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Review Article

Bariatric surgery for the management of type 2 diabetes mellitus-current trends and challenges: a review article

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Abstract: Obesity has become an epidemic and has emerged as a serious ailment of global concern. Longstanding obesity may lead to several complications, including type 2 diabetes mellitus (T2DM). Considering the role of the gastrointestinal tract (GIT) in glycemic control, altering it would be relevant to the T2DM management algorithm. Bariatric surgery is a well-known surgical procedure that alters the GIT for managing T2DM among moderate to severely obese patients. T2DM remissions (adequate glycemic control without any other antidiabetic drugs) among the post-bariatric patients are due to weight loss related and weight loss unrelated pathophysiological mechanisms, including caloric intake restriction, increased insulin secretion, sensitivity, and malabsorption. Evidence suggests that bariatric surgeries among T2DM patients improved micro and macrovascular complications. Bariatric surgical procedures have more advantages of post-operative weight loss and glycemic control in biliopancreatic diversions than other available bariatric surgical procedures. Several concerns raised on the short and long-term risks associated with the bariatric surgery were nutritional deficiencies, psychological issues, GIT ulcers, and survival rates. Data related to follow-up of complications related to the above-stated risk are still elusive. According to some of the recently published studies, relapse of T2DM after remission is a worrying phenomenon among post-bariatric surgery patients, requiring more clinical trials and long-term follow-up on the relapsed patients. The effectiveness of reoperation among the relapsed patients also needs to be evaluated. Other unresolved issues related to bariatric surgery are patient compliance, cost-effectiveness, quality of life among post-bariatric patients, and the effectiveness of the post-operative holistic approach to avoid relapse. Future studies, especially randomized controlled trials, are recommended to resolve the existing controversies associated with bariatric surgery.

Keywords: Bariatric surgery, type 2 diabetes mellitus, remission, nutritional deficiency

Introduction

Obesity has become a global epidemic and has emerged as a serious ailment of global concern. Worldwide, obesity and overweight prevalence area round 650 million among the adult population, affirmed by the World Health Organization (WHO). Many pieces of literature highlight the cardiovascular, metabolic, physical, and psychological complications of longstanding obesity, and one of them includes type 2 diabetes mellitus (T2DM) [1]. T2DM is a chronic disease increasing in prevalence, characterized by hyperglycemia, arising from a combination of insulin resistance, decreased or inadequate insulin secretion, and/or inappropriate secretion of glucagon hormone [2, 3]. Uncontrolled T2DM may lead to several acute and chronic complications such as diabetes ketoacidosis, cardiovascular diseases (CVD), and nephropathy [2]. More than 75% of T2DM patients' body weight is either overweight or obese. The T2DM development risk is proportionately defined by their body mass index (BMI). Waist circumferences have become the unique marker of this metabolic risk [4, 5]. Early action on this metabolic risk and epidemic of obesity should be considered as an urgent global priority as very few people adhere to lifestyle interventions and achieve long-term weight loss and glycemic control [6].

Bariatric surgery is also named as metabolic surgery due to its metabolic control, which is

aimed to modify the upper gastrointestinal tract (GIT) to treat obesity and its associated diseases [7, 8]. Physiologically, the GIT plays a significant contribution in metabolic regulation. It is discussed and juxtaposed as growing shreds of evidence and find it is relevant to target GIT for the management of T2DM [9-11].

There was increased speculation that metabolic surgery is more beneficial than conventional management of obese patients with T2DM which was proved by *Geltrude M* et al. by a 5-year follow-up randomized control trial. This study remarked the surgical group with significantly lower plasma lipids, medication use, and cardiovascular risks [12]. Other meta-analysis studies on obese patients with T2DM claimed that metabolic surgery is more effective in lowering patients' weight, blood sugar, and other cardiovascular risk factors [13-15].

