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REVIEW

Multidisciplinary Approach for Weight Regain—how to Manage this Challenging Condition: an Expert Review

Maria Paula Carlin Cambi[1] · Giorgio Alfredo Pedroso Baretta[1] · Daniéla De Oliveira Magro[2] · Cesar Luiz Boguszewski[3] · Igor Braga Ribeiro[4] · Pichamol Jirapinyo[5] · Diogo Turiani Hourneaux de Moura[4,5]

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Abstract

Weight regain is a multifactorial condition that affects many patients following bariatric surgery. The purpose of the paper is to review the multidisciplinary approach for the management of weight regain. We performed a search in current clinical evidence regarding the causes, consequences, and treatments of weight regain. The multidisciplinary approach with periodic monitoring is of fundamental importance to prevent or treat weight regain. Several therapeutic options are ranging from nutritional to surgical options, which should be tailored according to patients' anatomy, lifestyle behavior, and compliance. Specialized multidisciplinary care is the key to achieve optimal long-term weight loss and maintenance goals following bariatric surgery.

Keywords Weight · Obesity · Weight regain · Bariatric surgery

Introduction

Weight regain is a common phenomenon following bariatric surgery [1–3], and it is observed in longitudinal studies associated with the recurrence of obesity and comorbidities, including type 2 diabetes [2]. The causes of weight regain are multifactorial with the main contributing factors being the lack of lifestyle changes, patient adherence to the support groups, and preoperative body mass index (BMI) [1–3]. Many bariatric patients remain sedentary and do not significantly change their eating habits following surgery [2]. Currently, there is no consensus regarding the definition of weight regain [4]. Weight regain has been associated with deterioration in health-related quality of life, the re-emergence of type 2 diabetes, and other comorbidities [4].

There are at least seven definitions of weight regain: (1) an increase BMI to ≧ 35 kg/m^2 after successful weight loss; (2) an increase > 25% excess weight loss (%EWL) from nadir; (3) EWL < 50% after experiencing ≧ 50% EWL; (4) an increase > 10 kg from nadir; (5) maintaining < 20% of total weight loss (TWL); (6) an increase > 15% of total weight initially lost; and (7) an increase in BMI of 5 kg/m^2 above the weight loss nadir [2, 4, 5].

✉ Igor Braga Ribeiro
igorbraga1@gmail.com

Maria Paula Carlin Cambi
mpcarlini@hotmail.com

Giorgio Alfredo Pedroso Baretta
giorgio.baretta@gmail.com

Daniéla De Oliveira Magro
danimagro@terra.com.br

Cesar Luiz Boguszewski
clbogus@uol.com.br

Pichamol Jirapinyo
pjirapinyo@bwh.harvard.edu

Diogo Turiani Hourneaux de Moura
dthmoura@hotmail.com

[1] Clínica Baretta, Curitiba, Brazil

[2] Department of Surgery, Faculty of Medical Sciences, State University of Campinas UNICAMP-SP, Campinas Sao Paulo, Brazil

[3] Department of Internal Medicine, Federal University of Parana, Curitiba, Brazil

[4] Gastrointestinal Endoscopy Unit, Hospital das Clínicas, University of Sao Paulo School of Medicine, Av. Dr Eneas de Carvalho Aguiar, 225, 6o andar, bloco 3, Cerqueira Cesar, Sao Paulo 05403-010, Brazil

[5] Division of Gasteoenterology, Hepatology and Endoscopy, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA

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An increase greater than 15% of TWL may occur in 25–35% of patients at 2 to 5 years following bariatric surgery, the majority of which are associated with the return of comorbidities. [6] Weight regain was observed within 24 months after surgery in approximately 50% of patients. Seven year follow up of 2348 patients, 1738 with Roux-en-Y gastric bypass (RYGB), and 610 with laparoscopic adjustable gastric band (LAGB), showed that there was weight loss in both procedures; however, in RYGB, the prevalence of comorbidities (dyslipidemia, type 2 diabetes, and systemic arterial hypertension) was lower. Among RYGB trajectory groups with weight regain, mean 3-year weight loss ranged from 22 to 44% of baseline weight, followed by the mean year three to seven regain ranging from 3 to 6% of baseline weight [6].

Surgical failure is defined as %EWL ≤ 50% or BMI > 35 kg/m^2 for severe obese and EWL ≤ 50% or BMI > 40 kg/m^2 for superobese. Both weight regain and surgical failure was higher in the superobese group [3, 7].

Management of weight regain includes medical, endoscopic, and surgical revision. Medical management usually involves care by the multidisciplinary team including the surgeon, nutritionist, endocrinologist or obesity medicine physician, psychologist, psychiatrist, and physical educator. Endoscopic management has several treatment options such as argon plasma coagulation (APC), with or without full thickness endoscopic suture. Revisional surgery is an option in the setting of weight regain usually performed in patients that did not respond to medical and endoscopic management. [8]. Surgical revision can have the risk of complications such as primary surgery and mortality [8]. All advantages and disadvantages of each approach must be presented and discussed with the patient [9–11]. Endoscopic management is a treatment option for patients with weight regain who do not want to undergo surgical treatment again and should be discussed in the multidisciplinary context [12].

This article aims to present different viewpoints and treatment options of a multidisciplinary approach for the management of weight regain following bariatric surgery.

