Diabetes Risk Reduction and Metabolic Surgery

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KEYWORDS

- Metabolic surgery • Type 2 diabetes mellitus • Roux-en-Y gastric bypass
- Vertical sleeve gastrectomy • Duodenal switch
- Single-anastomosis duodeno-ileal bypass

KEY POINTS

- Type 2 diabetes mellitus (T2D) is an insidious, chronic medical condition that has a low rate of remission when treated with medication and lifestyle changes alone.
- The incidence of T2D diabetes continues to rise and have a negative impact on the economic well-being of the American health care system.
- Metabolic surgery has been shown to be effective in treating T2D and has afforded patients the best opportunity for remission.
- There are several surgical procedures, including the Roux-en-Y gastric bypass, the vertical sleeve gastrectomy, and the biliopancreatic diversion, that have been shown to be effective in patients with T2D.
- Metabolic surgery is highly underutilized, and increasing access to surgical care may help decrease expenditure on T2D related disease and complications.

INTRODUCTION

Type 2 diabetes mellitus (T2D) remains among the most common chronic medical conditions in the United States. The National Diabetes Statistics Report, published by the Centers for Disease Control and Prevention (CDC), reports that 10.2% of Americans (34.2 million) carried a diagnosis of T2D in 2018, an increase from 7% in 2002.[1] The disease remains underdiagnosed, however, with another 2.8% of Americans (7.3 million) meeting the laboratory criteria for T2D, without a formal diagnosis. Older adults ages greater than 65 have had the sharpest increase in disease burden from 2000 to 2017 (15.8% to 19.1% prevalence, respectively); however, all age groups, including children 10 years old to 19 years old, have experienced significant increases over the past 2 decades.

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The demographics of diabetic patients have remained consistent, with elderly patients age greater than 65, male patients, and Native Americans carrying the greatest burden of disease. The racial distribution of disease in descending order is Native Americans (14.7%), Hispanic (12.5%), blacks (11.7%), non-Hispanic Asians (9.2%), and non-Hispanic whites (7.5%). Hispanics and blacks have been found to have a 2-fold to 3-fold risk of developing T2D during the course of their life compared with their white counterparts (**Fig. 1**). Although central obesity and the development of subsequent metabolic syndrome is associated with insulin resistance (IR) in the general population, the relationship clearly is stronger in some ethnic groups over others. For example, after controlling for obesity, behavioral factors and body fat distribution, blacks continue to have higher IR compared with whites, whereas the difference in IR between Hispanics and whites appears associated with obesity and fat distribution.[2] The black population, therefore, is particularly vulnerable to developing T2D in spite of lower rates of metabolic syndrome and similar environmental exposures.[3]

Although the prevalence of T2D has been increasing nationwide, the burden of disease always has remained highest across the Southern states. Arkansas and Alabama became the first 2 states to have greater than 9% of the population diagnosed in 2001. By 2015, the entire Southeast and Southwestern regions reported greater than 9% prevalence as well as Indiana, Ohio, Pennsylvania, and Michigan.[4] The reason for this trend is multifactorial; however, Southern states tend to have higher populations of nonwhite ethnicities, who are particularly at risk for the disease. In addition, lower socioeconomic class places patients at higher risk for developing the disease, independent of access to medical care. Disparities continue to exist in countries with nationalized health care systems meant to improve access to care, with lower education and income level independent risk factors for the development of T2D.[5,6]

The economic impact of T2D both on individuals and the health care system at large is substantial and is increasing steadily. Between the years of 2012 and 2017, the total direct treatment costs of all diabetics in the United States increased by 21%, from $188 billion to $237 billion. Indirect costs also increased by 19%, resulting in a total

