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Mohamed Hossameldin Hussein Rushdy Zidan,
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*CORRESPONDENCE
Yixing Ren
yixingren@nsmc.edu.cn

†These authors have contributed equally to this work

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Prognosticating post-bariatric surgery outcomes and management of postoperative recurrent weight gain and diabetes recurrence

He Xiao[1,2†], Yudie Du[1,2†], Yuanyuan Tan[1,2] and Yixing Ren[1,2,3*]

[1]Department of Gastroenterology, Affiliated Hospital of North Sichuan Medical College, Nanchong, China, [2]Institute of Hepatobiliary Pancreatic Intestinal Diseases, North Sichuan Medical College, Nanchong, China, [3]Department of General Surgery, Chengdu XinHua Hospital Affiliated to North Sichuan Medical College, Chengdu, China

Bariatric surgery stands as the most potent treatment for achieving substantial weight reduction and alleviating the complications associated with obesity. However, it is not the treatment of choice for patients with obesity combined with type 2 diabetes mellitus, and the benefit of bariatric surgery varies widely among individuals. There is a noticeable inconsistency in the outcomes following these procedures. The ability to predict how an individual will respond to bariatric surgery is a valuable asset in clinical practice. And the importance of postoperative interventions should not be underestimated. Proactive measures targeting both pre- and post-operative eating habits and lifestyle adjustments are of greater significance than the investigation into pre-operative factors alone. The judicious application of medication, endoscopic intervention and conversional surgeries after bariatric surgery can yield superior outcomes in managing recurrent weight regain and the recurrence of diabetes, albeit with consideration for the associated complication rates.

KEYWORDS

bariatric surgery, type 2 diabetes mellitus, recurrent weight gain, glucagon-like peptide-1, conversional surgery

1 Introduction

Obesity represents a complex and widespread chronic condition, ranking among the most prevalent health issues globally (1). Bariatric surgery (BS) has become the most effective intervention for the treatment of obesity. However, many patients yet suffer from the postoperative complication of recurrent weight gain (RWG). It is important for those patients to increase their moderate to vigorous physical activity (MVPA) to mitigate RWG (2). And dietary interventions are significant since irregular eating habits are linked to RWG (3). Anti-obesity drugs can act as a potent supplementary treatment following BS, aiding in enhancing weight reduction after the procedure or averting the RWG (4, 5). Furthermore, laparoscopy intervention is a minimally invasive and safe treatment for RWG which provides sustainable weight loss (6). Conversion of previous BS may be necessary in instances of RWG and the presence of complications while conversional surgery has greater morbidity than primary surgery (7).

Furthermore, bariatric surgery is also capable of alleviate type 2 diabetes mellitus (T2DM). A range of predictive models have been utilized to forecast the remission of T2DM, including Individualized Metabolic Surgery (IMS) (8), ABCD score (9), the Diabetes Remission

(DiaRem) and the Advanced Diabetes Remission (Ad-DiaRem) (10). However, some patients may present complication of T2DM recurrence (11). Regarding the management of this postoperative complication, exercise is connected with the decrease of blood glucose (12) and the American Diabetes Association (ADA) advocates for individualized eating plans in nutrition therapy (13). Currently, there is no standardized pharmaceutical treatment for managing recurring T2DM, but emerging data may assist physicians in selecting appropriate medications (14). Additionally, conversional surgery was found to markedly control blood glucose with higher risks of complications compared to the primary surgery.

Our study provides a narrative review of the factors that can predict weight loss, remission of diabetes, and strategies for managing the post-BS RWG and diabetes recurrence.

2 Predictors of postoperative outcomes

2.1 Predictors of postoperative weight loss

The extent of weight loss variation is likely influenced more by biological elements that affect neuro-endocrine processes, as well as psychological factors that impact eating habits (15). It is probable that a sophisticated interaction between biological and mental processes plays a significant role (15). An increase in age has often been identified as a factor that predicts a reduced weight loss outcome post-surgery (16–19). Elder people often exhibit a decreased basal metabolic rate coupled with a reduction in physical activity (20). Additionally, as age advances, there is a growing challenge to alter established dietary and lifestyle habits, which leads to a less significant reduction in weight (21). A higher starting BMI typically correlates with a more substantial absolute weight loss (22). However, when weight loss is measured relatively, those with a higher initial BMI may experience a smaller percentage reduction (23–26). Specifically, patients with T2DM tend to achieve less weight loss (17, 23).

A majority of research on preoperative weight loss has yielded either negative or inconclusive findings. In a randomized controlled trial, Kalarchian et al. (27) compared patients who underwent a 6-month behavioral lifestyle intervention with those who received standard pre-surgical care. They found no significant discrepancy in post-operative weight reduction between the two groups. Similarly, Krimpuri et al. (28) have noted that the predictive power of pre-operative weight loss diminishes gradually by the one-year mark. Several retrospective studies have also failed to find compelling evidence that pre-operative weight loss is reliable for predicting post-operative weight loss (29–31). The American Society for Metabolic and Bariatric Surgery (ASMBS) has concluded that few medical evidence can support the notion that preoperative weight loss offers any advantage in terms of bariatric surgery outcomes (32). Meanwhile, Mocanu et al. (33) supposed that prroperative weight loss is needed since they verified that a reduction in weight prior to surgery correlates with better chances of survival within 30 days and a decreased likelihood of postoperative leaks. Tolvanen et al. (34) discovered that individuals who have made efforts to lose weight demonstrated enhanced cognitive restraint in their dietary habits which highlights the critical need for pharmacological and psychological assessments before BS.