This literature review aimed to discuss the rationale behind bariatric surgery for T2DM, different bariatric surgical procedures, pathophysiological mechanisms behind T2DM remissions in bariatric surgery, different outcomes of metabolic surgery, indications for metabolic surgery for the obese patients with T2DM, and patients' perceptions towards bariatric surgery. This study also aimed to critically analyze current trends knowledge gaps in bariatric surgery for managing T2DM and make recommendations for future directions.

Literature search methods

The research team did an extensive literature search from PubMed, Google Scholar, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Psychological Information Database (PsycINFO), and Web of Science. This literature review included both observational and experimental studies. We followed the medical subject headings (MeSH) keywords to search the pieces of literature. The following keywords used separately and/or with combinations and keywords we followed as per MeSH were "Bariatric surgery", "Metabolic Surgery", "Type 2 Diabetes Mellitus", "Outcome", and "Remission". The present review included only original research of different categories (including systematic reviews and meta-analysis) and excluded case reports and case series.

The rationale behind bariatric surgery for T2DM

The current global obesity epidemic leads to an increased incidence of T2DM [16, 17]. At times, the human body cells may not respond to insulin adequately. This term is called insulin insensitivity. The continuation of insulin insensitivity may lead to insulin resistance and sequentially develops prediabetics and T2DM in the end [18].

Obesity is considered one of the leading causes of the development of metabolic diseases such as T2DM. Researchers have developed numerous hypotheses to account for the correlation between obesity and insulin resistance, which later developed into T2DM. Some of the hypotheses related to pathophysiological mechanisms include white adipose tissue toxicity, increased proinflammatory materials, leptin, adiponectin, and elevated non-esterified and free fatty acids [19-21]. For the development of insulin resistance in obese patients, β-cells of the pancreas should not be able to compensate fully for decreased insulin sensitivity. Continuous and elevated circulation of non-esterified and free fatty acids released from white adipose tissue of the obese patients may lead to β-cells dysfunction and development of T2DM [22-24]. Management of obesity is the cornerstone of the control of hyperglycemia among obese patients with T2DM.

Lifestyle modifications such as dietary and physical activities can be adequate to manage obesity and prevent metabolic alterations at the initial stages of the disease [25, 26]. Patients who lost their weight through lifestyle modifications are inclined to gain back their weight at some point in time [27]. Management of T2DM through oral hypoglycemic drugs and insulin to treat obese patients is challenging as some of the oral hypoglycemic drugs (sulfonylureas and thiazolidinediones) and insulin tend to increase body weight [28, 29]. Even with the management of recently developed anti-diabetic drugs, several patients are unable to bring down their glycemic control at the desired level (HbA1C <7%) as recommended by the American Diabetes Association [30]. Compared to the methods mentioned earlier, bariatric surgical methods have several advantages in the T2DM management of obese patients [9, 31, 32]. Post-bariatric surgical patients substan-

1. Caloric restriction
2. Increased meal-induced Thermogenesis
3. Physiological changes in energy Balance
4. Alteration of hormones and neural circuits
    a. Control of Appetite
    b. Food choices, and
    c. Altered eating patterns
5. Altered GIT Microbiome
6. Increased secretion of bile acids
7. Alteration in adipokines - increased circulating adiponectin
8. Alteration in GIT hormones
    a. Increased insulin secretion - stimulated by glucagon-like peptide-1
    b. Peptide YY
    c. Oxyntomodulin
    d. Obestatin
    e. Ghrelin
    f. Cholecystokinin

Figure 1. Illustration of different mechanisms for T2DM control among diabetes patients.

