeletal muscle adapts to spend fewer calories per unit of work (27-29). This physiologic resistance is even greater in obese patients, as they experience a faster rate of fat restoration and must eat fewer calories than individuals without a history of obesity to maintain the same body mass index (BMI) (27). Despite these findings, the exact role of fat homeostasis in weight recidivism after bariatric surgery is unknown (27-29). Interestingly, Santo *et al.* (30) found that patients who experienced WR had less elevation of glucose-dependent insulinotropic polypeptide (GIP) and glucagon-like peptide-1 (GLP-1) levels after meals. Likewise, Tamboli *et al.* (31) have proposed the use of the preoperative measure of ghrelin as a proxy of weight recidivism.

Surgical complications from the index procedure, such as sleeve and pouch dilatation, expansion of the gastrojejunostomy, "neofundus" formation, or gastro-gastric (GG) fistulas, play a major role in the pathophysiology of WR. Two common mechanisms are the loss of restriction and insufficient malabsorption (32-34). In patients with laparoscopic sleeve gastrectomy (LSG), an incomplete resection of the fundus or antrum can lead to the development of a new reservoir (25,35). This can also occur after laparoscopic Roux-en-Y gastric bypass (LRYGB) with pouch or stoma expansion (34). In both cases, the loss of restriction favors the ingestion of larger meals and WR (36-40). On the other hand, short limbs and GG fistulas directly undermine the malabsorptive effects of LRYGB by allowing a close to normal gastrointestinal (GI) transit (41,42). These pitfalls weaken the metabolic advantages of bariatric surgery by reducing gastric emptying, diminishing the secretion of GLP-1 and GIP, promoting the tolerance of dumping syndrome and favoring the upregulation of the secretion of ghrelin (32,43,44).

Other explanations for WR after bariatric surgery lie in maladaptive postoperative behaviors. These conducts may be related to preoperative morbidity or can arise *de novo.* Naturally, poor adherence to nutritional recommendations (45-47), the lack of physical activity (48,49), and the presence of depression, or anxiety (50) will strongly promote WR.

Unraveling contentions

Frequent measures of postoperative weight loss include change in BMI, percent of total weight loss (%TWL), percent excess BMI loss (%EBMIL), and percent excess weight loss (%EWL) (51). Traditionally, success after bariatric surgery has been defined as the achievement of at least 50% of %EWL or the loss of at least 20% of %TWL (52,53). In consequence, "weight loss failure" is conventionally used to describe patients who have failed to achieve "success", while WR is reserved for those who have reached their weight loss goal but failed to maintain their weight in the long term. However, the clinical relevance of 50%EWL or 20%TWL to determine "success" is uncertain (51,54,55).

It seems that %TWL is the more objective measure, as it does not vary among BMI categories or is correlated with preoperative BMI (53,56,57), while the clinical consequences of weight recidivism might be better assessed by the percentage of maximum weight loss (PMWL) (26). In fact, King *et al.* (26) significantly associated a PMWL of less than 20% with diabetes recurrence [relative risk (RR) 1.64, 95% CI: 1.22–2.19] and with a decline in quality of life (RR 1.55, 95% CI: 1.33–1.82).

Surgical evaluation of the patient who is regaining weight

The best approach to surgery in the patient with WR after a bariatric procedure is to consider the technical factors from index operations, long-term complications and behavioral aspects. A multidisciplinary approach and thorough evaluation are paramount. Contrasted studies such an upper gastrointestinal (UGI) series and endoscopic evaluation can provide detail on current anatomy and discern if complications are present (58). Revisional surgery should be considered in cases with aberrant anatomy or when surgical complications are found. In this respect, the review of prior operative notes or direct conversation with the surgeon of the index operation can be useful. In the absence of an anatomical problem, surgeons should rely on behavioral modification and pharmacological intervention with support of a multidisciplinary team. Patients who are at a high preoperative risk of regaining weight, i.e., high baseline BMI, binge eaters, insulin dependent diabetics, black race, etc. Should be closely followed and prophylactically intervened upon (59). Nutritional and psychosocial support are key prophylactic measures to complement the effects of surgery (60,61). During the postoperative period and in the mid to long term, the use of validated weight loss nomograms and planned clinic visits can allow surgeons to detect WR early and provide objective and timely care (62-64).