2.2 Predictors of postoperative T2DM remission

T2DM remission is characterized by a spontaneous or intervention-induced return of hemoglobin A1c (HbA1c) levels to below 6.5% (or less than 48 mmol/mol), which is maintained for a minimum of 3 months without the diabetes medications (35). Effectiveness of Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) in decreasing blood sugar levels in obese patients with uncontrolled T2DM had been proven (36). The likelihood of remission can differ based on the specific surgical procedure performed. Furthermore, factors such as the duration of T2DM, pre-operative C-peptide levels as well as HbA1c levels have been identified as predictors of T2DM remission (8, 37).

Additionally, various scoring systems have been devised to estimate the likelihood of diabetes remission for individual patients. Aminian et al. (8) utilized a dataset comprising T2DM patients who accepted RYGB and SG procedures to create a nomogram that generated an Individualized Metabolic Surgery (IMS) score which was used to evaluate the effectiveness of different surgical techniques in achieving diabetes remission rates across various stages of T2DM severity. Lee et al. (9) introduced the Diabetes Surgery Score, also known as the ABCD score, which takes the age, C-peptide levels, BMI, and T2DM duration of patients into account. The ABCD score demonstrated prominent specificity and accurant predictivity, while it only targeted the Asian group. The Diabetes Remission (DiaRem) score incorporated preoperative clinical variables to predict the probability of T2DM remission over a five-year period. However, Aron-Wisnewsky et al. (10) discovered that the DiaRem score had limited predictive power for lower scores. As a result, the DiaBetter score was introduced, incorporating factors such as T2DM duration and glycated hemoglobin levels. Both the DiaBetter and DiaRem scores were found to have comparable predictive value for two-year T2DM remission rates following both RYGB and SG procedures (38). Ultimately, the DiaRem score's precision and predictive capabilities were enhanced by taking into account the duration of T2DM and the dosage of hypoglycemic medications used. This led to the development of the Advanced Diabetes Remission (Ad-DiaRem) score (10). Within a cohort of Israeli individuals with five-year post-operative diabetes status data, the Ad-DiaRem score demonstrated a slight improvement over the DiaRem score in the prediction of long-term T2DM remission following RYGB surgery (39). As seen above, a highly predictive and accurate diabetes scoring system is important in predicting remission of type 2 diabetes after bariatric surgery.

3 Management of RWG

3.1 RWG after BS

In the latest meeting held by International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) (40), an agreement was established to utilize the term "recurrent weight gain (RWG)" for individuals who undergo substantial weight increase following their initial weight reduction post-surgery. This term is defined as a weight gain exceeding 30% or an exacerbation of an obesity-related complication that was a pivotal reason for undergoing surgery. Given the different efficacy of each BS procedures (41, 42) and variable

effects in different patient groups, these criteria should be personalized, complemented by the expertise of clinical judgment.

3.2 Behavioral interventions

Empirical studies endorse the significance of MVPA, in curbing post-bariatric surgery weight regain (43). Notably, the numerous evidences are based on objective daily assessments of patients' MVPA, which minimizes the bias associated with self-reported activity levels. As highlighted in a previous review (44), it is essential for future research to detail exercise adherence rates to guide the formulation of effective exercise programs. Consequently, interventions should focus on imparting behavioral strategies—such as self-monitoring of exercise, setting achievable goals, and scheduling exercise routines—to ensure the long-term maintenance of physical activity habits (45).

Ongoing and regular consultation with a dietitian specializing in BS is linked to enhanced outcomes in terms of weight loss success (46). Continued dietary guidance post-surgery is highly advantageous for the majority of patients (47). Patients' capacity to digest solid foods is restricted, which calls for a gradual dietary progression from liquids to solids (48). The primary objective of dietary counseling following BS is to ensure an adequate intake of high-quality protein and recommended daily protein intake ranges from 60 to 120 grams, contingent upon the specific surgical procedure performed (49). Furthermore, it is crucial to ensure patients comply with the prescribed regimen of vitamin and mineral supplements (50). The dietary guidelines for post-BS recommends such as restricting meal portion sizes to 125 grams every 30 min and choosing foods that are rich in protein and high in fiber. This includes a variety of options like eggs, poultry, fruits, lean meats, fish, vegetables, low-fat dairy products, legumes, and whole grains (51).

3.3 Anti-obesity medicine

Anti-obesity medicine (AOM) options that are currently approved by the US Food and Drug Administration (FDA) include liraglutide, phentermine, phentermine/topiramate extended release (ER), naltrexone sustained release (SR) /bupropion sustained release (SR) and orlistat (52).