tially lose and maintain weight better than the conventional methods [32]. This weight loss is due to various mechanisms like caloric restriction (due to altered GIT), increased meal-induced thermogenesis, physiological changes in energy balance, alteration of hormones, and neural circuits leading to control of appetite, food choices, and altered eating patterns [33, 34]. Caloric restrictions with bariatric surgery will reduce liver fat for a short period and enhance insulin sensitivity [32]. An animal (Ossabaws) model study done by Simianu et al. revealed that bariatric surgical procedures lead to significant weight loss and T2DM resolution [35]. Other common factors responsible for the remission of T2DM among post-bariatric surgery patients are altered intestinal (gut) microbiota and increased serum bile acids [36]. Remodeling of the gut due to bariatric surgery is commonly associated with the altered microbiome. This spatial alteration in microbiome among post-bariatric patients is due to modifications in biliary acid metabolism, alteration in gastric acidity (pH), persistent changes in GIT mucosa, alteration in fecal fermentation, and hormonal metabolism alteration [37, 38]. These gut microbiotas potentially involved the development of obesity and its analogous complications. Several clinical data in the past establish evidence that the concentration of bile acids in the serum increases significantly after metabolic surgery. It is evinced that serum bile acids stimulate the secretion of glucagon-like peptide-1 [39-41]. Glucagon-like peptide-1 is a gut hormone that has a significant role in glycemic control by stimulating insulin secretion, inhibiting glucagon, and gastric emptying [39, 40]. The alteration of other GIT hormones namely, peptide YY, oxyntomodulin, obestatin, ghrelin, and cholecystokinin are implicated in the glucose homeostasis for T2DM management. All these factors explain the rationale of doing bariatric surgery for the management of T2DM in obese patients (**Figure 1**).

Different bariatric surgical procedures and mechanism of weight loss

The American Society for Metabolic and Bariatric Surgery (ASMBS) approved several types of bariatric procedures, namely Sleeve Gastrectomy, Roux-en-Y Gastric Bypass (RYGB), Adjustable Gastric Band (AGB), Biliopancreatic Diversion with Duodenal Switch (BPD/DS), and Single Anastomosis Duodenal-Ileal Bypass with Sleeve Gastrectomy (SADI-S). These procedures are broadly categorized into gastric restrictive procedures (AGB, sleeve gastrectomy), Intestinal bypass procedures (RYGB, BPD), or combined (SADI-S) (**Figure 2**). All these bariatric surgeries are done through laparoscopy. The complications related to surgery are very low. The summary of different metabolic surgical working mechanisms, advantages, and disadvantages are described in **Table 1**.

Sleeve gastrectomy is done by removing about 80% of the stomach portion along the gastric greater curvature. In this method, the stomach is freed from nearby attached organs, and the remaining stomach part will be the shape and size of a banana or like a tube. The operated small size stomach holds less food, decreases hunger, and decreases emptiness. The patients lose weight and sustain healthy weight along with good glycemic control (**Figure 2A**) [42].

RYGB involves both the stomach and small intestine. In this procedure, the stomach is divided into a smaller pouch on the lesser curvature (through stapling) and anastomosed with the jejunum, called Roux Limb. This will form as a “Y” shape. The remnant of the gastric pouch is no longer able to store food (**Figure 2B**) [43].