WR and the index operation

Factors to consider in primary LSG

LSG is conducted by vertically removing ~80% of the lateral stomach to cause alimentary restriction (35,65). The procedure has shown excellent weight loss outcomes with effective comorbidity resolution (9). However, a recent metanalysis of 9 cohort studies with over 600 patients and at least 7 years of follow-up, estimated a WR rate for LSG of 27.8% with a range of 14% to 37% (66). Several anatomical/technical factors have been described as potential causes of WR after LSG and include larger bougie size, incomplete fundal resection, and partial antrectomy (25,35).

Although early reports have failed to find an association between bougie size and weight change (67-69), more recent evidence with larger sample sizes supports the opposite. Abd Ellatif *et al*. (65) retrospectively analyzed 1,395 LSG cases 7 years after surgery to determine long-term predictors of success. After segregating the cohort by the size of the bougie (≤36 Fr n=837, or ≥44 Fr n=558), they concluded that big sizing bougie resulted in greater WR (29 patients, 3.5%, *vs*. 8 patients, 1.4% P=0.001). Likewise, after comparing their 10-year LSG outcomes with two other similar studies (70,71), Chang *et al*. (72) found that the use of 34–36 Fr yielded greater %TWL, %EWL, and lower BMI. As a caveat, smaller bougie sizes (32–36 Fr) have been associated with postoperative complications, increased risk of leaks, stricture, nausea, vomiting, longer hospital stays, and higher readmission rates (68,69,73-75) Hence, a recent expert consensus has recommended a bougie caliber of 36–40 Fr (73).

Beyond bougie size, surgeons must balance the importance of a complete resection of the gastric fundus and antrum while maintaining a safe distance from the gastroesophageal junction and pylorus. An incomplete fundal removal can lead to the dilatation of the sleeve and "neofundus" formation (33,43,76), while a loose antrectomy may allow the future development of a new reservoir (36-38). A recent systematic review and meta-analysis of six randomized controlled trials and two cohort studies, with a total population of 619 patients showed that antral resection (staple line starting 2–3 cm from pylorus) has better weight loss (%EWL 70% *vs*. 61% at 24 months follow-up; P<0.005), without differences in complications rates *vs*. antral preserving primary LSG (38). However, both, complete antral resection and improper removal of the fundus have been linked with the development of gastroesophageal reflux disease (GERD) symptoms and poor food tolerance (33,36-38).

Factors to consider in primary LRYGB

LRYGB is the current gold standard procedure for the management of obesity (30). This is directly related to its favorable complication risk profile, metabolic benefits, flexible technique, and excellent, sustained weight loss outcomes (77,78). However, most studies following LRYGB patients in the long-term report a WR rate of around 25% to 40% (79-81). From an anatomical/technical standpoint, WR after LRYGB has been postulated to arise from the dilatation of the gastrojejunostomy (stoma), the dilatation of the gastric pouch, or secondary to a GG fistula (34).

Several observational studies have linked WR with stoma dilatation. Abu Dayyeh *et al*. (82) evaluated the GI anatomy of 165 consecutive patients who underwent upper endoscopy (UE) 5 years after successful LRYGB, and found that each 10-mm increase in stoma diameter was associated with an 8% decrease in the percentage of maximal weight loss. Likewise, Heneghan *et al*. (83) associated abnormal anatomy on UE with WR, after comparing UE results of two groups of LRYGB patients; one that experienced WR, and another that had functional symptoms. Interestingly, the group with WR had a significantly greater pouch length and stoma diameter (71.2% *vs*. 36.6% P<0.001).

Of note, two randomized controlled trials carried out before the studies of Abu Dayyeh *et al*. (82) and Heneghan *et al*. (83) failed to find a correlation between stomal size and weight loss, 12 and 24 months after the index procedure (84,85). Currently, the consensus is that the size of the gastrojejunostomy should be 1.5 to 2 cm (86).

When it comes to pouch size, the evidence is equally ambiguous. Several retrospective observational studies with a follow-up range of 1–4 years have failed to report a significant correlation between %EWL and remnant gastric volume (44,87,88). Nonetheless, prospective studies have found that patients with a smaller pouch configuration from the outset have significantly better weight loss outcomes than those with larger pouches (89,90).

These inconsistencies may be related to pouch configuration. Accordingly, it is theorized that a slower flow rate inside a long, narrow pouch promotes the metabolic effects of surgery by extending gut hormone secretion (39,40).