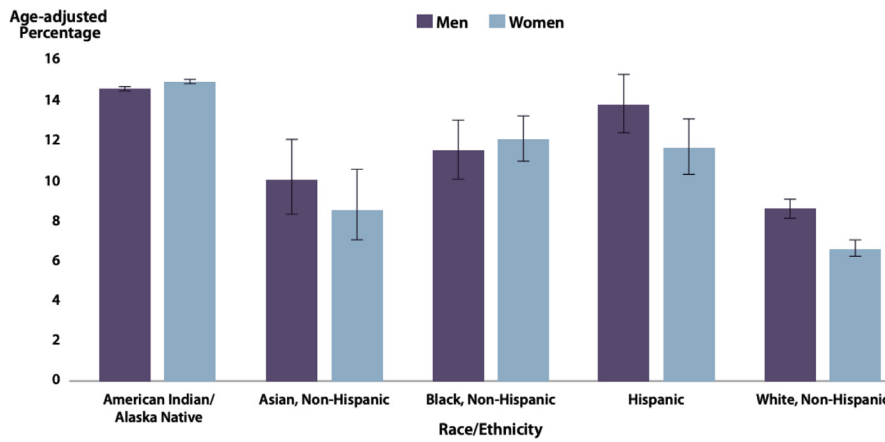

Fig. 1. Trends in age-adjusted prevalence of diagnosed diabetes, undiagnosed diabetes, and total diabetes among adults aged 18 years or older, United States, 1999 to 2016. (*From* Centers for Disease Control. National Diabetes Statistics Report 2020. Estimates of Diabetes and Its Burden in the United States.; 2020.)

of $327 billion expense to the US health care system, making up 9.3% of total health care spending.[7] The increase in the prevalence of disease is partially to blame; however, novel, more-expensive treatment strategies also play a role. The annual costs per person due to diabetes management increased from $8417 to $9601 in the same time frame.[1] Management of T2D is becoming more burdensome financially both on individual patients and health care system at large; therefore, the pursuit of a durable cure has intensified.

COMORBIDITIES ASSOCIATED WITH TYPE 2 DIABETES MELLITUS

The most common and feared comorbidities associated with T2D are atherosclerosis, nephropathy, and retinopathy. All of these are the direct result of the damage chronic hyperglycemia has on the vasculature throughout the body through multiple pathways. The atherosclerotic lesions found in diabetic patients are identical to those in nondiabetic patients and share a similar pathogenesis. A chronic hyperglycemic state causes an overproduction of adenosine triphosphate through the electron transport chain, of which superoxide is a by-product. This oxidative stress signals macrophage recruitment to the intimal lining and the subsequent retention of low-density lipoprotein in foam cells. In addition to recruiting inflammatory mediators to the intimal lining, reactive oxygen species within the plaque core causes apoptosis of macrophages, destabilizing the plaque structure as well as breaking down the fibrous cap.[8] The result is a higher risk of plaque rupture and thrombotic events in diabetics compared with nondiabetics with a similar atherosclerotic burden.[9]

Furthermore, microvascular effects of hyperglycemia are due primarily to vascular permeability, which leads to the high rates of nephropathy and retinopathy seen in diabetics. The initial finding in diabetic nephropathy is albuminuria, due to increased renal perfusion and degradation of the glomerular basement membrane. Oxidative stress combined with alterations to endothelial membrane surface proteins, called advanced glycosylation end-product, signals apoptosis of podocytes that maintain the endothelial lining. In addition, proinflammatory signals cause glomerulosclerosis, which exacerbates the glomerular basement membrane permeability. The result is a complete breakdown of plasma filtration through the glomeruli, leading to an intrinsic nephropathy.[10] The CDC reports that diabetes is the leading cause of end-stage renal disease, accounting for 38% of cases, followed by hypertension (26%) and glomerulonephritis (16%).[11]

A similar pathway leads to macular edema, angiogenesis, and vitreous hemorrhage that cause retinopathy in these patients. The same oxidative stress and advanced glycosylation end-product production causes apoptosis of pericytes that line the retinal capillaries. This leads to increased permeability of the vascular walls and ultimately macular edema. Retinal ischemia ensues as a result of apoptosis, and the retina reacts by up-regulating vascular growth factors, such as vascular endothelial growth factor and erythropoietin. This leads to microvascular overgrowth and hemorrhage within the retina, ultimately exacerbating vision loss.[8,10]

PHYSIOLOGIC EFFECTS OF METABOLIC SURGERY ON TYPE 2 DIABETES MELLITUS

The effect of bariatric surgery on the neurohormonal axis of energy metabolism recently has gained increased attention. Anatomic alterations change nutrient presentation to the gut, thereby altering the up-regulation and down-regulation of a variety of intestinal hormones and modulators, each of which has paracrine and endocrine effects on glucose metabolism, energy storage, and appetite.[12] Glucagon-like peptide 1 (GLP-1) is 30–amino acid peptide produced in the L cells of the distal small bowel.