Liraglutide, an injectable glucagon-like peptide-1 (GLP-1) receptor agonist, has received FDA approval as an AOM agent at a dosage of 3.0 mg. It is believed to control appetite via both peripheral and central nervous system pathways and has demonstrated efficacy in bariatric surgery patients with RWG (53). Furthermore, preliminary evidence hints that GLP-1 agonists might offer a therapeutic advantage in addressing hypoglycemia (54). In addition to liraglutide, another, semaglutide, a GLP-1 agonist approved for T2DM treatment, has shown efficacy in promoting weight loss (55) and potentially surpassing liraglutide (56). The mechanism of GLP-1 (Figure 1A) and the effects of GLP-1 on the body (Figure 1B) are illustrated in Figure 1. Phentermine functions as a sympathomimetic amine, which stimulates the release of catecholamines in the hypothalamus, resulting in the suppression of appetite. When administered as a standalone treatment or in conjunction with topiramate, it has been demonstrated a reduced RWG (57) and facilitated weight reduction in cases where the outcomes of BS have been suboptimal (58). Topiramate, a medication primarily used to treat epilepsy and migraines, has not been officially approved for monotherapy in obesity treatment. However, it is frequently prescribed off-label due to its appetite-suppressing properties. It has been utilized both as a solo treatment and in combination with phentermine, as well as for the management of binge eating disorder (59). Notably, topiramate has turned into a highly effective option for managing weight regain in a subset of postoperative patients in a specific study (60). Naltrexone SR/Bupropion SR represents another FDA-approved dual-drug AOM. Each of these medications targets the central nervous system (CNS) reward pathways, and there is a theorized synergistic impact on human appetite regulation. This effect is suggested by animal studies, which propose that the combination acts on the specific receptor to enhance gorged feelings and prevent inhibited feedback. A number of randomized, double-blind, placebo-controlled trials have substantiated the efficacy of this medication pairing in combating RWG (61). Orlistat functions as a lipase inhibitor, which leads to the reduced absorption of 25–30% of the dietary fat consumed through the gastrointestinal tract (62). Current therapeutic options are reviewed in Table 1.

3.4 Endoscopic interventions

Endoscopic sleeve gastroplasty (ESG) involved creating a two-row plication, effectively reducing the size beginning from the gastroesophageal joint to the prepyloric antrum by forming a narrow sleeve-like structure (63). The first instance of a revisional ESG following SG was documented by Sharaiha and colleagues, resulting in 9-kilogram decrease (64). Across a retrospective investigation of five individuals who received a revisional ESG due to an enlarged gastric sleeve, a consistent TWL ranging from 6.7 to 17.2% was noted at the 12-month mark (65). A subsequent report detailed the revisional ESG as a "sleeve-in-sleeve" process, which involved creating additional applications in the stomach based on a special approach. The patient in this case experienced a favorable post-procedure outcome, with a weight loss of 7 kilograms, equating to an 8% TWL, reported at the three-month follow-up (66).

Transoral Outlet Reduction (TORe) after RYGB operates by constricting the gastrojejunal anastomosis (GJA) diameter with the aid of endoscopic tools and platforms that are commercially accessible. The TORe procedure diminishes the GJA's size, thereby facilitating weight loss through a mechanical limitation that curtails hunger and enhances satiety (67). The execution of TORe can be varied, encompassing full-thickness endoscopic suturing, plications, and hybrid techniques that may include the ablation or resection of the GJA's mucosal layer (68). The follow-up results indicated that patients who underwent TORe achieved a 3.5% total weight loss (TWL), a statistically significant improvement over the 0.4% TWL observed in the control group that received a sham procedure ($p = 0.02$) after 1 year (69). Subsequent advancements in the TORe approach have been made to boost its effectiveness (70). Argon Plasma Coagulation (APC) is a noncontact method of electrocoagulation, leading to a gradual reduction in diameter (71). The use of APC in the context of the GJA was primarily showcased in 2006 as a supplementary step during the standard TORe flow. Patients who received APC prior to suturing exhibited greater weight loss compared to those who underwent suturing without this preliminary step (72).