Finally, WR after LRYGB can also arise in the presence of a GG fistula. GG fistulas diminish the restrictive and hormonal effects of surgery by allowing food to travel the natural GI route. Meticulous transection between the two gastric parts has greatly reduced its occurrence (24). Currently, the incidence of GG fistulas is 1.2% (42). The diagnostic test of choice for GG fistulas is an UGI contrast study, and revisional bariatric surgery is indicated when conservative measures fail or if significant WR is present (42).

WR and revisional surgery

Revisional procedures for LSG

Re-sleeve gastrectomy (ReSG)

ReSG is a revisional option after LSG due to its technical simplicity and the lack of complications such as dumping syndrome, malabsorption, and marginal ulcers (91). ReSG involves the laparoscopic reconfiguration of the gastric remnant to its original capacity of 100–150 mL (91). The largest series to date, by Nedelcu *et al.* (92), reported the results of 61 ReSG cases in patients with poor weight loss (28 patients), WR (29 patients), and gastroesophageal reflux (4 patients). The average BMI and %EWL in the cohort fluctuated from 38.1 kg/m^2 (range, 35.2–59.8 kg/m^2) and 51.2% (±26.2%), before revision, to 29.8 kg/m^2 (range, 20.2–41 kg/m^2) and 62.7% (±29.2%) 20 months after surgery. These findings have been corroborated by other observational trials (93-95).

Although there are no publications directly evaluating robotic reSG, a large study has reported the outcomes of robotic conversions of several index procedures to SG (96). These findings may help predict the safety and efficacy of robotic surgery if applied to reSG. Acevedo *et al.* (96) matched demographics, ASA classification and preoperative comorbid conditions of 788 revisional laparoscopic SG cases with 788 robotic SG cases from the MBSAQIP database. After analysis, robotic-assisted revisional SG (rRSG) was associated with a significantly longer operative duration (143.8±56.6 *vs.* 106.9±47.4 min, P<0.0001) and a higher rate of postoperative sepsis (1.0% *vs.* 0%, P=0.04). Moreover, although postoperative length of hospital stay (LOS) was similar between techniques (1.8 *vs.* 1.9 days; P=0.43), rRSG was associated with a nonsignificant increase in the incidence of several complications including higher rates of conversion, 30-day reoperation, and 30-day readmission (96). Further studies are needed to validate these results. Until more evidence is available, the robotic platform should be reserved for more complex revisional surgery involving RYGB or biliopancreatic diversion with duodenal switch (BPD-DS).

LSG to LRYGB

LRYGB is considered the gold standard revisional option for LSG (91). Technically, conversion to LRYGB from LSG is not complex, as the procedure is carried out following standard primary technique (97-99). However, the surgeon must be aware of adhesions, especially to segments 2 and 3 of the liver. Also, careful inspection of the left and right diaphragmatic crus is recommended to check for hiatal hernias, especially in patients with GERD symptoms. Usually, gastric pouch volume is reduced to <50 mL, and the roux limb is positioned antegastric, antecolic. Finally, roux limb length is adjusted depending on the patient's characteristics and weight loss needs.

To date, most case series reporting weight loss outcomes after conversion to LRYGB are small (*Table 1*). Generally speaking, LRYGB is a safe, feasible, and effective revisional option for LSG, with most patients experiencing satisfactory weight loss at a mean follow-up of ~18 months (97-104). LRYGB has proven to be particularly effective to overcome GERD, as over 90% of patients report symptom remission after surgery (98,99,102,103).

Several authors have reported their experience with the conversion of restrictive procedures to RYGB in the DaVinci platform (105-110). The findings of the two largest series to date specifically assessing the results of robotic revisional RYGB (rRRYGB), are encouraging (108,110). Rebecchi *et al.* (110) reported the outcomes of 68 rRRYGB cases, 1 year after surgery. Ten patients (14.7%) were converted from laparoscopic adjustable gastric banding (LAGB), 43 (63.2%) from vertical banded gastroplasty

Table 1 Weight loss outcomes in the literature after the conversion of LSG to LRYGB (97-103)