GLP-1 is described as an incretin, a metabolic hormone that can stimulate a decrease in blood sugar levels. GLP-1 does this by directly increasing the release of insulin and inhibiting the release of glucagon.[13] Certain bariatric surgical procedures increase the delivery of nutrients and food particles to the distal small bowel and L cells, leading to their stimulation and release of GLP-1. It is the profound hypersecretion of GLP-1 after bariatric surgery that seems to have the most effect on postoperative plasma glucose levels. Other gut hormones, especially peptide YY (PYY), glucose-dependent insulinotropic polypeptide, and oxyntomodulin, also are potential agents that work in a complicated, poorly understood concert to maintain energy homeostasis.[14] These hormone levels also are affected by bariatric procedures and are targets for pharmacologic intervention in an effort to replicate the success of the GLP-1 pathway alterations commonly used today in medical practice.

Because of the effects of bariatric surgical procedures on the function of this neurohormonal axis of energy metabolism, a more clinically appropriate and relevant term for this class of procedures is metabolic surgery rather than bariatric surgery, which implies only weight loss benefits. As the concept of metabolic surgery is promoted to primary care physicians and patients, the positive effects of the surgery on T2D are highlighted and the weight-reduction effects become secondary. This terminology may decrease the inherent bias against weight loss surgery and patients who suffer from obesity.

PATIENT EVALUATION

Metabolic surgery provides superior glucose control and remission of T2D compared with medical management alone.[15] Not all diabetic patients respond equally, however, with T2D remission rates ranging widely from 30% to 80%, when patients are followed further than 5 years after their operation.[16] The durability of glycemic control is dependent on β-cell function at the time of surgery. As diabetes progresses over time, β-cell are required to maintain hyperinsulinemia in the face of persistent hyperglycemia and peripheral IR. This metabolic stress combined with the systemic inflammatory state ultimately causes damage and death to the islet cells of the pancreas, commonly referred to as *burnout*. The severity of disease is measured by the residual secretory function of the pancreas that ultimately declines if hyperglycemia goes unchecked.

In mild disease, residual β-cell are able to provide sustained insulin production over time after surgery, whereas severe diabetics suffer shorter remission of disease due to the lack of islet cell reserves.[17] Older age, longer duration of disease, higher hemoglobin A_{1C} (HbA_{1c}), use of more than 2 diabetes medications, and insulin requirement prior to surgery can act as surrogate markers for islet cell function and all have been associated with worse glycemic control after 5 years after surgery.[18] This information can be used clinically to predict patient outcomes when discussing the risks and benefits of metabolic surgical options. Patients with severe disease may choose a lower risk surgical option if the chances of remission are similar between vertical sleeve gastrectomy, gastric bypass, or duodenal switch (DS) (**Fig. 2**).

Aminian and colleagues created and externally validated an individualized scoring system based on a patient's severity of disease to aid in the decision between vertical sleeve gastrectomy (VSG) and Roux-en-Y gastric bypass (RYGB).[17] The individualized metabolic surgery (IMS) score is based on preoperative diabetes medications, preoperative insulin use, duration of diabetes, and glycemic control defined as HbA_{1c} greater than 7%. They performed a retrospective review of 659 patients who had at least 5 years of follow-up after either VSG or RYGB, assigning a point system to the

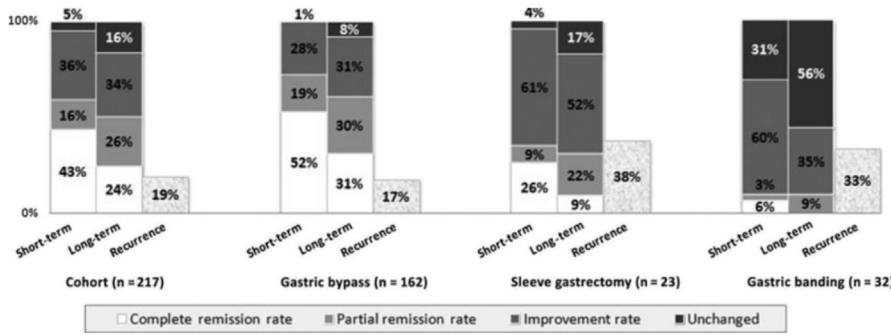

Fig. 2. Short-term and long-term diabetes remission and recurrence rates according to procedure type. (*From* Brethauer SA, Aminian A, Romero-Talamás H, et al. Can diabetes be surgically cured? Long-term metabolic effects of bariatric surgery in obese patients with type 2 diabetes mellitus. *Ann Surg*. 2013;258(4):628-637; with permission.)