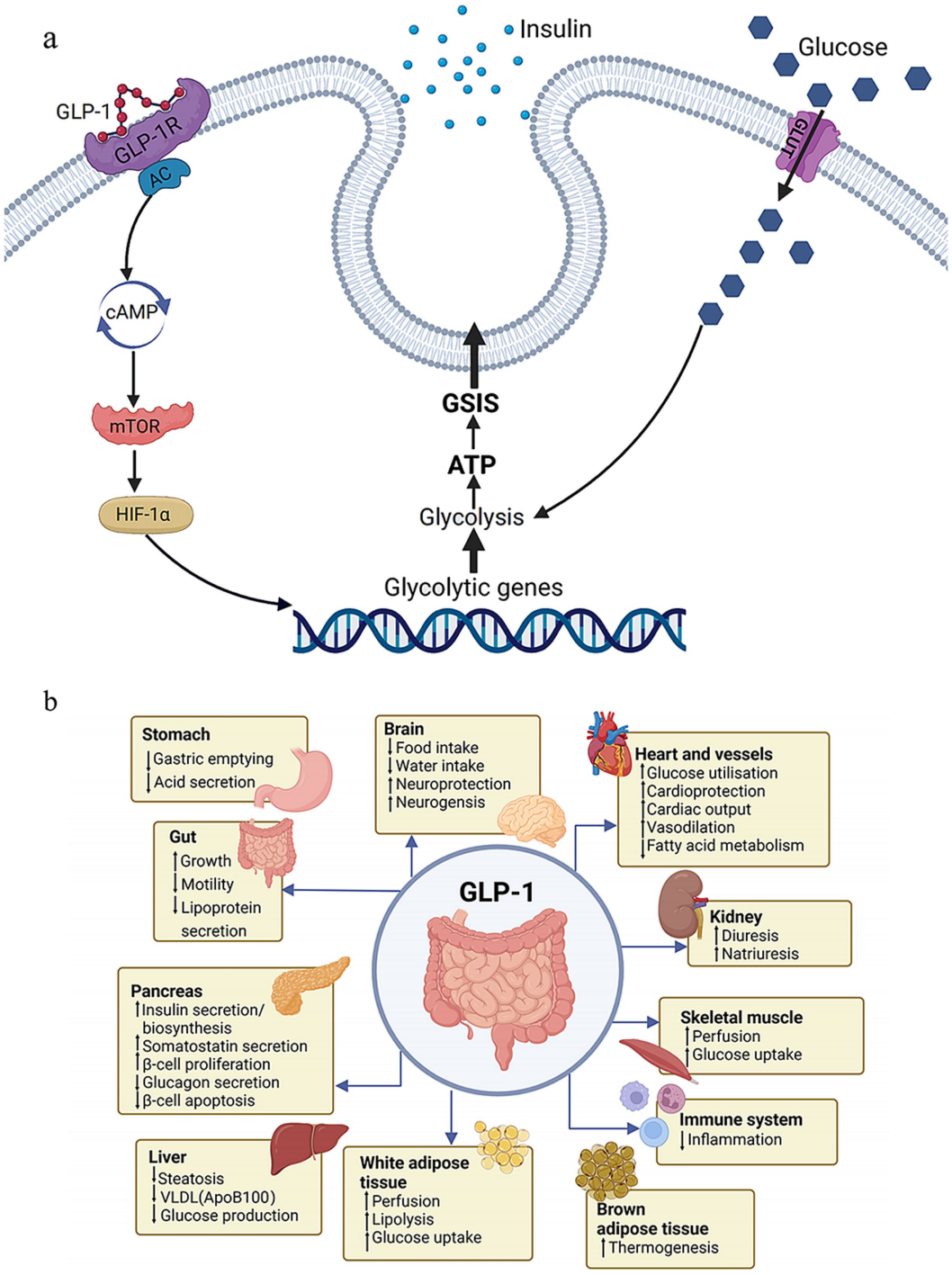

FIGURE 1
Function of GLP-1. **(A)** Molecular mechanism of GLP-1. **(B)** Effects of GLP-1 on the body. GLP-1, glucagon-like peptide-1; glucose-stimulated insulin secretion.

Restorative obesity surgery endoluminal (ROSE) is an alternative process to tackle RWG after RYGB (71). A multicenter registry reported on the outcomes of a cohort of patients who employed a non-invasive revision method to reduce the dimensions of their stoma and pouch. The study demonstrated that, at 6 months post-procedure (with data from 96 patients), there was an average weight reduction equivalent to 32% of the weight regained from the lowest weight point (73).

3.5 Conversional surgery

3.5.1 Conversional surgery after SG

Conversional surgeries for RWG after SG include endoscopic sleeve gastroplasty (ESG), re-sleeve gastrectomy (RSG), RYGB, one-anastomosis gastric bypass (OAGB), single-anastomosis duodeno-ileal bypass (SADI), and duodenal switch (DS) (74). Efficacy

TABLE 1 Overview of anti-obesity medicine and the pertinent clinical factors to consider.

Drug	Use consideration	Weight loss (drug/placebo)	Slide effects
Liraglutide (117)	3.0 mg, OD, subcutaneous injection	−8%/−2.6%	Nausea/vomiting, diarrhea, constipation, pancreatitis, gallstone
Semaglutide (118)	2.4 mg, once weekly, subcutaneous injection	−14.9%/−2.4%	Nausea/vomiting, diarrhea, constipation
Phentermine (119)	15–30 mg, OD, oral	−6.6 to −7.4%/−1.7% (dose-dependent)	Palpitations, elevated blood pressure
Phentermine/topiramate ER (120)	15 mg/92 mg, OD, oral	−7.8% to −9.3%/−1.2% (dose-dependent)	Depression, suicidal ideation, memory loss, birth defects, cardiovascular events
Naltrexone SR/bupropion SR (61)	32 mg/360 mg, BID, oral	−5.0 to −6.1%/−1.3% (dose-dependent)	Seizures, palpitations, transient blood pressure elevations
Orlistat (121)	120 mg TID, oral	−10.2%/−6.1%	Liver injury, gastrointestinal symptoms

of different conversional surgeries on BMI during follow-up are showed in Figure 2.

ESG is a non-invasive, incisionless procedure that reshapes the stomach by applying full-thickness sutures, thereby decreasing its capacity and slowing down gastric emptying (75). An observational study conducted by Sharaiha and colleagues (76) has demonstrated that ESG can lead to positive metabolic changes and improvements in obesity-related comorbidities. In cases where RWG is experienced following a SG, RSG may be considered, particularly if the stomach's dilation exceeds 4 cm in diameter (77). RSG involves the reshaping of the remaining stomach volume. It has been suggested under circumstances where the stomach volume, as measured by a gastroscanner, surpasses 250 cc, as proposed by a French research team in 2014 (78). However, due to the high rates of postoperative gastroesophageal reflux disease (GERD), RSG is typically recommended only for select individuals with a significantly excessed the gastric fundus or antrum (79). A conversional OAGB involves the construction of a gastric pouch and the creation of a gastrojejunal anastomosis with a relatively broadened biliary limb (80). The absence of a jejuno-jejunal anastomosis in OAGB reduces the potential for future complications (81), and this procedure is also believed to decrease operative time as it necessitates the formation of only one anastomosis (82). The SADI-S was devised as a streamlined version of the biliopancreatic diversion/duodenal switch, aiming to reduce operating time and postoperative complications while retaining the same principles and effectiveness (83). The separation of the ileum results in the formation of two separate segments, which are then rejoined using a surgical connection, establishing the helpful channel that facilitates digestive absorption post-conversion from SG to DS. While DS is recognized for reaching the most significant weight reduction outcomes following an unsuccessful SG, it comes with the trade-offs of a higher risk of developing complications and the complexity inherent in the surgery (84, 85).