Causes of Weight Regain after Bariatric Surgery

Weight loss occurs rapidly in the first months following bariatric surgery, with most patients reaching their nadir weight at 1 year as shown in the Swedish Obese Subjects study [12]. In another multicenter study with a 7-year follow-up, weight increased from the third year after surgery. [6]

Overall, bariatric surgery remains the most effective treatment approach for weight loss. Specifically, RYGB is associated with an average of 38 ± 7% TWL, sleeve gastrectomy (SG) with 26 ± 10% TWL, and LAGB with 21 ± 10% TWL [12]. However, within 10 years, patients with RYGB regain 34%, and those with LAGB regain 38%, of the maximum weight initially lost [9]. Success of weight loss following RYGB is closely related to the reduction in gastric pouch size, which provides a decrease in daily caloric intake and absorbed nutrients. Hormonal mechanisms with decreased ghrelin secretion and increased glucagon like peptide-1 and peptide YY may contribute to early satiety and decreased hunger, further leading to weight loss, although the exact mechanism is not completely understood. For SG, there is no increase in ghrelin secretion until 5 years after the surgery [13, 14]. The factors that may contribute to weight regain are listed in Table 1.

Multidisciplinary Intervention for Weight Regain

Obesity is a chronic inflammatory disease that requires a multidisciplinary approach for its management. Although bariatric surgery is effective at treating obesity, weight monitoring following the procedure is essential. When weight regain occurs, the patient should be evaluated in the multidisciplinary clinic prior to referral to the rest of the bariatric team according to the description below [13–15] (Fig. 1).

Nutritional Assessment

Nutritional evaluation is an important initial assessment for weight regain. It is important to know the date of the operation, whether the patient has had regular follow-ups, weight before the surgery, and nadir weight. These visits may be made in person, as well as virtually, such as via phone calls, and online platforms to increase adherence and reduce the number of required staff [15, 16] (Table 2).

Several nutritional deficiencies may be present in patients with weight regain. Common deficiencies include deficiencies of vitamin B_{12}, vitamin A, zinc, vitamin D, increased parathyroid hormone, and decreased prealbumin [17]. Additionally, physical assessment is required (Table 3) [18]. It is not uncommon for female patients of reproductive age to have severe iron deficiency and anemia. Many have irregular menstrual cycles and do not take iron supplements. It is necessary to ensure adherence to all nutritional and vitamin supplements [19]. In postoperative, iron deficiency and anemia were associated with low one-year weight loss. Fatigue is a common symptom of anemia and may explain the sedentary behavioral tendencies both in pre- and post-surgery. Correcting iron deficiency before surgical treatment of obesity may decrease fatigue and contributed to physical activity, fostering greater weight loss. [20–22]

Some eating behaviors may lead to weight regain. The nutritionist should evaluate these conditions and provide tools to help patients resume healthy eating habits [23, 24] (Table 4).

Protein deficiency may lead to muscle loss and decreased satiation and satiety. Therefore, protein supplement is important starting from the liquid feeding phase immediately

Table 1 Predisposing factors and possible causes of weight regain

Preoperative factors	Postoperative factors
High initial Body Mass Index	Loss of follow up with the multidisciplinary team
Personality disorders such as eating disorders, depression, anxiety, and substance abuse	Metabolic and hormonal imbalance
Presence of type 2 diabetes	Psychiatric comorbidities such as binge eating and grazing
Older age	Use of psychiatric drugs

following surgery. Although there is no consensus regarding the ideal amount of protein supplement, it is recommended that patients should take 1.05 g/kg of ideal weight or 60 to 120 g of protein per day [25, 26]. Nutrition education may be conducted using the Bariatric Plate Model [27, 28] and Bariatric Traffic Light System [29], which focus on the intake of high-quality proteins, as well as vitamins and minerals. Table 5 summarizes how patients should eat to prevent and/or minimize risks of weight regain.

Microbiota and Bariatric Surgery

In the general population, gut microbiota consists of Bacteroidetes (~25–40%), Firmicutes (~40–65%), Proteobacteria (~5–10%), and Verrucomicrobia phyla (<1%) [30, 31]. In some studies, it has been demonstrated that patients with obesity have a lower proportion of Bacteroidetes and a higher proportion of Firmicutes (an increased F/B ratio) [32, 33], although this finding has not been shown consistently [10, 34, 35].

Microbiota dysbiosis, defined as an increase or decrease in specific bacterial groups, has been identified in some patients with overweight and moderate obesity [36–38]. This dysbiosis can be reversed with certain weight loss interventions, such as bariatric surgery [37].

Studies have shown that following bariatric surgery, the microbiota composition changes. Specifically, *Firmicutes phylum* (*Blautia*, *Dorea*, *Ruminococcus*), which are dominant in patients with obesity, decreases following RYGB. On the other hand, Proteobacteria (*Escherichia, Klebsiella*), *Verrucomicrobia* (*Akkermansia*), and *Bacteroidetes* (*Alistipes*) increase following RYGB [39]. Microbiota changes after bariatric surgery indicated