Reference	Patients (WR or IWL)	Pre-LSG BMI (kg/m^2)	Mean interval between LSG and LRYGB in months	Pre conversion BMI (LRYGB) (kg/m^2)	Mean follow-up after conversion in months (LRYGB)	BMI at final follow-up (kg/m^2)	Pre-conversion % EWL	% EWL at final follow-up
AlSabah *et al.* (100)	36 [12]	52	N/A	41	12	36	37.9%	61.3%§
Antonopulos *et al.* (101)	144 [83]	N/A	43.2 (16.0–132.0)	41.7 (29.4–60.1)	12	32.5 (19.1–45.6)	20.7% (0–65.9%)	61.2% (−10% to 142.9%)§
Casillas *et al.* (97)	48 [27]	45.8†	26 [2–60]†	40.8	24	N/A	40.5%	35.4%‡
Quezada *et al.* (98)	50 [28]	36.4 (34.0–40.0)	49 [24–67]†	35.4 (33.9–37.9)	36	28.6 (24.0–36.0)	15.5% (5– 27%)	70.5% (36–92%)§
Iannelli *et al.* (99)	40 [29]	47.7 (37.8–66.0)	32.6 (8.0–113.0)	39.2 (34.0–50.0)	18.6 (9.0–60.0)	30.7 (20.8–43.0)	29.7% (10–52.9%)	48.6% (4.6–102.7%)‡/64.5% (24.1–103.0%)§
Carmeli *et al.* (102)	19 [10]	44.5 (±5.1)	36.2 (±17.4)	39.8 (±5.7)	15.6 (±9.0)	30.0 (±4.8)	28% (±16.4%)	66.6% (±33.9%)§
Homan *et al.* (103)	43 [11]	50 [40–59]	30 [9–56]	39 [36–48]	34 [14–79]	N/A	34% (8–60%)	57% (20–91%)§

All data is specific to the fraction of patients in each cohort with WR or IWL unless otherwise indicated. Data is presented as means. Ranges are in parenthesis. †, data from entire cohort; ‡, calculated using patients' weight on the day of revision (LRYGB) as initial weight; §, cumulative %EWL using patient weight before LSG as initial weight. LSG, laparoscopic sleeve gastrectomy; LRYGB, laparoscopic Roux-en-Y gastric bypass; WR, weight regain; IWL, insufficient weight loss; BMI, body mass index (kg/m^2); %EWL, percent excess weight loss; N/A, not available.

(VBG), and 15 (22.1%) from SG. Overall, 23 patients (33.8%) were intervened due to weight loss failure. The mean operative time in the cohort was 265.6 (±54.1) min, the mean LOS was 5.5 (±3.9) days, and no postoperative anastomotic leak or transfusions were recorded. Although morbidity was 8.8%, there was no mortality. Regarding weight reduction, mean %EWL 1 year after rRRYGB was equivalent to revisional LRYGB at 55.4% (±34.7%) (110). Likewise, Bindal *et al.* (108) retrospectively reviewed 32 patients undergoing robotic conversion to RYGB from restrictive primary procedures. The indication in 20 (62.5%) patients was WR. Their results were consistent with the findings of Rebecchi *et al.* (110). The mean operative time was 226 (±45.3) min, average LOS was 3 days, and there was no mortality, leaks or gastrojejunal (GJ) stenosis. Moreover, in the subgroup of patients with weight loss failure, the mean %EWL at 1 year of follow-up was 53.8%, and 60.7% 2 years after the intervention (108).

rRRYGB seems to be safe and effective when compared with laparoscopy. Beckmann *et al.* (109) retrospectively compared 41 rRRYGB cases with 18 revisional laparoscopic RYGB (rLRYGB) cases in terms of 30-day postoperative morbidity. They found that robotic interventions lasted, on average, 37 min less, were associated with a significantly lower increase in postoperative C-reactive protein (CRP) levels, and had an overall lower rate of complications (7.3% in rRRYGB *vs.* 22.2% in rLRYGB) (109). Similarly, after a 1:1 case-control matching of 668 laparoscopic and 668 robotic revisional RYGB cases from the MBSAQIP database, Acevedo *et al.* (96) reported equivalent rates of mortality, morbidity, and 30-day adverse outcomes between the groups. However, they associated robotic-assisted RYGB with a significantly longer operative duration (186.6±68.0 *vs.* 151.4±67.6, P<0.0001) (96).

The potential benefits that robotics may bring to revisional RYGB are exciting; however, its true role remains uncertain (96,106-111). Although early evidence shows that rRRYGB has at least a comparable safety and efficacy profile to rLRYGB, the robot's overall superior costs plus a likely increased operative time may not justify its use (96,110,111). A thorough risk-benefit assessment is recommended. Structured guidelines for patient selection and prospective randomized controlled trials are needed.