3.5.2 Conversional surgery after RYGB

Conversional surgeries after RYGB include the conversion of the GJA and/or pouch, gastric band around the upper pouch with laparoscope (LGB), a band with laparoscope combined with pouch resizing, distalization-RYGB (D-RYGB) and a duodenal switch (DS). Franken et al. (86) estimated the function and safety of those clinical techniques following RYGB for RWG. Efficacy of various conversional operations on BMI in the follow-up assay is shown in Figure 3.

GJA or pouch conversion can be performed by either reshaping these structures or by removing part of the GJA followed by a reconstruction (87). LGB is a restrictive procedure that involves placing an artificial band near the gastrojejunostomy (88). DS is a more complex operation that includes creating a partial sleeve gastrectomy while keeping the pylorus intact, forming a Roux limb, extending the biliopancreatic limb, and establishing a short useful channel (89). D-RYGB is achieved by reducing the channel length, thereby enhancing the malabsorptive effect of the RYGB. There are two main methods of distalization: either by reconfiguring the Roux limb (Type 1) or the Y limb (Type 2). Shin et al. (90) suggested that an optimal total length of the alimentary limb should be around 300 centimeters to minimize the risk of malnutrition and reduce the occurrence of diarrhea, thereby improving the overall quality of life for patients undergoing these complex conversional procedures.

4 Management of T2DM recurrence

4.1 T2DM recurrence after BS

BS is typically linked to substantial enhancements or even the remission of diseases related to obesity, with a particularly notable impact on T2DM. T2DM is a multifaceted hormonal and metabolic condition characterized by varying levels of insulin resistance and impairment of the pancreatic β-cells (91). In the Swedish Obese Subjects (SOS) trial, a significant proportion of participants with T2DM at the outset—72%—were observed to be in remission after a 2-year post-bariatric surgery follow-up period. However, a noteworthy 50% of these individuals saw a return of T2DM symptoms by the 10-year check-up (92). The STAMPEDE was a randomized trial evaluating and comparing RYGB versus sleeve gastrectomy SG in obese patients with T2DM. The trial's data indicated a decline in the remission rates of T2DM; after RYGB, the percentage dropped from 78% in the initial year to 45% at the 5th year, and following SG, it decreased from 51 to 25% over the same period (93). Definition of baseline T2DM and the recurrence within a 10- or 15-year period is defined as an HbA1c level of 48 mmol/mol

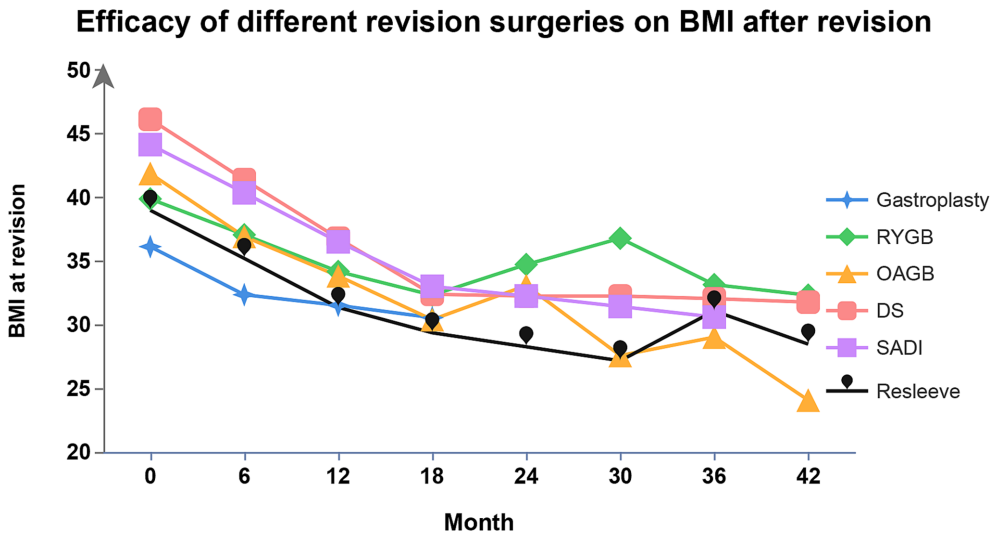

FIGURE 2
Efficacy of different conversional surgeries after SG on BMI. BMI, body mass index; SG, sleeve gastrectomy; RYGB, Roux-en-Y gastric bypass; OAGB, one-anastomosis gastric bypass; SADI, single-anastomosis duodeno-ileal bypass; DS, duodenal switch.

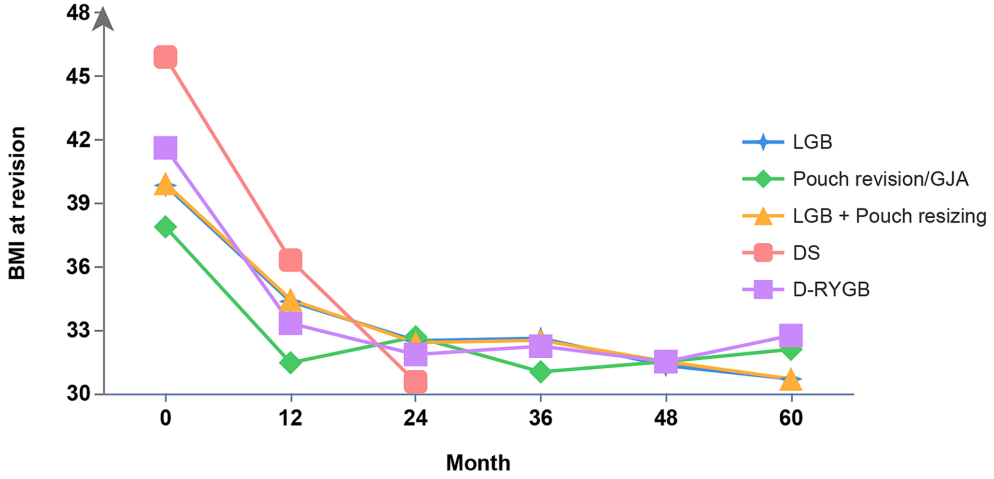

FIGURE 3
Efficacy of different conversional surgeries after RYGB on BMI. BMI, body mass index; RYGB, Roux-en-Y gastric bypass; LGB, laparoscopic gastric band; D-RYGB, distalization- Roux-en-Y gastric bypass; GJA, gastrojejunal anastomosis; DS, duodenal switch.