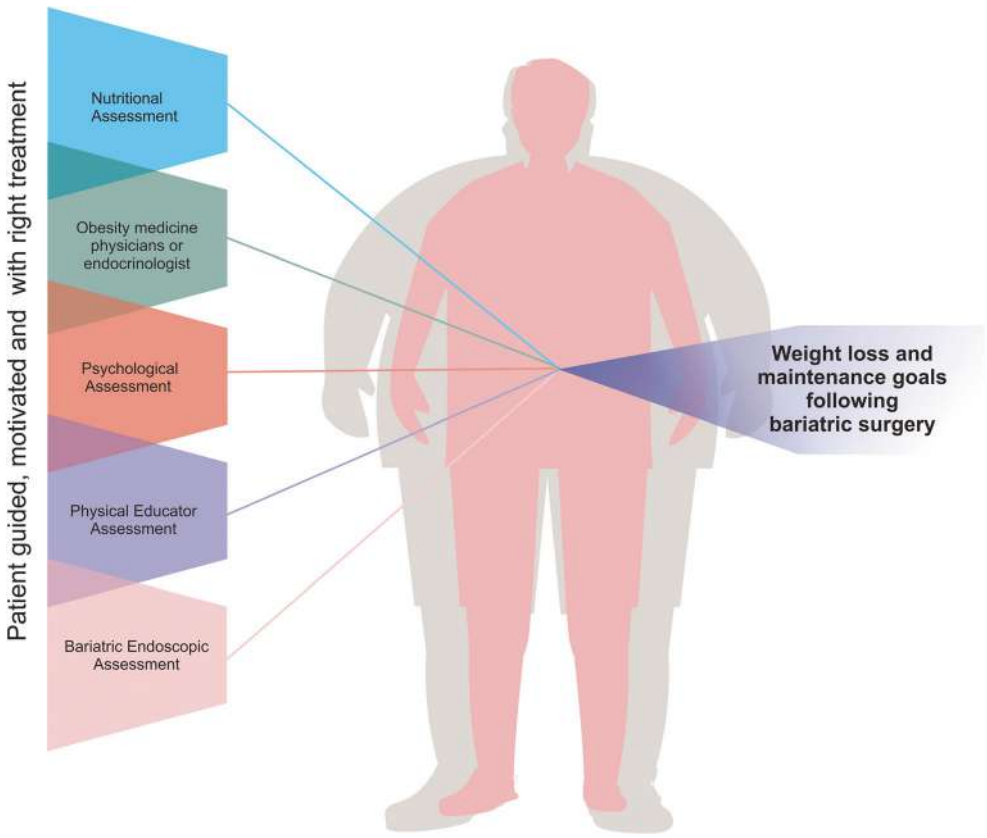

Fig. 1 Multidisciplinary team

Table 2 Data from the nutritional assessment of patients with weight regain

Recommended
Age, gender, race, height, weight (determine the nadir, when and how much weight regain, and compare with the percentage of weight lost), body mass index
Body weight history
Bioelectrical impedance
Use of medicines and supplements (vitamins, minerals, and proteins)
Laboratory tests: complete blood count, iron, ferritin, copper, ionized calcium, zinc, magnesium, vitamins A, C, B_{12} and D, prealbumin, glycemia and glycated hemoglobin, total cholesterol, and fractions, consider adding PTH, B1
24-h food record (include weekend)
Water intake, including juice, soda, and alcohol consumption
Physical examination
Physical activity
For women: menstrual cycle and parity

a profound modification of bacterial gut composition 6 months postoperative in parallel with weight loss. RYGB had greater impact on microbiome composition than SG [40]. The change in gut microbiota composition is thought to contribute to a decrease of body weight, BMI, and fat mass, in addition to improving metabolic and inflammatory parameters, such as fasting glucose, glycated hemoglobin, homeostasis model assessment, C reactive protein, monocyte chemoattractant protein-1, and tumor necrosis factor α, respectively [38–41].

In reviewing the literature, few studies assessed the role of microbiota in management of postoperative weight regain. Faria et al. showed difference in the gut microbiota profile of individuals who underwent RYGB with weight regain or not, five to 7 years after surgery. Individuals without regain presented an increase in Verrucomicrobia and a decrease in Proteobacteria compared with those who regained weight. According to the authors, the anatomical barrier due to surgery may prevent the proliferation of bacteria related to obesity. [37]

In addition to changes in microbiota composition, metabolomic studies have revealed a decrease in short chain fatty acids (SCFA) to branched chain fatty acid ratio after RYGB, suggesting an increase in amino acid fermentation [42, 43]. The abundance of Bacteroidetes in the gut microbiota has been directly associated with the fecal concentration of SCFAs, especially propionate, butyrate, and acetate fatty acids [44].

The various rates of SCFA production from fibers may explain the observed difference in the SCFA ratio within the population. Specifically, types of SCFA generated in the intestine depend on the types of fiber consumed as well as the specific composition of the gut microbiome, which metabolize those fibers [45].

Resistant starch leads to more butyrate whereas pectin leads to more acetate and propionate. Interestingly, soluble fiber supplementation relates mostly to the potential to increase the production of SCFAs via microbial fermentation [46]. Patients who underwent bariatric surgery may benefit from diets containing these specific types of fibers to increase and maintain microbial diversity for a long period. *Phascolarctobacterium* (an SCFA producer) and *SMB53* (contributes to obesity) are specific to eating habits and related to weight loss or weight regain, respectively. [37]

Administration of probiotics, prebiotics, and symbiotics has been described as potential treatment strategies for patients with obesity. Nevertheless, the exact mechanisms of these gut microbiome interventions on obesity treatment remain unclear [39, 47, 48]. Some studies showed that 4-month probiotic administration after mini gastric bypass surgery improves inflammatory markers, body weight loss, and status of vitamins B12 and D [49]; however, these effects disappeared at 9 months after cessation of therapy [48]. Furthermore, the dosage and duration of microbiota therapy remain unknown for patients with obesity and weight regain [50, 51].