LSG to BPD-DS

BPD-DS is a two-staged, technically challenging surgery, with significant restriction and malabsorption. Briefly, the procedure starts with the division of the stomach under standard SG technique, followed by the transection of the duodenum 2–3 cm post-pyloric, above the gastroduodenal artery. Reconfiguration of the gastrointestinal tract is completed with the construction of an end-to-side duodenoileal anastomosis and a side-to-side ileoileal anastomosis. A 150-cm alimentary limb (AL) and a 100-cm common channel (CC) are standard (112). To avoid excessive weight loss and malnutrition, the surgeon may consider leaving a rather generous gastric sleeve, especially if remnant gastric dilation has not occurred. This will help counter malabsorption and balance weight outcomes.

Revisional BPD-DS has demonstrated to achieve greater weight loss than rLRYGB, without a significant increase in complications (102,103,113). Homan *et al.* (103) retrospectively analyzed and compared data from 43 patients who underwent either BPD-DS (n=25) or LRYGB (n=18) after failed primary LSG. Although they found a non-significant predominance of vitamin and mineral deficiencies in patients who underwent revisional BPD-DS (18 *vs.* 8 patients; P=0.107), BPD-DS demonstrated greater %EWL than RYGB at a median follow-up of 34 months (72% *vs.* 54%; P=0.02). These results are consistent with earlier findings by Carmeli *et al.* (102) who also reported better post revisional %EWL in BPD-DS when compared to LRYGB (80% *vs.* 65.5%). Regarding complications, the authors comment on two patients that had significant nutritional deficiencies after robotic BPD-DS (rBPD-DS), while no nutritional problems were encountered after rLRYGB (102).

There is scarce evidence on robotic revisional surgery of restrictive procedures to BPD-DS (106,114,115). Gray *et al.* (106) compared robotic *vs.* laparoscopic revisional procedures and included three patients in their robotic group who underwent conversion of SG to BPD-DS. Similarly, in the series of Moon *et al.* (114), the authors report five cases of conversion from adjustable gastric banding (AGB) to BPD-DS with the DaVinci platform. Lastly, an early report of robotic surgery in the revisional context describes the successful conversion of a female patient from LAGB to PBD-DS (115). Although safety can be inferred by the lack of description of major complications in the studies by Gray *et al.* (106) and Moon *et al.* (114), outcomes are uncertain. Further data is warranted to make any conclusions.

LSG to single anastomoses procedures

Single anastomosis procedures carry the theoretical benefit of reducing the complexity of revisional surgery without compromising outcomes. Early results from observational studies show that revisional single anastomosis duodenoileal bypass (SADI) is a feasible and effective revisional option for failed LSG (116-118). In the series of Sanchez-Pernatute *et al.* (118) 16 patients underwent a SADI procedure as a second step after LSG and achieved a mean %EWL of 72% 2 years after conversion. Likewise, in a prospective study by Balibrea *et al.* (116), the %TWL of 30 consecutive super obese patients increased from a mean of 28.1% at the time of revisional SADI to 46.26% at 24 months follow-up. Moreover, conversion to SADI may achieve better weight loss outcomes than rLRYGB, while maintaining a similar complication profile (117). Despite this, some authors have associated SADI with severe hypoalbuminemia (116); therefore, close surveillance after surgery and careful patient selection is warranted.

When it comes to mini-gastric bypass as a secondary intervention, evidence is largely lacking (119-121). Even though preliminary results show promise, its benefits over other established revisional options are uncertain (119-121). Recently, Poublon *et al.* (120) retrospectively compared data form 185 one anastomosis gastric bypass (OAGB) cases with 306 LRYGB cases after failed restrictive procedures (LAGB, LSG), and found a larger %TWL in the OAGB group *vs.* the LRYGB group, 24 months following conversion (23.9% *vs.* 20.5%; P=0.023). However, this difference did not reach statistical significance 36 months after surgery (22.5% *vs.* 17%; P=0.056). Likewise, even though the cumulative rates of early and late complications were equivalent between groups (OAGB *vs.* RYGB; 9.2% *vs.* 12.4%; P=0.227), biliary reflux was significantly more prevalent in the OAGB group. It is difficult to conclude on the paucity of evidence available.

Endoscopic revision of LSG

Endoscopic suturing or plication has been proposed to reduce gastric sleeve diameter, however, this approach is yet to be validated (122). Even though endoscopy is an attractive, minimally invasive solution, its long-term durability must be confirmed before it can be recommended as a revisional operation after LSG.