or higher, a blood glucose level of 6.1 mmol/L or above (plasma glucose of 7 mmol/L or above), or the use of T2DM medications (11) (Table 2).

The ADA holds the stance that there is not a uniform dietary approach suitable for all individuals with diabetes. Traditionally, the ADA has endorsed a personalized dietary plan developed through a collaborative effort tailored to the specific necessities and preferences of the diabetes populations (13). The following eating patterns are listed in Table 3. Various dietary patterns for specific individuals have been shown to achieve varying levels of health benefits as evidence accumulates. Healthcare providers should concentrate on the fundamental elements shared across these patterns, which include reducing the consumption of added sugars, prioritizing the intake of nonstarchy vegetables and refined grains, and opting for whole foods over their highly processed counterparts whenever feasible (94).

4.2 Hypoglycemic agents

The ADA lists first-line hypoglycemic agents in its latest guidelines, including GLP-1 receptor agonists (GLP-1RA), dipeptidyl peptidase 4 (DPP-4) inhibitors (DPP-4i), sodium–glucose cotransporter 2 (SGLT-2) inhibitors (SGLT-2i), metformin, thiazolidinediones (TZDs), sulfonylureas and insulin (95). GLP-1 RAs

TABLE 2 Physical interventions which ADA recommends and its corresponding frequency and targeted individuals.

Physical intervention	Frequency	Targeted individuals
Aerobic activities of a moderate to intense nature	60 min/day or more	Youth with T2DM
Intense muscle-fortifying and bone-strengthening exercises	At least 3 days/week	Youth with T2DM
Aerobic exercises that are either of moderate or vigorous intensity	A minimum of 150 min per day of physical activity, distributed over at least 3 days per week, ensuring that there are no more than two consecutive days without engaging in any form of activity	Most adults with T2DM
Strength training exercises performed on alternate days	2–3 sessions/week	Most adults with T2DM
Exercises aimed at enhancing flexibility and improving balance	2–3 times/week	Older adults with T2DM

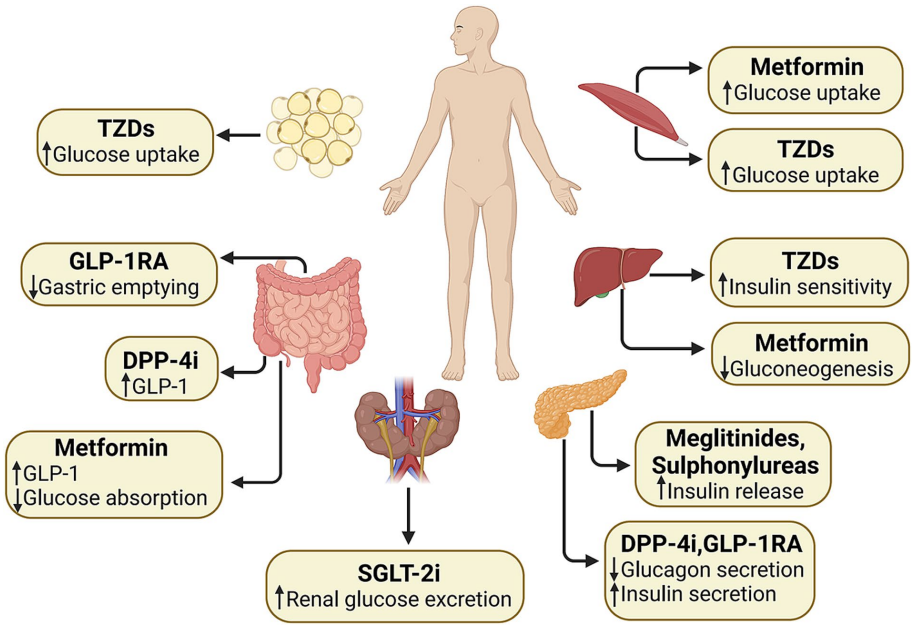

FIGURE 4
Effects of different types of hypoglycemic agents on the body. GLP-1, glucagon-like peptide-1; GLP-1 RA, glucagon-like peptide-1 receptor agonists; DPP-4i, dipeptidyl peptidase-4 inhibitors; SGLT-2i, sodium–glucose cotransporter 2 inhibitors; TZDs, thiazolidinediones.

target the pancreas to stimulate the release of insulin and curb the production of glucagon with the function within the gastrointestinal tract to slow down the process of gastric emptying (96). DPP-4i elevate endogenous incretin levels by inhibiting the activity of DPP-4 (96). SGLT-2i decrease renal glucose reabsorption (97). Metformin might target the liver to suppress gluconeogenesis and skeletal muscles to improve the utilization of glucose (98). It may also play a role in the gut by increasing the levels of GLP-1 (99). TZDs enhance insulin sensitivity in the skeletal muscles, adipose tissue, and liver. Sulfonylureas stimulate the pancreas to augment the secretion of insulin (100). Figure 4 shows the mechanism and target organ of hypoglycemic agents. Factors that are specific to the individual and influence the selection of treatment encompass personalized blood sugar targets (101), the person's susceptibility to hypoglycemia, and their medical history or risk factors associated with cardiovascular, renal, hepatic, and other comorbidities and complications related to diabetes (102–104). Potential therapeutic options are reviewed in Table 4.