each of these characteristics based on their impact on long-term remission (defined as HbA_{1c} <7% without medications). In patients with severe disease (>95 IMS score), they found no difference in glycemic control between VSG or RYGB, with long-term remission rates approximately only 12%. VSG is recommended in these patients because the risk of RYGB does not result in more reward. In patients with moderate disease (25–95 IMS score), however, RYGB resulted in 35% improvement in T2D remission (60% vs 25%; $P = .0001$), prompting the investigators to recommend RYGB for patients who fall in this category as the higher-risk procedure results in significant rewards. Patients with mild disease (<25 IMS score) saw the highest rates of disease remission with only marginal differences between VSG and RYGB. Because RYGB resulted in a significant reduction in the number of diabetes medications over SG, however, the investigators suggest RYGB to for these patients as well. These data were used to create a user-friendly calculator that can be utilized in the office to aid in the discussion of the risks and potential benefits of surgical options.[19]

One criticism of the widespread distribution and use of the IMS is the lack of data for other alternative surgical options, such as the one-anastomosis gastric bypass (OAGB), the DS, and a modification of the DS: the single-anastomosis duodeno-ileal bypass with VSG (SADI-S). The physiologic effects of the DS and its variants are discussed later. The OAGB initially was described by Rutledge and colleagues,[20] in 1997, as the mini–gastric bypass and has gained wide acceptance in the international community. In the era of high-utilization of the gastric sleeve as an alternative to the RYGB and the DS, the OAGB has not yet achieved widespread adoption in the United States. Recent studies have demonstrated positive physiologic effects of the OAGB and its modifications on T2D.[21] As additional studies reveal the relative strengths of all operations to place T2D into remission, the procedure selection algorithm for surgeons and patients will become more robust and accurate.

SURGICAL OPTIONS

Roux-en-Y Gastric Bypass

The RYGB has become the mainstay of metabolic surgery since the publication in 1995 of the landmark article by Pories and colleagues,[22] delightfully entitled, "Who Would Have Thought It? An Operation Proves To Be the Most Effective Therapy for

Adult-onset Diabetes Mellitus." The mechanisms of its effect on glycemic control generally can be divided into 2 categories: calorie restriction and gut hormone stimulation.[23] Calorie restriction has a cascade of effects on glycemic control, from reducing postprandial glycemic load, reducing lipotoxicity through lipolysis, reducing hepatic steatosis, and free radical reduction leading to improved β-cell survival. Calorie restriction is accomplished by creating a small gastric pouch that restricts caloric intake as well as proximal small bowel bypass that causes malabsorption of calories. The proximal enteric bypass also causes rapid transit of food particles to the terminal ileum, which in turn stimulates gut hormones. These hormones augment glycemic control by regulating insulin production, reducing glucagon secretion, and enhancing peripheral uptake of glucose; and they have anorexic properties that also reduce caloric intake. This powerful combination of caloric restriction and hormone augmentation has allowed the RYGB to stand the test of time as the standard metabolic surgical intervention.[19]

The antidiabetic effects are showcased by the acute improvements in glycemic control postoperatively, even prior to any weight loss. Within the first 6 days of surgery, patients experience improvements in their postprandial blood glucose levels and may eliminate the need for diabetic medications altogether.[24] Wallenius and colleagues[25] studied fasting blood glucose, insulin, GLP-1 levels, and IR at 2 days, 3 weeks, and 12 months in diabetic patients undergoing RYGB and SG. They found significant reductions in fasting blood glucose at 3 weeks, with decreased insulin levels (**Fig. 3**) and IR as soon as 2 days following surgery, which continued to improve over the 12-month extent of the study.[25]