Revisional procedures for LRYGB

Gastric pouch banding (GPB)

GPB or salvage banding, is the simplest revisional option for failed LRYGB. Technically, compartmentalization of the pouch is achieved by placing an adjustable or non-adjustable silicone ring just distal to the gastroesophageal junction. This increases gastric restriction and promotes weight loss (123). Despite achieving satisfactory weight reduction in the short and mid-terms (%EBMIL 47.3% at 1–3 years follow-up) (123), early reports of revisional GPB were fast to reveal alarming high rates of slippage, erosion, and re-revision (124,125). Two recent studies evaluating secondary GBP after failed LRYGB have confirmed these findings (126,127).

Gastric pouch and stoma resizing

Laparoscopic pouch resizing (LPR) entails the reconfiguration of the gastric remnant with or without a redo of the gastrojejunostomy. Similar to GPB, this procedure aims to restore restriction by reducing the size of the pouch or stoma to <30 mL in volume and/or <1.5 cm in length, respectively (123). It is uncertain if LPR improves weight loss after failed LRYGB. In the series of Iannelli *et al.* (128), 20 LRYGB patients were followed for a mean of 20 months after undergoing secondary LPR. Notably, the cohort reached an average %EWL of 69% at final follow-up. Conversely, Hamdi *et al.* (129) could not find statistically significant weight loss after analyzing 25 LRYGB patients 2 years after revisional LPR, moreover, weight at final follow-up was equivalent to pre-revision values (pre-revision %EWL 39.8% *vs.* post-revision %EWL 42.7%). Two other series with a similar number of patients and short follow-up times have also reported mediocre results (130,131). These differences may be related to variations in technical approach (pouch trimming *vs.* pouch and stoma size reduction *vs.* pouch reduction and stoma rebuild), small sample sizes, insufficient follow-up, and high attrition at final follow-up. Larger controlled trials with standardized technique are needed to estimate the real impact of LPR.

Data on rRRYGB to specifically address a failed primary RYGB is scarce. Most cases of redo robotic RYGB are mentioned as part of comparative studies evaluating laparoscopic *vs.* robotic surgery (105,106,111,132). Gray *et al.* (106) found that robotic conversion from an stapled procedure (VBG, SG, RYGB) was associated with a shorter LOS (average of 2 days less than laparoscopy), with a trend towards decreased operative time (193±41 min robotic *vs.* 238±81 min laparoscopic). Conversely, in their comparative analysis of 35,988 laparoscopic with 1,929 robotic revisional cases, including 105 (5.4%) robotic revisions of GJ anastomosis and 676 (35.0%) rRRYGB procedures, Clapp *et al.* (111) found longer operative time (167.7 *vs.* 103.7 min; P=0.001) and LOS (2.3 *vs.* 1.7 days; P=0.004) for robotic procedures. Both studies, however, found equivalent 30-day adverse events, mortality and major complications rates between the groups (106,111).

To our knowledge, the only study specifically evaluating the outcomes of rRRYGB after primary RYGB is the report of Diaz-Vico *et al.* (132), who published their experience with robotic-assisted redo gastrojejunostomy due to stoma stricture in nine RYGB patients. The results of this study are consistent with pooled reports (105,106,111). The cohort's mean operative time was 184.5 (range, 122–231) min, and the median LOS was 2 (range, 1–4) days. No conversions or deaths were recorded. Twenty-four months after surgery, all patients had complete resolution of symptoms and successfully recovered their nutritional status (132).

Stoma reduction and endoscopic procedures

Intraluminal procedures have been proposed as incisionless options to manage gastrojejunostomy and pouch enlargement. The general principle of these interventions is the reduction of gastric capacity and stoma size through tissue plication (133-139).

Technically, the most straightforward technique is transoral outlet reduction (TORe). TORe involves the placement of suture patterns around the dilated stoma to reduce its diameter. Unfortunately, results have been disappointing. Jirapinyo *et al.* (135) evaluated 252 TORe cases 12 months after the intervention and found a %TWL of 8.4% (±8.2%). Moreover, a metanalysis of relevant studies by Vargas *et al.* (134) found a pooled absolute weight loss at 18–24 months of only 8.4 kg (95% CI: 5.9–10.9). Similar outcomes have been reported after longer follow-ups (133).

A parallel technique to TORe is restorative obesity surgery endoscopy (ROSE). ROSE is an intraluminal procedure that uses anchors to create tissue folds at the stoma/pouch wall and promote alimentary restriction. The results from the few published series evaluating ROSE are not different from those in TORe. Horgan *et al.* (139) reviewed data from 116 LRYGB patients 6 months after ROSE and found a mean %EWL of 18%. Likewise, Raman *et al.* (138) described a final %EWL of 23.5% in 37 consecutive patients after an average follow-up of 4.7 months.