4.3 Conversional surgeries

Yan et al. (105) has evaluated the influence of conversional surgery on T2DM. Aleassa EM et al. corroborated findings that the overall improvement in T2DM can vary from 65 to 100%, contingent upon the specific indices and types of reconstructive surgery performed (106). Below, we will review types of conversional operations undergone: vertical banded gastroplasty (VBG) to Roux-en-Y gastric bypass (RYGB), adjustable gastric banding (AGB) conversions, sleeve gastrectomy (SG) conversions, and conversion of pouch/stoma after RYGB.

Challenges such as band erosion, dysphagia, and staple line failure have diminished the use of VBG. However, due to the anatomical changes induced by the procedure, converting VBG to RYGB has been shown to offer metabolic benefits for individuals with T2DM (107–109). Gagné et al. (110) examined data from patients under this conversion from July 1999 to April 2010 and discovered that T2DM improved or resolved in 90% of cases. Sarhan et al. (111) reviewed

TABLE 3 Eating patterns recommended.

Category of eating pattern	Description
Mediterranean-style (122)	Highlights the consumption of plant-derived foods and seafood; designates olive oil as the primary source of dietary fats; includes dairy in moderate to small quantities; allows for a typical intake of less than four eggs per week; limits the intake of red meat to infrequent and small portions; permits wine in measured amounts; and discourages the regular use of concentrated sugars or honey
Vegetarian or vegan (123)	Vegetarian diets are typically categorized into two primary types: vegan diets, which exclude all animal flesh and by-products, and vegetarian diets, which forgo animal flesh but may include eggs and/or dairy products. A vegetarian dietary pattern is defined by a lower intake of saturated fats and cholesterol, coupled with a higher intake of fruits, vegetables, whole grains, nuts, soy products, fiber, and plant-derived compounds
Low-carbohydrate (124)	Concentrates on consuming foods that are rich in protein, such as meats, poultry, fish, shellfish, eggs, cheese, as well as nuts and seeds. Emphasizes the intake of healthy fats from sources like oils, butter, olives, and avocados, along with low-carbohydrate vegetables including salad greens, cucumbers, broccoli, and summer squash. While most plans permit some carbohydrates in the form of fruits, particularly berries, and higher carbohydrate vegetables, they generally discourage the consumption of sugary foods and grain-based products like pasta, rice, and bread
Low-fat (125)	Emphasizes the intake of vegetables, fruits, and starchy items such as bread, crackers, pasta, whole grains, and starchy vegetables. It also includes lean protein sources like legumes and suggests the use of low-fat dairy options. This dietary approach is characterized by a total fat intake that does not exceed 30% of total daily calories and a saturated fat intake that is capped at 10% or less
Dietary Approaches to Stop Hypertension (DASH) (126)	Highlights the consumption of fruits, vegetables, and low-fat dairy, alongside whole grains, poultry, fish, and nuts, while limiting intake of saturated fats, red meats, desserts, and sugary drinks. The most effective version of the DASH diet also incorporates a reduced sodium content

records of 102 patients who had a conversional RYGB following an unsuccessful VBG from April 2014 to January 2018, noting a T2DM improvement rate of 75.7% with complete remission and a 24.3% partial remission. Ngiam et al. (112) demonstrated the effectiveness of these conversional surgeries in resolving diabetes compared to AGB. Vidal et al. (113) reported comparable resolution rates for T2DM after SG and RYGB (51.4% vs. 62.0%) at the four-month mark post-surgery. Yeung et al. (114) observed little significant discrepancy in medication reduction for diabetes and hypertension at 12 months after RYGB (33% reduction, no cessation of diabetes medication) and SG (60% reduction, 40% off diabetes medication). Lee et al. (115) divided T2DM into three assessed stages at the initial time, enabling selection of procedures from evidence-based practices. Both procedures significantly improved T2DM in mild (IMS score $\leq$ 25) and severe cases (IMS score > 95), but RYGB was notably more effective in intermediate cases due to its more pronounced neurohormonal impact. Conversion of pouch/stoma after RYGB in cohort demonstrated by Aleassa et al. (106) resulted in further significant weight reduction and controlling T2DM better. Rawlins et al. (116) reviewed cases from 2002 to 2009 involving the conversion of RYGB to a distal gastric bypass, revealing that patients who underwent this distalization to 100-cm distal common channel experienced improvements in diabetes management.