Table 3 Physical assessment of a weight regain patient

Organ	Aspect	Possible diagnosis
Hair	Thin, opaque, brittle	Protein malnutrition Biotin, silicon, vitamin A or zinc deficiency
Skin	Lifeless, flabby	Protein malnutrition, essential fatty acids deficiency
Eyes	Hipped mucosae Decreased visual acuity	Iron deficiency, anemia, Vitamin A deficiency
Nails	Spoon shaped With white stripes Brittle	Iron deficiency, anemia, protein malnutrition, biotin, silicon, vitamin A or zinc deficiency
Memory	Forgetfulness Difficulty with concentration	Megaloblastic anemia
Hands and feet	Constant tingling	Megaloblastic anemia

Table 4 Nutritional management for weight regain

Feeding mistake	Nutritional behavior
Inadequate chewing	Observe dentition. Encourage consumption of solid diets such as leafy vegetables, steaks. Chew greater than 20 times prior to swallowing. Practice mindful eating
Consume hypercaloric liquids such as sodas, milkshakes, alcoholic beverages, smoothies, and sweetened juices	Demonstrate the caloric value of these liquids and propose new alternatives that are nutritious and of low caloric value. Referral to psychiatrist if alcoholism is suspected
Do not meet daily protein requirement	Encourage consumption of fresh foods rich in iron, calcium and proteins, and whey protein (in powders and enriched yogurts) to promote preservation of muscle mass and the basal metabolism rate
Do not take prescribed nutritional supplements	Review nutritional status through laboratory tests and replete vitamins, minerals, and fibers if needed. Offer alternatives for supplements such as gums, tablets, pills, gel tablets/pills, and liquids to provide better adherence to use
Consume high carbohydrate or high glycemic index diets	Propose new nutritional education through the Bariatric Plate and Traffic Light Model

In summary, few studies have evaluated weight regain and intestinal microbiota after bariatric surgery; however, publications direct the role of intestinal microbiota in the loss and maintenance of late weight loss.

Endocrinologist Assessment

Weight loss medications may be used off label for the treatment of weight regain following bariatric surgery.

Table 5 Bariatric traffic light

NUTRIENTS (in order of importance)	GREEN (allowed to consume)	YELLOW (consume moderately)	RED (avoid as much as possible)
Proteins	Iron-rich proteins: lean meats such as chicken breast, knuckle, topside, outside flat, tenderloin, whitefish (all grilled, baked, or cooked)	Medium fat, iron-rich proteins: visible fat meats, fish such as salmon.	Fat & iron-rich proteins: rump cover steak, hump steak, pork, bacon, jerked beef, fried chicken, battered fish.
	Calcium-rich proteins: milk and low-fat derivatives such as skimmed milk, white cheese, cottage cheese, ricotta, unsweetened yogurt, and fat.	High-fat, calcium-rich proteins: semi-skimmed milk, mozzarella cheese	Calcium-rich proteins: whole milk, highly fat yellow cheeses such as gouda, parmesan, Swiss, etc.
Vitamins, minerals, and fibers	Highly colored and nutrient-rich fruits, vegetables, and beans.	Fruits and vegetables, juices.	Battered vegetables, sugary fruits.
Carbohydrates	Low calorie whole grain breads, brown rice and noodles, wholegrain cereals, chia, golden flaxseed, amaranth, oats.	Crackers, noodles, rice, white flour breads, chocolate with 70 to 80 % cocoa.	Sweetbreads, stuffed cakes, desserts, candy in general, chocolates with high fat contents. **Other foods**: general alcoholic beverages, excess margarine, butter, fried foods in general.

Table 6 Weight loss medications

Drug	Action mechanism	Side effects	Regular weight loss annual
Orlistat	Decreases appetite, decreases intestinal absorption by 30%, inhibits pancreatic and gastric lipase	Increases the number of bowel movements and urgencies, flatulence	3 to 4 kg
Phentermine (can be associated with topiramate)	Decreases appetite	Insomnia, affects memory	8.6 kg
Naltrexone (associated with bupropion)	Antidepressant that inhibits dopamine and norepinephrine	Headache, dry mouth, nausea, vomiting, and gastrointestinal discomfort	4.8 kg
Liraglutide	Glucagon like peptide 1 (GLP 1) maintains normal glucose levels and induces postprandial satiety, decreases gastric emptying time, and decreases appetite	Nausea, vomiting, diarrhea, constipation, dyspepsia	5.8 kg

Nevertheless, currently there is no randomized study specifically assessing the role of pharmacotherapy for the treatment of weight regain or insufficient weight loss after bariatric procedures. The current recommendations are based on a few retrospective studies in small groups of patients, with short-term follow ups and significant dropouts. The experience also depends on the hospital settings, as approved weight loss medications vary from country to country [52, 53]. (Table 6).

The effect of orlistat was evaluated in 38 patients who stopped losing weight after 18 ± 6 months following LAGB. Half of the patients were treated with a low-fat diet alone, and the other half with the same diet in addition to orlistat 120 mg before each meal. The amount of weight loss was significantly higher after 8 months in the orlistat-treated group (8 ± 3 kg vs. 3 ± 2 kg; $p < 0.01$) and gastrointestinal side effects were considered minor. Fifteen orlistat-treated patients were observed for an extension period of 9 months (eight on drug and seven off drug) and the weight remained stable for the on drug and off drug groups [53].