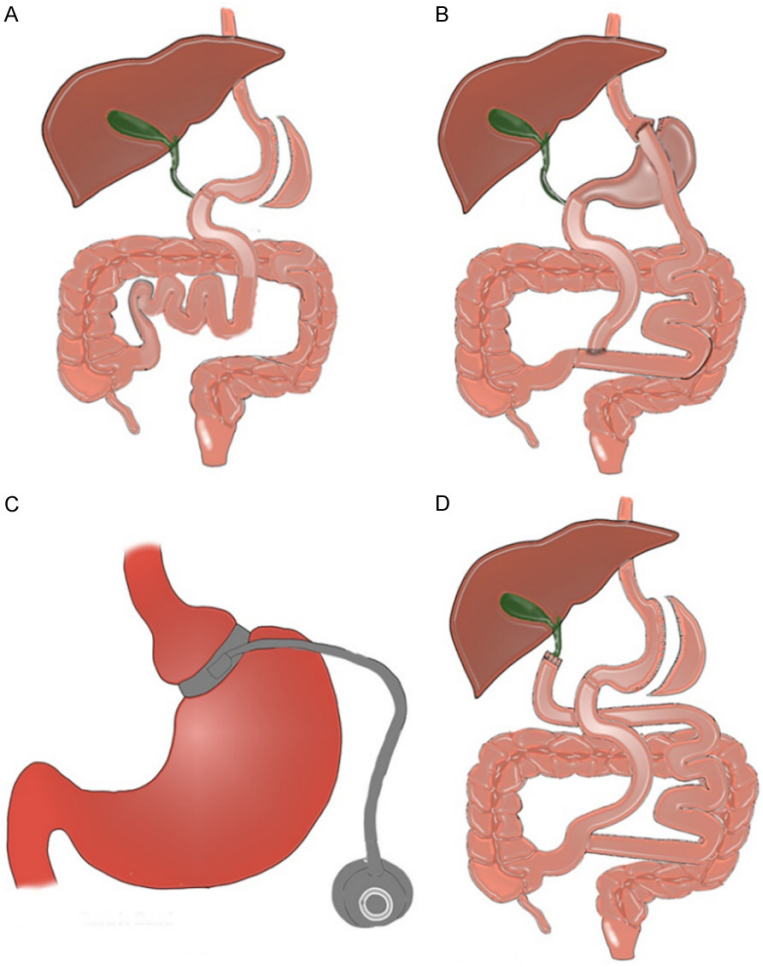

Figure 2. Different bariatric surgical procedures illustration. A: Sleeve Gastrectomy. B: Roux-Y Gastric Bypass. C: Adjustable Gastric Band. D: Duodenal Switch.

The AGB is a silicone-based material kept around the upper portion of the stomach. This device is firmly attached to a balloon to create a small pouch with a capacity of 20 ml. This will limit the intake of food. This procedure is least popular. Usage of this procedure has been declining during the past decade due to its low impact on obesity-related comorbidities and weight loss (**Figure 2C**) [44].

BPD can be done either with or without a duodenal switch. This type of metabolic surgery is the most effective procedure for obese patients with T2DM. In this procedure, the stomach is cut to make a sleeve-like structure, and the anastomosis between the remaining gastric structure and distal fourth of the intestine is made. Absorption of calories is low in this procedure. BPD also alters the intestinal hormones to lower hunger, decrease emptiness, and improve glycemic control (**Figure 2D**) [45].

Numerous factors influence the remission rate of T2DM. The type of surgery, T2DM following RYGB, is 80-85% for obese patients who underwent this procedure [46]. A study postulated by *Scopinaro et al.* found that the remission rate following BPD is around 95% at 1st year and 60.7% at 5 years after bariatric surgery [47]. A meta-analysis done by Wang GF et al. to identify the predictors of the T2DM remissions found that T2DM remission following bariatric surgery is inversely associated with age, duration of diabetes, pre-surgical insulin use, and HbA1c level [48]. Most of the studies revealed that BMI does not have any association with the outcome of surgery on T2DM remissions [9, 47, 49, 50]. We believe that bariatric surgery should be offered for T2DM patients at the early stages, especially those whose BMI is 35 and above.

Indications for metabolic surgery for the patients of T2DM

As per the ASMBS, bariatric surgery is indicated for the following category patients: 1. Patients with a body mass index (BMI) of 40 kg/m^2 and above. 2. Patients with a BMI ≥35 kg/m^2 and the presence of one or more obesity-associated co-morbidities such as T2DM, dyslipidemia, cardiovascular diseases, hypertension, obstructive sleep apnea, osteoarthritis, and non-alcoholic fatty liver disease. 3. Those who were unable to achieve and sustain a healthy weight with the previous non-surgical weight loss management.