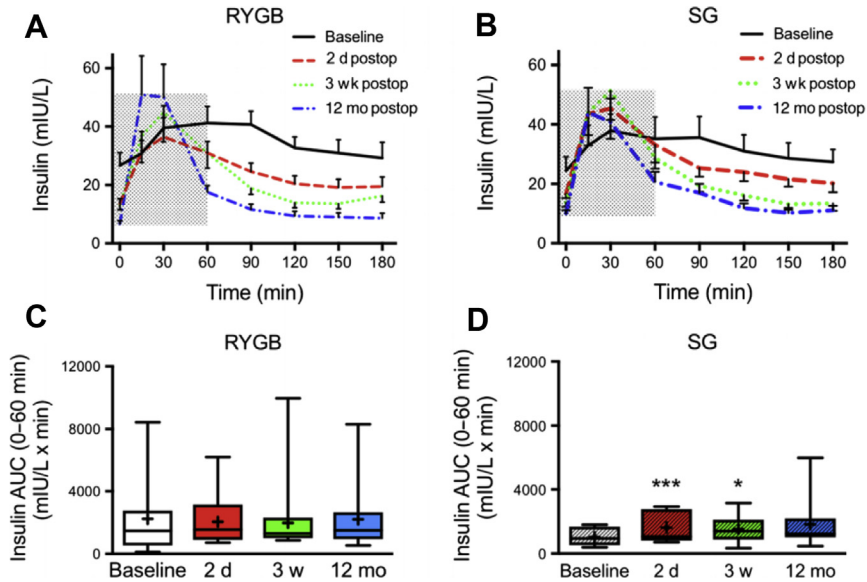

Fig. 3. Within-group plasma insulin levels 0 minutes to 180 minutes after a modified 30-g oral glucose tolerance test at baseline, 2 days, 3 weeks, and 12 months after ([*A*] and [*C*]) LRYGB or ([*B*] and [*D*]) LVSG after Roux-en-Y gastric bypass, RYGB (see panels A and B) or after vertical sleeve gastrectomt, VSG (panels C and D). AUC, area under the curve. (*From* Wallenius V, Dirinck E, Fändriks L, Maleckas A, le Roux CW, Thorell A. Glycemic Control after Sleeve Gastrectomy and Roux-En-Y Gastric Bypass in Obese Subjects with Type 2 Diabetes Mellitus. Obes Surg. 2018;28(6):1461-1472; with permission.)

The durability of glycemic control has been corroborated by the 5-year follow-up of the STAMPEDE (Surgical Treatment and Medications Potentially Eradicate Diabetes Efficiently) trial, which randomized patients to intensive medical management, RYGB, or SG.[13] Ultimately, patients in the surgical arm achieved the highest rates of remission (HbA_{1c} <6.5% without medications): 30.6% after RYGB, 23.4% after VSG, and 0 patients in the medical therapy group. After 5 years, patients requiring insulin in the RYGB arm dropped by 35%, and 45% of patients required no diabetic medications at all. This study was performed on all patients regardless of severity of diabetes, even though it now is understood that remission rates vary depending on an individual patient's severity of disease.[14] Even so, the ability to achieve immediate glycemic control along with durable diabetes remission has established the RYGB as the gold standard metabolic procedure since the 1990s.

Vertical Sleeve Gastrectomy

The concept of the VSG was born from the restrictive portion of the DS and later used as a stand-alone operation.[26] Until recently, its effects on T2D were thought to be limited to calorie restriction and weight loss with very little effect on the gut hormone axis. In spite of the lack of intestinal bypass, however, GLP-1 and PYY levels have been found to increase perioperatively to levels that rival the RYGB.[27] The small gastric reservoir results in rapid transit of food particles into the small bowel, stimulating the intestinal enteroendocrine axis in a way similar to bypass procedures. Wallenius and colleagues found that GLP-1 levels increased similarly 2 days postoperatively; however, patients who underwent RYGB maintained higher levels at 3 weeks and 12 months.[25] Ultimately, they found that both early glycemic control and late glycemic control were similar between VSG and RYGB in spite of less weight loss. Although GLP-1 may play a role in early glycemic control, there clearly are other non–weight-dependent pathways that contribute to the durable euglycemic effect of SG.

This theory has been supported by the 5-year follow-up of the STAMPEDE trial, which showed no significant difference in HbA_{1c} between VSG and RYGB. Diabetic remission rates (HbA_{1c} <6.5% without medication) were better in the surgical arm with no significant difference between the 2 procedures (23.4% vs 30.6%; $P = .043$).[13] These findings have been corroborated in a large metanalysis by Guraya and Strate,[28] who also noted that 5-year remission rates were lower after SG; however, this difference did not reach statistical significance ($P = .07$). Clearly the metabolic effects of VSG are potent but largely have been overshadowed by the gastric bypass through the early years of bariatric surgery. When attempting to predict successful remission for an individual patient, the choice between these 2 procedures is less important than patient severity of disease preoperatively. A thorough assessment of a patient's goals and risk tolerance can be assessed using the Web-based Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program risk/benefit calculator, which can empower patient and surgeon to make an informed decision.[29]

Biliopancreatic Diversion with Duodenal Switch

The mechanisms of glycemic control from biliopancreatic diversion (BPD) with DS are identical to RYGB; however, they are augmented by the technique. A much longer portion of jejunum is excluded by creating a 150-cm Roux limb and a 100-cm common channel (**Fig. 4**). Restriction is achieved by performing a VSG first, and dumping symptoms are mitigated by locating the Roux anastomosis to the postpyloric duodenum. This anatomic arrangement results in a decreased absorptive capacity for nutrients and a more rapid transit of food particles to the terminal ileum, thereby stimulating