Two small retrospective studies have examined the role of liraglutide for post-bariatric surgical weight regain. Pajecki et al. [54] evaluated 11 women and four men with EWL <50% or > 15% regain from the nadir weight following RYGB ($n = 9$), LAGB ($n = 4$), and biliopancreatic shunt ($n = 1$) or SG (n = 1). Liraglutide dosage ranged from 1.2 to 3.0 mg/day with the treatment duration ranging from 8 to 28 weeks. The average weight loss was 7.3 kg (range 2–18 kg). Six patients had nausea and two discontinued therapy due to the cost of medication. Wharton et al. [55] evaluated 117 bariatric patients (53 RYGB, 50 LAGB, and 14 SG), to whom liraglutide 3.0 mg/day was prescribed for weight regain. Over 7.6 ± 7.1 months of follow up, patients lost 6.3 ± 7.7 kg, which was not related to the type of surgery they had. Nausea was reported in 29.1% of the patients [55].

Phentermine at a dose of 37.5 mg daily was used for 90 days in 52 bariatric surgery patients who experienced weight regain or weight loss plateau after RYGB ($n = 41$) or LAGB ($n = 11$) [48]. The average weight loss was 6.35 kg (range 4.25–8.44 kg). In the same study, topiramate (initial daily dose 23 mg, maintenance daily dose 46 mg) was used in conjunction with phentermine (initial daily dose 3.75 mg, maintenance daily dose 7.5 mg) in 13 patients. This group experienced a significantly greater weight loss in comparison to other groups (3.8 kg: range 1.1–6.5 kg). There were no serious adverse events [56]. Topiramate has been shown to promote a significant weight loss in a retrospective series of 16 patients with binge eating disorder and insufficient weight loss after LAGB [57].

In a study including 319 patients (gastric bypass = 258; sleeve gastrectomy = 61), 15 different medications were prescribed, including phentermine, topiramate, zonisamide, metformin, bupropion, orlistat, sibutramine, liraglutide, exenatide, pramlinitide, naltrexone, lorcaserin, phentermine + topiramate, canagliflozin, and bupropion + naltrexone. Patients treated with topiramate were twice as likely to lose at least 10% of their weight, and patients who underwent RYGB were significantly more likely to lose ≥5% of their total weight with the aid of weight loss medications [58]. In another study with 428 patients who underwent RYGB, 79.2% had a mean weight regain of 10% with symptoms of hypoglycemia and not adhering to dietary treatment. [59]

In summary, pharmacotherapy appears to be effective at promoting weight loss in patients with insufficient weight loss or weight regain following bariatric surgery. Nevertheless, larger, and randomized studies are warranted to further investigate the role of medications for the treatment of weight regain.

Psychological Assessment

According to Karmali et al., mental health and weight loss outcomes have a linear relationship. Psychological assessment

in the preoperative period is important to identify appropriate candidates for surgery, as well as to prepare them for post-surgery counseling and lifestyle changes. Some countries use assessment by both the psychologist and psychiatrist, while Brazil and the USA use either [8].

There is no standard psychological profile of severely obese individuals, but evidence has shown that obese patients seem to differ from the general population in that they have greater difficulty with impulse control [8].

Weight relapse is multifactorial and includes metabolic and endocrine changes, anatomical surgical failures, nutritional deficiencies, physical inactivity, and mental health problems. The extent and importance of these factors are currently uncertain and are likely to vary between individuals and the surgical procedure performed. Several observational and non-randomized studies and some randomized clinical trials have been reported with a focus on improving postoperative weight loss. In all behavioral and supportive group studies, patients in the treatment groups showed no modestly greater benefit or weight loss than patients in the control groups. There are no randomized clinical trials that specifically target weight recovery. Additional clinical research is needed to identify etiological factors and intervention strategies. [1]

Cognitive compartmental therapy seems to be effective in reducing risk factors for weight regain after bariatric surgery, such as disordered eating behavior and depression [60].

One study evaluated 117 adults with an age range of 21 to 56 years, at the postoperative 12th–98th months with several tools (Night Eating Questionnaire, Dutch Eating Behavior Questionnaire-Emotional Eating Subscale, Eating Disorder Examination Questionnaire, Eating Concern Subscale of Eating Disorder Scale, and Beck Depression Inventory), and showed that 13.7% of participants regained weight. The results displayed that depression, night eating, emotional eating, and eating concern scores were higher in the participants with less weight loss. Being married, emotional eating, and time elapsed after the surgery positively predicted, while knowledge on the amount of daily nutrients needed negatively predicted weight regain. [61]

Psychological assessment needs to focus on the patients' true motivations to undergo the surgery, their commitment to lifestyle changes, emotional connection with food, stress level, family, and other social support [14]. Identifying patients with eating disorders such as binge eating disorder, substance abuse, post-traumatic stress disorder, depression, and anxiety are also the focus of the assessment. When these conditions are suspected, further investigation should be pursued to ensure the stability of the condition before bariatric surgery.

A study demonstrated that binge eating disorder and grazing are associated with inadequate weight loss and weight regain after RYGB [14] and LAGB [16]. Consumption of small amounts of food several times a day, without the discipline of real food fractionation, makes it difficult to control food intake.

Grazing, which is excessive pinching, is present in 31% of patients after RYGB. The reasons range from stress, boredom, and emotional changes. Mindful eating, which consists of developing awareness for healthy food choices, understanding physical hunger, emotional hunger, and satiety, can be an effective tool. [62]

Mindful eating is a key component of behavioral therapy that does not aim at diets and restrictions, but at paying full attention to the food experience, observing the smell, texture, and taste of the food. It makes plans for guided meditations to understand the focus of food awareness, identifying the emotional triggers that lead the patient to eat rampantly, as well as manage desires, careful analysis of the cause and effect of what one eats, the reason behind each behavior, and alternative paths without judgments or restrictions [62, 63].