Considering the progressive nature of T2DM, with the deterioration of pancreatic β-cells, weight control management should be initiated

Table 1. Summary of different metabolic surgical working mechanism, advantages and disadvantages

	Sleeve Gastrectomy	Roux-en-Y Gastric Bypass	Adjustable Gastric Band	Biliopancreatic Diversion
How it works?	↑Glucose homeostasis ↑Weight loss ↓Hunger and ↑Stomach fullness	Smaller stomach pouch holds the lesser food ↓Hunger ↑Fullness ↓Absorption of calories	↑Fullness Slowing down emptiness	Significant ↓absorption of calories ↑Glucose homeostasis ↑Weight loss ↓Hunger and ↑Stomach fullness
Advantages	Simpler procedure than other bariatric surgery Can be done with the T2DM patients with other high risk medical conditions It can be a bridge surgery to other bypass surgeries like SADI-S	Sustainable weight loss Obesity associated complications remissions are high	Least occurrence of complication AGB can be removed, if needed Low risk of nutritional deficiencies than other procedures	Most effective method for the remission of T2DM Best in weight loss and improvement of obesity Lower rate of relapse
Disadvantages	Irreversible Worsening of existing reflux disease and/or onset of new ↓Effectiveness on metabolism	Complex procedure than sleeve gastrectomy ↑Incidence of micronutrients deficiencies Possibility of developing ulcer while using non-steroidal anti-inflammatory drugs (NSAID) Dumping syndrome	Several re-arrangements of band to be done during the first years Weight loss is lower and slower than other procedures Slippage of band movement	Complications and mortality are higher than other procedure Higher rate of nutritional deficiencies

at the early stages of the disease [47, 49]. We recommend that metabolic surgery choices should be offered to T2DM patients, especially those whose BMI is 35 kg/m^2 and above. This will help halt and/or slow the progression of micro and macrovascular complications of T2DM.

The risks and complications associated with bariatric surgery

The risks and complications associated with bariatric surgeries ranges from immediate surgical related complications to mortality (**Figure 3**).

Nutritional deficiencies

The American Society of Hematology stated that post-bariatric surgery patients have a significantly higher risk of developing anemia. Up to half of the post-bariatric surgery patients are diagnosed to have anemia within two years after surgery. The most common type of anemia among those patients was iron deficiency, followed by vitamin B12 and folic acid deficiencies [51-53]. Remodeling of the GIT due to bariatric surgery and malabsorption may lead to calcium and/or vitamin D deficiency, which may significantly impact bone metabolism. The weight loss achieved through non-surgical methods also reduces the bone density, but the proportion is much lower than surgical methods [54, 55]. A study done by Çalapkorur S et al. in 2020 found that other fat-soluble vitamins like A, E, and K are found deficient in BPD and RYGB procedures [56]. Some authors revealed that due to remodeling and bypass of the jejunum, the absorption of thiamine has been found in about 60% of the patients. Most of these thiamine deficiencies patients are presented clinically with the symptoms of nausea, constipation, and rarely Wernicke-Korsakoff Syndrome [53, 56-58]. Though vitamin C deficiency is prevalent among the patients, they do not show any clinical signs and symptoms [56]. Protein-energy malnutrition is one of the severe complications related to bariatric surgeries. Though it may occur among the patients who have undergone RYGB, a higher incidence (up to 21%) was reported among the patients who underwent the BPD procedure [59, 60]. From our extensive study on literature, we found that there are only limited studies that assessed the preoperative nutritional status among bariatric surgery candidates, even though bariatric surgeries may lead to certain nutritional deficiencies.