Other endoscopic alternatives are sclerotherapy and endoscopic gastric plication (EGP). Sclerotherapy involves the intraluminal injection of a sclerosing agent into the GJ anastomosis to trigger scar formation and reduce the stomal aperture. Despite theoretically promising, the evidence does not support this technique (123,137). In a large series of 231 patients who underwent sclerotherapy as a revisional procedure for WR, average weight loss at 6 months follow-up was only 4.5 kg (137).

On the other hand, EGP is a procedure similar to ROSE that employs polypropylene fasteners within the StomaphyX (EndoGastric Solutions, Redwood City, CA, USA) device to create gastric plications. EGP was evaluated by Eid *et al*. (136) in a single-center, single-blinded randomized controlled trial that compared StomaphyX to a sham procedure in post-LRYGB patients. Although the study planned to randomize 120 patients, enrollment was terminated early because of poor preliminary results. At the closing of the study, 75 patients had completed follow-up. Of those, 45 had been randomized to the StomaphyX arm but only 10 (22%) achieved the primary efficacy endpoint (pre to post StomaphyX decrease of %EBMIL >15% and BMI <35 kg/m^2, 1 year after revision).

Although endoscopic revision is a safe and reasonable option, mid-term results have been discouraging. A possible explanation for this may be poor long-term durability of plications as folds likely become undone. Another potential reason could be that an arbitrary location and number of plications cause some patients to receive "insufficient treatment".

Conversion to distal LRYGB D-LRYGB)

The surgical modification of gastric bypass anatomy to enhance malabsorption is known as D-LRYGB. D-LRYGB is a very effective revisional procedure, however, it carries an important risk of malnutrition (140-145). There are two main techniques of performing revisional D-LRYGB; type 1 D-LRYBG and type 2 D-LRYGB (123,141,142). Regardless of the method used, surgeons must pay special attention to the lysis of adhesions to identify the underlying anatomy (112). Also, bowel limbs must be carefully measured and marked by running the bowel both antegrade from the gastric pouch and retrograde from the ileocecal valve (112). In type 1 D-LRYGB, the jejuno-jejunostomy is taken down at the alimentary side, and the AL is then reconnected 150–200 cm proximal to the ileocecal valve. This results in an AL of 100–150 cm (original length), a CC of 150–200 cm, and a long, usually unmeasured biliopancreatic limb (BPL) (123). Conversely, in type 2 D-LRYGB, the jejuno-jejunostomy is taken down at the biliopancreatic side, and the BPL is then reconnected ~ 75 cm proximal to the ileocecal valve. This yields a CC of ~75 cm, a BPL of ~25 cm (original length), and a long, usually unmeasured AL (123). Despite these pointers, changes in surgical technique and modification in limb lengths are common.

The findings of Rawlins *et al*. (145) and Brolin *et al*. (144) underline the importance of the length of the BPL. Both studies evaluated weight loss after revisional D-LRYGB following primary gastric bypass, however, Rawlins *et al*. (145) employed a long BPL, while Brolin *et al*. (144) opted for a long AL. Even though Rawlins *et al*. (145) reported a %EWL of 60.9% at 1 year and 68.8% 5 years after conversion, 20.7% (n=6/29) of the patients in their series developed significant protein-calorie malnutrition. On the other hand, although the results of Brolin *et al*. (144) were modest (%EWL of 48% 1 year after conversion), protein-calorie malnutrition was only evident in 7.4% of the cohort (n=4/54).

Recently, van der Burgh *et al*. (142) proposed a modified D-LRYGB in which an extended AL (250–300 cm) was coupled with a short CC (100 cm). After following 44 patients for a mean of 34 months (range, 12–58 months), average %TWL had increased from a pre-revisional value of 12% to 26% (P<0.01), cumulative %EWL at final follow-up was 60%, and more than 50% of the cohort experienced remission of diabetes (67%) and hypertension (50%). However, 89% of patients had nutritional deficiencies, 14% developed severe protein-calorie malnutrition, 16% reported debilitating diarrhea, and in five patients (11%) the CC had to be lengthened to 250 cm due to intractable diarrhea (n=3) or severe malnourishment (n=2). Interestingly, after proximalization, all five patients recovered. The deleterious effects of a short CC (100–150 cm) have also been described in other series, notably, 10% to 20% of patients with short CCs have had to undergo reoperation due to nutritional morbidity (140,141,143).