However, psychological factors and stressors can cause weight regain and impair the patient's judgment regarding their eating habits. A study with weekly psychological interventions for 6 weeks in patients with depression, binging, and alcohol abuse showed improvement in dietary patterns with reduced binging episodes [64].

Therefore, psychological and psychiatric evaluation is a key component of weight regain management as it allows the providers to recognize and treat any emotional triggers that lead to eating disorders and subsequently weight regain. Additionally, any pre-existing illnesses that may have been neglected such as depression, anxiety, and bipolar disorder that directly affect food intake must be assessed and treated [65, 66].

Physical Educator Assessment

As there is no guideline on the prescription of physical exercises after bariatric surgery, in general, 150 to 250 min per week of moderate to vigorous exercise (1200 to 2000 Kcal per week) is recommended to prevent weight relapse, and more than 300 min per week for maintenance after weight loss [67, 68].

After 30 days since bariatric surgery, routine exercise is recommended with a combination of weight training and aerobic exercise. The patient who remains sedentary may lose muscle mass more rapidly, while maintaining their fat mass. This leads to inefficient energy expenditure, resulting in less weight loss in the long term [69].

Physical inactivity is another possible cause of weight regain. Following bariatric surgery, patients may lose more muscle mass and should be counseled to perform routine exercise and take adequate amounts of protein daily. Physical inactivity affects vital organs and directly impacts the health of muscles and bones. The human body is programmed to function better when it receives stimuli, so a sedentary lifestyle may lead to worsening of body functions [69].

A systematic review with observational studies identified a relationship between the level of physical exercise and greater weight loss after bariatric surgery. Patients undergoing vigorous and frequent physical exercise suggest association with greater weight loss following bariatric surgery. [70]

However, by randomizing 76 women after gastric bypass, it was found that the implementation of a vigorous physical exercise routine for 150 min per week associated with a good dietary protein supply (1 g/kg of ideal weight per day) complemented with the use of whey protein improves muscle strength, but not necessarily weight loss and ponderal maintenance [71].

Physical activity is a vital part of weight management programs for enhancing weight loss, maintaining ideal body weight, and preventing weight regain [71].

An active lifestyle of at least 150 min weekly should be strongly encouraged in patients with weight regain. With the assistance of a physical educator, routine physical activities and exercises should be created to fit an individual's lifestyle and preference [72].

Bariatric Endoscopic Assessment

Endoscopic Assessment

Upper gastrointestinal endoscopy is part of the assessment of a patient with weight regain after bariatric surgery, allowing the evaluation of altered anatomy and surgical complications such as gastrogastric fistulas [73, 74]. The endoscopic approaches vary depending on the surgical technique. In this topic, endoscopic management of patients with weight regain after RYGB and SG are discussed.

a) Weight regain after RYGB:

Several studies have already demonstrated the correlation of patients with larger pouch size and the larger diameter of the gastrojejunal anastomosis (GJA) increased postoperative weight gain. [75–78].

Endoscopic treatments are recommended in patients with GJA dilatation greater than 15 mm, or gastric pouch dilatation over 5 cm in length. The endoscopic approaches include sclerotherapy [15], APC [11], endoluminal reduction of the GJA and/or pouch with plication or suturing with or without APC [79, 80], and endoscopic submucosal dissection (ESD) with APC and suturing [81, 82]. We will describe below the most used endoscopic techniques:

Sclerotherapy

Sclerotherapy is injection of sodium morrhuate around the GJA using an endoscopic needle to reduce GJA aperture and tissue compliance. This solution is injected in 2-ml aliquots with a total of 10 to 30 ml injected along the rim of the GJA. Bleeding or late perforation can occur. Subsequent sessions are scheduled every 3 months, until the GJA measures less than 12 mm in diameter [15].

Argon Plasma Coagulation

APC is a non-contact electrocoagulation method in which radiofrequency energy is applied to the tissue through ionized argon gas. The process reduces the GJA size and tissue compliance through gastric healing; therefore, it needs a slow and progressive dietary advancement [79]. A systematic review with meta-analysis [83] evaluating 888 patients demonstrated a percentage total body weight loss of 9.0% (95% CI, 4.1–13.9%), 10.2% (95% CI, 8.4–12.1%), and 9.5% (95% CI, 5.7–13.2%) at 3, 6, and 12 months, respectively, with no weight loss difference at 3 and 6 months ($p > 0.05$). Another paper with 30 patients with post-gastric bypass weight regain showing dilation of the gastrojejunal anastomosis for a minimal postoperative period of 18 months. After three sessions of APC in the anastomosis, its diameter was reduced, along with a decrease in final body weight and BMI. [84]