Mortality associated with the surgical procedure

A study, done in England by Alam et al. revealed that metabolic surgical procedure-related deaths are low among the patients who had undergone primary bariatric surgery. In gener-

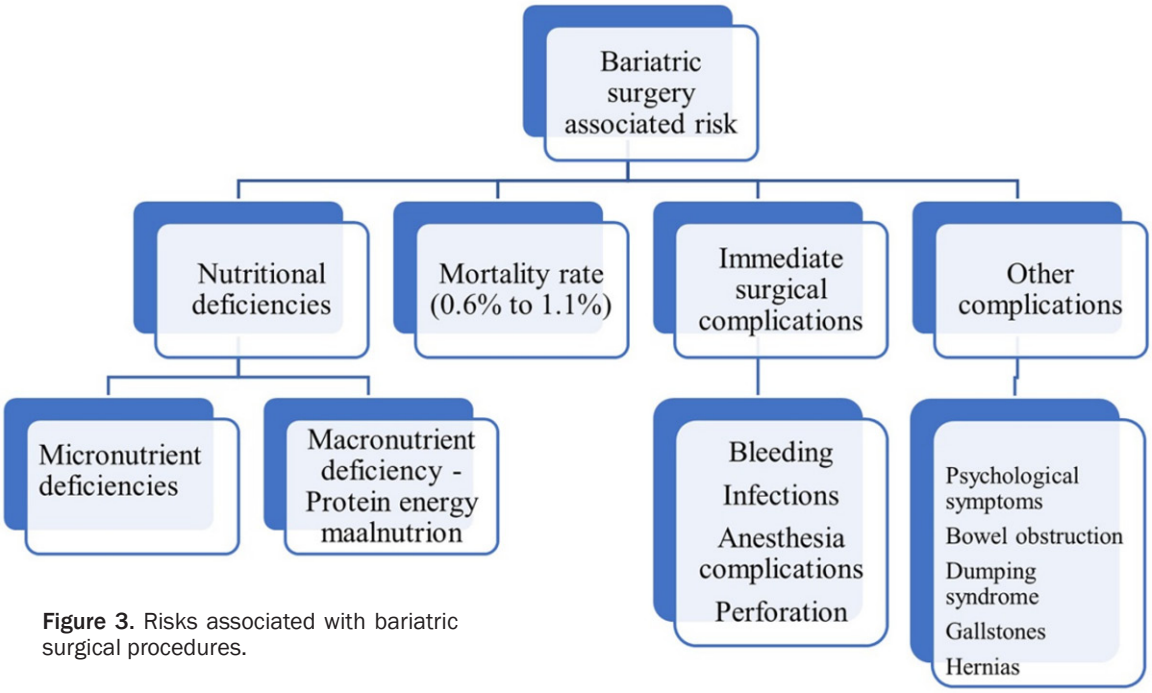

Figure 3. Risks associated with bariatric surgical procedures.

al, in hospital and 30 days follow-up after discharge rates are very low (0.07% and 0.08%) [61]. Another study that followed the bariatric surgery patients to identify the case fatality rate found that the one year and five-year case fatality rate was about 1% and 6%, respectively. The case fatality rate increased significantly with increasing age [62].

Mortality rates among post-bariatric surgeries patients must be compared with the T2DM and obesity patients who are inadequately managed. Several studies have found that long-term mortality rates are lower among obese patients undergoing metabolic surgery treatment than the patients who have undergone non-surgical management [31, 63, 64]. It is suggested that these perceived low-level risks of bariatric surgery should not be considered as obstacles for obese patients with T2DM who seek treatment.

Outcomes of metabolic surgery based on the duration of follow up

The outcome of metabolic surgery is generally classified into short-term-up to one year, mid-term-up to 3 years, and long-term more than 3 years. Preoperative poor residual pancreatic β-cells are the critical cause of type 2 diabetes relapse after bariatric surgery. Some authors revealed that the poor residual pancreatic β-cells are significantly associated with the patients on preoperative poor glycemic control, long duration of T2DM, and patients on more than one oral hypoglycemic drug [65, 66]. Even though some authors explored numerous predictors for the remissions of T2DM among post-bariatric patients, the type of surgical procedure also significantly impacts the outcome on relapse due to anatomic surgical failures. For instance, Braghetto I et al. stated that gastric pouch dilatation from 125 ml immediately after surgery to 524 ml in 5 years follow up among sleeve gastrectomy patients leading to increased food intake, increased satiety, and poor metabolic control [67]. **Table 2** illustrates the results of different studies done around the world that compared surgical and non-surgical management and its primary outcome as T2DM remissions (HbA1C <6.0%, without anti-diabetic medicines).