LRYGB conversion to BPD-DS

Conversion to BPD-DS is a challenging surgery that may be performed as a single or two-staged intervention. Similar to D-LRYGB, the goal of the procedure is to promote additional weight loss through malabsorption. Technically, the conversion of LRYGB to BPD-DS shares many steps with the previously described LSG to BPD-DS. The main difference is that BPD-DS after LRYGB requires normal anatomy to be first reconstructed. Hence, the surgery starts with the reestablishment of gastric continuity by taking down the gastrojejunostomy. Then, a modified SG is performed, and from there the procedure continues as already described. During conversion, surgeons should pay special attention to the lesser curve gastric vessels that feed the new gastrogastrostomy and SG (91).

Due to high technical complexity, evidence regarding conversion to BPD-DS from LRYGB is scarce. Moreover, the few available studies often describe technique variations to ease the procedure (146-148). Therefore, conclusions are difficult to draw. Several recent studies have proposed alternatives to BPD-DS that are similar in concept, these include conversion to single anastomosis duodenal switch (SADS) (147), BPD-DS with a hybrid sleeve that employs the roux limb (146), and singe anastomosis duodenoileal bypass with sleeve (SADI-S) (148).

Still, the two largest available studies that report outcomes after conversion to classic BPD-DS have found excellent %EWL. Keshishian *et al*. (149) followed 26 LRYGB patients for an average of 30 months after conversion to BPD-DS and found a cumulative %EWL of 67%. Likewise, Parikh *et al*. (150) performed BPD-DS in 12 patients and report a %EWL at 11 months of 63%. Of note, 13% of patients in the study of Keshishian *et al*. (149) experienced gastrogastric leak, while 33% of those enrolled in the study of Parikh *et al*. (150) developed a gastro gastric stricture.

Recently, Halawani *et al*. (151) reported their experience converting nine RYGB cases to BPD-DS, with four cases being robotically-assisted. All patients were intervened due to WR. Even though no mortality, leaks, reoperation or readmission over 30 days postoperatively were recorded, the operative time in robotic cases was on average longer than in their laparoscopic counterpart (average of 418 *vs*. 339 min). Moreover, the final average %EWL at 16 months of follow-up was similar between the two techniques (average %EWL in the robotic cases was 62.7% *vs*. 65.24% in laparoscopy). Although the robotic platform offers improved visualization, resistance to fatigue, increased range of motion, and better articulation; further studies with complex cases are needed to confirm the real benefit of these advantages in patient outcomes (106,111,114).

Conclusions

WR after bariatric surgery is a challenging, multifactorial complication. For primary LSG, surgeons should keep in mind that postoperative gastric volume is inversely correlated with WR, however, bougie sizes smaller than 36–40 Fr will not provide greater benefit and carry an increased risk of leaks. It is more important to perform an appropriate resection of the gastric fundus than simply focus on the bougie size. Also, during the index operation, surgeons should prioritize avoiding leaks, alimentary intolerance, and GERD over aggressively preventing WR. Hence, we recommend against extremely tight fundal removals and total antrectomies. A probable safe distance from the pylorus to start gastric division for antrectomy is 4 to 5 cm.

Regarding primary LRYGB, surgeons should aim to create a pouch no larger than 30 mL as there is a clear relationship between poor weight loss outcomes and larger pouches and stoma sizes. On the other hand, the diameter of the GJ anastomosis should not be smaller than 25 mm, as smaller stomas do not carry greater weight loss benefit and have a higher risk of stricture/ulceration.

In the postoperative period, patients should be closely followed and supported with continuous nutritional counseling and psychosocial motivation. All WR patients should undergo multidisciplinary assessment, including imaging and endoscopic evaluation to determine the underlying anatomy. We support ReSG in patients who do not have GERD, and who present with demonstrated stomach dilatation of at least 250 mL. For patients who present with GERD complaints or have a neofundus on imaging, the conversion to RYGB may be appropriate. BPD-DS can be reserved for patients with BMI ≥50 kg/m^2.

GPB and stoma resizing may have a place in carefully selected patients with failed LRYGB, where pouch or gastrojejunostomy dilatation is demonstrated. Surgeons should be specially weary of biliopancreatic and CC limb lengths when performing distalizations of LRYGB and conversion to BPD-DS. We cannot recommend endoscopic revisional procedures for either LSG and LRYGB on the available evidence. The robotic platform is best suited for complex, high-risk patients.

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