Endoscopic Suturing

The endoscopic suturing device—Apollo Overstitch (Apollo Endosurgery, Austin, TX, USA)—is used to place stitches around the GJA and/or pouch to reduce the size. A systematic review and meta-analysis showed that full thickness suturing (FTS) to reduce the GJA size is effective in treating weight regain after RYGB [79]. Performing APC before suturing appears to result in greater weight loss compared to suturing alone [79]. Kumar and Thompson [85] published their series with 150 patients who underwent transoral outlet reduction (TORe) for weight regain after gastric bypass in a 3-year follow up showing 19.2 + -4.6% EWL. Jirapinyo et al. [86] performed TORe in 331 patients with weight regain after gastric bypass with a dilated GJA. Patients experienced 8.5% + − 8.5%, 6.9% + − 10.1%, and 8.8% + − 12.5% TWL at 1, 3, and 5 years with follow up rates of 83.3, 81.8, and 82.9%, respectively. Brunaldi et al. [87] recently published a pilot single-center open label randomized trial comparing the efficacy and safety of APC alone versus FTS plus APC (FTS-APC). Forty patients were included in two groups of 20 patients each. At 12 months, the mean %TWL was 8.3 ± 5.5% in the APC alone group versus 7.5 ± 7.7% in the FTS-APC group ($p = 0.71$). They concluded that APC alone is similar to FTS-APC in terms of safety and efficacy outcomes at 1 year.

Endoscopic Revision Obesity Surgery

This is a multichannel 54-French instrument that creates full thickness plications to reduce the pouch and GJA size. Jirapinyo et al. [80] prospectively studied 44 patients with weight regain after RYGB submitted to APC around the GJA prior to plication placement. At 1 and 2 years, patients experienced 10.3 ± 7.4% of TWL and 8.4 ± 12.6% of TWL, respectively ($p = 0.01$ for both). They concluded that this procedure appears feasible and safe, with a high response rate and durable weight loss at 2 years. This procedure is good when the pouch >5 cm with dilated GJA < 30 mm.

Endoscopic Submucosal Dissection + Plasma Argon Endoscope + Suturing

A series combining tissue dissection with APC and suturing showed a greater and more durable weight loss for patients with weight regain. In this study, 19 ESD-TORe patients were matched with 57 APC-TORe patients based on GJA and pouch sizes. At 12 months, the ESD-TORe group experienced greater weight loss compared to the APC-TORe group (12.1% ± 9.3% vs. 7.5% ± 3.3% TWL, respectively; $p = 0.036$). Additionally, in regression analysis, ESD remained a significant predictor of TWL percent at 12 months after controlling for age, gender, BMI, weight regain, and years from RYGB ($\beta = 5.99$, $p = 0.02$). [81]

b) Weight regain after gastric sleeve:

Traditionally, endoscopic approaches for the treatment of weight regain have been performed in patients with RYGB anatomy. Nevertheless, given a rising prevalence of SG, endoscopic suturing and plication for the treatment of weight regain following SG is becoming more popular [82]. Eid et al. recently published a series of five patients who underwent revision of FTS for treatment of weight regains after SG [88]. At 1 year of follow up, the mean total loss percentage, EWL, and BMI reduction were 10.6%, 33% and 3.8 kg/^{2}, respectively. There were no serious adverse events, and all patients were discharged 1 day after the procedure.

De Moura et al. [89] presented a retrospective multicenter study including 34 patients with weight regain after sleeve gastrectomy who underwent an endoscopic sleeve gastroplasty to tighten the sleeve to augment weight loss. At 1 year, 82.4 and 100% of patients achieved ≥10% TWL and ≥ 25% EWL, respectively. Mean %TWL was 13.2 and 18.3% at 6 months and 1 year, respectively. No serious adverse events were reported. Additionally, the use of endoscopic plication in the management of these patients has also been described with favorable results.

Moving forward, more studies are warranted to further define the optimal techniques, safety, and efficacy profile of an endoscopic approach for the treatment of weight regain following SG.

Surgical Assessment

There are several revisional surgeries for weight regain following basic bariatric surgery. Nevertheless, to date, there is a lack of high-quality randomized controlled studies on these surgical revisional procedures [90].

The first consensus on revisional surgery was published in June 2019, where 70 bariatric surgeons from 27 countries with extensive experience in revisional surgery gathered. The experts voted on 39 revisional bariatric surgery (RBS)-related issues. An agreement of 70% or more was considered a consensus [90].

To date, SG and RYGB are the most performed bariatric surgeries worldwide. Most surgical re-operations are performed for a variety of reasons, such as complications (malnutrition, marginal ulceration, small bowel obstruction, gastrogastric fistula, leaks, dumping syndrome, severe hypoglycemia; gastroesophageal reflux disease GERD) [91] and failure to achieve clinically significant weight loss (inadequate weight loss, weight regain, inadequate metabolic control).

a) Gastric Bypass:

Several surgical procedures have been described for the revision of RYGB. Techniques include re-establishing restriction by trimming the GJA and/or pouch, placement of an adjustable gastric band around the upper pouch, complete reconstruction of gastric pouch, and GJA [12].

For distal RYGB, surgical revision techniques may include lengthening of the biliopancreatic limb and shortening of the common channel to decrease absorption. The conversion of RYGB to a duodenal switch, which is a more malabsorptive procedure, may also be performed. It is important to note that all revisional surgeries are usually associated with higher morbidity and mortality than the index procedure and with higher risks of nutritional deficiencies such as malnutrition, anemia, alopecia, chronic diarrhea, and foul smelling gases [12].

Nguyen et al. [92] showed good results in weight loss with 30 patients who underwent trimming of the pouch and/or redoing anastomosis (TPA), 8 TPA, and conversion from retrocolic to antecolic Roux limb, and 6 TPA with remnant gastrectomy. The mean follow-up period was 26.1 ± 22.7 months. The post-revision mean %EWL was 38%, and the BMI loss was 7 kg/m^2. In the pre-revision to 48 months post-revision period, mean %EWL and BMI were 28.6% and 4.9 kg/m^2 in the TPA only group, 52% and 8.8 kg/m^2 in the TPA with conversion to antecolic, antegastric group, and 33.4% and 5.9 kg/m^2 in the TPA with gastrectomy group, respectively (%EWL, $p = 0.096$; BMI, $p = 0.227$).