Diabetic patients' perception and acceptance towards metabolic surgery

Patients' perceptions, acceptance, and positive attitude towards bariatric surgery is essential for the enrollment of patients in need of bariatric surgery. A study conducted by Altaf et al. in 2019 in the Kingdom of Saudi Arabia revealed that public knowledge, perceptions,

Table 2. Summary of different studies on the outcomes of metabolic surgery in T2DM patients

Study	Study description	Intervention methods	Follow up period	Key findings
Mingrone et al., 2021 [68]	An Italian, open label, RCT N=60 T2DM patients with BMI 35 kg/m^2 and above	RYGB, BPD vs Medical Allocation ratio (1:1:1)	10 years	T2DM remission ↑ in both surgical methods vs medical management 58.8% had a relapse during follow up period but they maintained their euglycemic status. The relapse rate was higher among RYGB than the BPD group (52.6% vs 66.7%) ↓diabetes related complications Adverse events were higher among the BPD group
McGlone et al., 2020 [9]	T2DM patients who require insulin A retrospective study based on secondary data	RYGB, AGB and sleeve gastrectomy vs Basic medical treatment (BMT)	5 years	↑insulin cessations among surgical group ↓overeall health cost
Young L et al., 2019 [69]	T2DM patients with impaired renal parameters N=101	RYGB, Sleeve Gastrectomy	10 years	↑T2DM remissions and glycemic control, ↓BMI and ↓albuminuria
Schauer et al., 2017 [70]	Patients with a BMI between 27 to 43 kg/m^2 N=150	RYGB, Sleeve Gastrectomy	5 years	↑Weigh loss, ↓insulin use, Imporved lipid profile and quality of life among surgical group
Cummings et al., 2016 [71]	Adults aged 25-65 years BMI - 30-45 N=43	RYGB vs Lifestyle and Medical intervention	1 year	↑T2DM remissions and ↓weight of the patients in RYGB groups No life threatening complications occurred in both group
Schauer et al., 2014 [72]	T2DM patients with poor glycemic control N=150	RYGB, Sleeve gastrectomy vs Intensive Medical treatment	3 years	↑T2DM remissions, ↓Oral hypoglycemic drugs, ↑Quality of life vs Medical treatment
Arterburn et al., 2013 [73]	Multicentric and retrospective cohort study from USA N=4434 Uncontrolled T2DM patients and/or controlled with oral hypoglycemic agents	RYGB, Sleeve gastrectomy and AGB	10 years	↑T2DM remissions in first 5 years of follow up. Nearly one third of relapse for the patients who got initial remission
Iaconelli A et al., 2011 [74]	Unblinded case-controlled trials Newly diagnosed T2DM with BMI 35 and above N=110	BPD vs medical treatment	10 years	↑T2DM remissions observed in all patients of BPD group after one year follow up ↓microvascular complications BPD group

and attitude towards bariatric surgery was not satisfactory. In their study, 41.2% of participants responded not to seek bariatric surgeon's help, even if they were diagnosed with morbid obesity [75]. A study done by Sarwer et al. among the T2DM patients with a BMI between 30 and 40 revealed that nearly half of the patients had a negative attitude towards bariatric surgery. Similarly, most of the patients believed that bariatric surgery would be unsafe to do. Two-thirds of the participants reported that the likelihood of developing complications and death due to bariatric surgery is very high (66.5%) [76].

Another study done by Chua VM et al. revealed that 61% of T2DM patients favored surgical methods for their glycemic control and weight loss. Post-bariatric surgery complications and duration of remissions outcome were their major worrying factors. They also reported that certain socio-demographic factors (like educational status) were associated with positive perceptions towards bariatric surgery [77]. Evidence from recent studies has shown that the mortality rate is low among post-bariatric surgery patients [61, 62]. It is suggested to improve those predictive factors to change the patients' perceptions towards bariatric surgery.