5 Conclusion

BS remains the most potent treatment for weight reduction and alleviating the T2DM. However, the postoperative outcomes can vary significantly among patients. Factors after the surgery have a more substantial influence on predicting postoperative weight loss compared to those assessed before the procedure. Despite this, there is a scarcity of holistic predictive models that anticipate weight loss outcomes post-surgery. Therefore, there is a need for scoring systems that can amalgamate various factors and accurately forecast weight loss outcomes. In this context, certain models, notably the Ad-DiaRem, demonstrate a relatively strong ability to predict the remission of T2DM following BS. It is essential to recognize that enhanced diabetes management is a significant achievement, even if it does not result in complete remission. Some patients might experience RWG and a recurrence of diabetes. Given that most postoperative behavioral factors are modifiable, proactive measures to influence postoperative eating habits and lifestyle changes are crucial. Furthermore, recommendations for behavioral interventions should be tailored to meet the specific needs of each patient. In terms of pharmaceutical treatment, healthcare providers should adhere to the same principles for dose initiation and titration as they would for patients who have not undergone surgery. The treatment should commence with the lowest possible dose, with subsequent adjustments made based on individual requirements. In cases where monotherapy proves insufficient, combination therapies can be considered. Endoscopic management, recognized for its minimally invasive nature, has predominantly been realized through standard or modified TORe in patients who have undergone RYGB. Concurrently, ESG is gaining traction as a secure and effective method for those who have had SG. However, the sustainability of these procedures is uncertain without concurrent dietary and lifestyle interventions. There is an evident need for a prospective, randomized study to evaluate this innovative technique. It is crucial to acknowledge that the advantageous outcomes of conversional surgeries are often coupled with an increased risk and complexity of complications. Therefore, referral centers should be considered the most suitable venues for conducting conversional surgeries, and stringent postoperative surveillance is imperative.

TABLE 4 Overview of blood glucose-lowering medications and the pertinent clinical factors to consider.

Glucose lowering agent*	Efficacy (127, 128)	Body weight (127, 128)	Progression on DKD (129–133)	Effect on MACE (134–140)	Heart failure (141–144)	Using considerations (95)	Considerations for patients following BS (95)
GLP-1 RAs	High to vitally high	Loss (intermediate to vitally high)	Benefit for renal endpoints CVOTs, driven by albuminuria: dulaglutide, liraglutide, semaglutide	Benefit: dulaglutide, liraglutide, semaglutide	Neutral	• Refer to the product labels for guidance on dosage adjustments related to renal function for each specific medication • Regularly assess kidney function when starting or increasing the dosage of medications in patients with compromised renal function who experience serious gastrointestinal side effects • No dose adjustment for dulaglutide, liraglutide, semaglutide	• Advise patients on the likelihood of gastrointestinal side effects and reassure them that these are usually short-lived; offer recommendations for dietary changes to alleviate these effects and consider a more gradual dosage adjustment for those experiencing gastrointestinal discomfort • Warn patients about the possibility of ileus (semaglutide) • If symptoms of gallstones or cholecystitis arise, assess for gallbladder disease
SGLT-2 inhibitors	Intermediate to high	Loss (intermediate)	Benefit: canagliflozin, empagliflozin, dapagliflozin	Benefit: canagliflozin, empagliflozin	Benefit: canagliflozin, empagliflozin, dapagliflozin, ertugliflozin (141–144)	• Refer to the product labels for guidance on dosage adjustments related to renal function for each specific medication • The efficacy of SGLT2 inhibitors in reducing blood glucose levels is diminished when the estimated glomerular filtration rate (eGFR) is low	• There is an elevated risk of euglycemic diabetic ketoacidosis (eDKA) during the perioperative period, as well as an increased susceptibility to dehydration and vitamin D deficiency • Heightened vulnerability to genital mycotic infections • It is crucial to closely monitor the patient's volume status and blood pressure, and make necessary adjustments to other medications that could affect volume status
DPP-4 inhibitors	Intermediate	Neutral	Neutral	Neutral	Neutral (potential risk, saxagliptin) (145)	• Renal dose adjustment required (sitagliptin, saxagliptin, alogliptin) • No dose adjustment required for linagliptin	• Instances of pancreatitis have been documented in clinical studies, yet a definitive causal relationship has not been confirmed. Should there be any suspicion of pancreatitis, the medication should be discontinued immediately

(Continued)

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TABLE 4 (Continued)

Glucose lowering agent*	Efficacy (127, 128)	Body weight (127, 128)	Progression on DKD (129–133)	Effect on MACE (134–140)	Heart failure (141–144)	Using considerations (95)	Considerations for patients following BS (95)
Metformin	High	Neutral (potential for modest loss)	Neutral	Potential benefit	Neutral	• Contraindicated with eGFR <30 mL/min per 1.73 m^2	• GI side effects common due to increased bioavailability; to mitigate it, consider slow dose titration, administration with food and extended-release formulations • Increased risk of Vit B12 deficiency; monitor regularly
Thiazolidinediones	High	Gain	Neutral	Potential benefit: pioglitazone	Increased risk (146)	• No dose adjustment required • Typically, their use is not advised in cases of renal impairment due to the risk of fluid retention	• Congestive heart failure (pioglitazone, rosiglitazone) • Risk of bone fractures • Fluid retention (heart failure; edema)
Sulfonylureas	High	Gain	Neutral	Neutral	Neutral	• Glipizide and glimepiride should be started at a lower dose to minimize the risk of hypoglycemia • Glyburide: generally not recommended in chronic kidney disease	• Use with caution in individuals at risk for hypoglycemia
Insulin	High to vitally high	Gain	Neutral	Neutral	Neutral	• Lower insulin doses required with a decrease in eGFR; titrate per clinical response	• Higher risk of hypoglycemia with human insulin (NPH or premixed formulations) vs. analogs • Monitor injection site reactions

DKA, diabetic ketoacidosis; DKD, diabetic kidney disease; DPP-4, dipeptidyl peptidase 4; eGFR, estimated glomerular filtration rate; GI, gas-trointestinal; MACE, major adverse cardiovascular events; SGLT2, sodium–glucose cotransporter 2; * For agent-specific dosing recommendations, please refer to manufacturers' prescribing information (127, 128).

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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