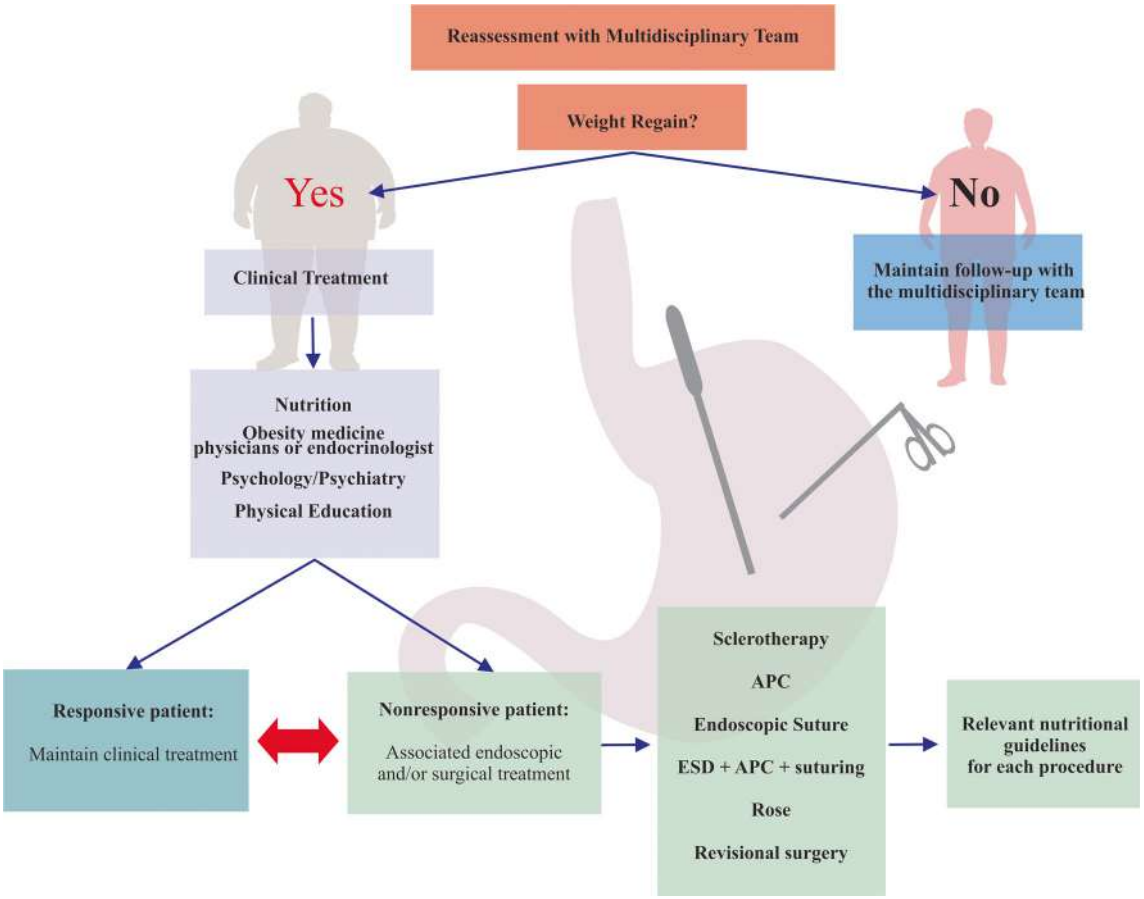

Fig. 2 Algorithm to treatment of weight regain after bariatric surgery

b) Gastric Sleeve:

Surgical revisions of SG involve having the sleeve rebuilt (re-sleeve). Furthermore, SG may be converted to RYGB, duodenal switch, or single anastomosis duodenal ileal with sleeve (SADI-S). Techniques may be chosen based on patients' BMI, the return of comorbidities, and acceptable surgical risk [93].

The benefits of revisional surgery are weight reduction and comorbidity resolution, which was supported by the remission or improvement of diabetes, hypertension, dyslipidemia, and GERD postoperatively. [94, 95] Unfortunately, revisional surgeries are associated with an increased rate of perioperative complications (incarcerated ventral hernia, anastomotic leak, stricture, marginal ulcer, recurrent intussusception, wound dehiscence), as well as mortality [8, 12, 96]. Revisional procedures should be performed by an experienced bariatric surgeon to avoid perioperative and postoperative complications. [95]

Based on a literature review and our experience, we suggest an algorithm for the treatment of weight regain following bariatric surgery (Fig. 2).

Conclusion

Bariatric surgery remains the gold standard for the treatment of obesity, but unfortunately, weight regain is frequently inevitable. The causes are multifactorial and include both pre- and postoperative factors. There are several possibilities for treatments for weight relapse but this is still a challenge for both the patient and the assisting teams, which must involve a multidisciplinary approach including an evaluation by dietitians, psychologists/psychiatrists, endocrinologists, obesity medicine physician (for countries that have this certification), physical educators, endoscopists, and surgeons. The strategies must be updated, and the proposals evaluated individually according to the needs of each patient.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Informed Consent For this type of study, formal consent is not required.

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