Critical analysis of current trends, knowledge gaps of bariatric surgery for the management of T2DM

The well-known international health organizations like the WHO, CDC, International Diabetes Federation (IDF), and National Institute of Health (NIH) have included bariatric surgery as a treatment guideline for managing T2DM among obese patients. Bariatric surgery is recommended for patients with a BMI of 40 and above, a BMI of 35 and above with one or more comorbidities, and patients with poor glycemic control refractory to maximal non-surgical methods. There are some controversies and complexities found during the current review. They are summarized below.

- There is no sufficient information available on the waiting period to do bariatric surgery among the patients with normal BMI, who are refractory in glycemic control with the conventional treatment. To date, most of the available studies have been done on the T2DM patients whose BMI is ≥35 kg/m^2.

- Temporal association between factors responsible for T2DM remissions is inadequate.

- With the increasing prevalence of T2DM and obesity among young adults, it is essential to assess the effectiveness on these group patients. Limited studies and data are available to date. It is warranted to have long-term follow-up among them.

- Relapse, revision, and reoperation data are unclear.

- Cost-effectiveness studies are limited, which can be essential in developing and poorly developed countries.

- Treatment acceptability by the patients is still on the lower side. More exploratory studies that assess the factors responsible for low acceptancy are to be done.

- It is necessary to do RCT among patients with preoperative high-risk comorbidities such as cardiovascular, renal, and cancer. Most of the available studies are observational studies.

- No studies were done to assess the long-term follow-up of complications related to the development of nutritional deficiencies developed due to bariatric surgery. Available data on the quality of life (short and long-term) after bariatric surgery is insufficient.

- T2DM management is always a holistic approach that involves several modalities. There is no data available on the multidimensional approach among post-bariatric patients. This may help in decreasing relapse, revisions, and reoperations.

- The data related to comparison between different bariatric procedures on their benefits, remission of T2DM, and long-term follow-up remains inconclusive.

Conclusions

The improved glycemic control benefited by the post-bariatric surgery patients is mediated by several pathophysiological mechanisms, including weight loss related and unrelated. Weight loss related mechanisms include change in appetite, food pattern, and malabsorption. Unrelated mechanisms include change in gut hormones, microbiota, and increased insulin sensitivity. Several observational studies and

experimental studies have shown the beneficial effects of different aspects of glycemic control. Many studies have attempted to find the factors responsible for good remission of T2DM, but their temporal association needs to be explored through RCT. Bariatric surgery is associated with several complications ranging from nutritional deficiencies to mortality. The current evidence from different studies justified that these complications outweigh the benefits of controlling T2DM. Despite metabolic surgery benefits on the T2DM patients, especially whose BMI is ≥35 kg/m^2. Future studies are recommended to solve the flowing critical issues. Even though metabolic surgery is well known and proven management of T2DM, still acceptability by the patients remains low. It is essential to do an RCT that yield data on remissions, relapse, and nutritional deficiencies, especially among young adults. Studies involving a holistic approach (surgical, medical, and lifestyle) management of T2DM among obese patients are warranted.

Disclosure of conflict of interest

None.

Abbreviations

AGB, Adjustable Gastric Band; BPD, Biliopancreatic Diversion; ASMBS, American Society for Metabolic and Bariatric Surgery; BMI, Body Mass Index; CDC, Centre for Disease Control and Prevention; CVD, Cardiovascular Disease; GIT, Gastrointestinal Tract; IDF, International Diabetes Federation; MeSH, Medical Subject Headings; NIH, National Institute of Health; RYGB, Roux-en-Y Gastric Bypass; T2DM, Type 2 Diabetes Mellitus; WHO, World Health Organization.

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