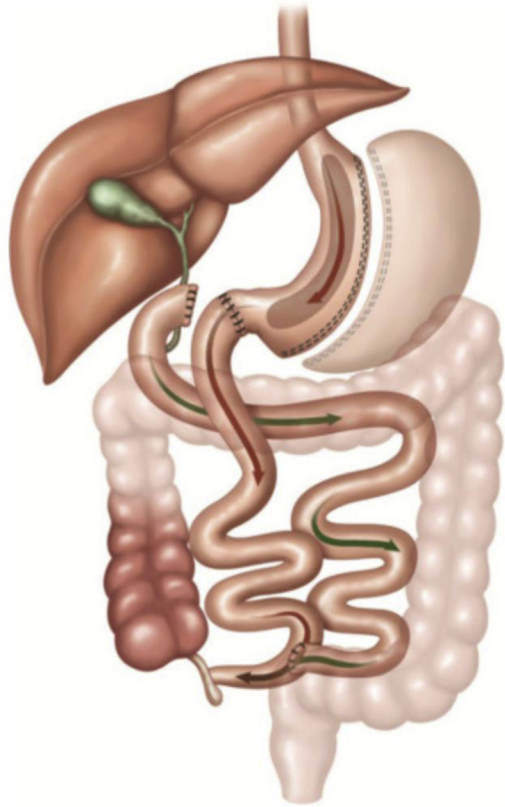

Fig. 4. BPD-DS. (*From* Biertho L, Lebel S, Marceau S, Hould FS, Julien F, Biron S. Biliopancreatic Diversion with Duodenal Switch: Surgical Technique and Perioperative Care. *Surg Clin North Am*. 2016;96(4):815-826; with permission.)

distal ileal hormone release (PYY and GLP-1). Studies of superobese patients (BMI >50 kg/m^2) have shown increased weight loss and glycemic control compared with RYGB; however, this comes at the expense of more potential adverse outcomes, such as gastroesophageal reflux disease (GERD), vitamin deficiencies, and diarrhea.[30] Mingrone and colleagues performed an RCT where they showed a 63% T2D remission rate on 5-year follow-up after BPD-DS compared with 37% in the RYGB group.[15] Compared with RYGB for weight loss and antidiabetic effects, BPD-DS is more effective; however, it also is the more technically challenging operation and can be associated with higher complication rates. As robotic surgery is changing current paradigms, the DS and its variants are becoming more feasible. The DS should be utilized, however, in patients who are able to realize the maximum rewards while being able to tolerate potential longer term nutritional complications.

Diabetes remission is but one of the many goals a patient may have when pursuing metabolic surgery, and these must all be considered when tailoring the correct procedure to a patient. A review of the Bariatric Outcomes Longitudinal Database showed that BPD-DS resulted in an average greater weight loss and improved resolution of diabetes mellitus and hypertension but was inferior to RYGB in resolution

of GERD symptoms and associated with a greater number of nutritional complications.[31] The ideal candidate should have mild-severity to moderate-severity T2D, minimal preoperative GERD, BMI greater than 50kg/m^2 and desire for substantial weight loss, and proved dietary compliance, because nutritional supplementation is required for life.

Single-Anastomosis Duodeno-ileal Bypass with Vertical Sleeve Gastrectomy

In the past 5 years, interest has grown in the SADI-S as an alternative to the DS.[32] The procedure involves creation of a VSG and division of the proximal duodenum as performed in the DS; however, a section of ileum 250 cm to 300 cm from the ileocolonic valve is brought up as a loop anastomosis to the duodenum (Fig. 5). The theoretic advantages include a technically simpler operation to perform with only 1 anastomosis, less potential internal hernia, and improved vitamin absorption because food is exposed to bile and pancreatic fluid through the entire length of the efferent limb. Current comparative studies have confirmed shorter operative times with equivalent weight loss; however, the rate of postoperative vitamin deficiencies remained unchanged between the 2 procedures.[33]

One of the largest studies by Sánchez-Pernaute and colleagues[34] followed the glycemic control of 97 patients after SADI-S. They found that 5 years after SADI-S, between 70% and 84% of their population were off all diabetic medication and maintaining HbA_{1c} less than 6. Successful long-term remission was more likely in non–insulin-dependent versus insulin-dependent diabetics (75% vs 38.4%, respectively) and in patients who had a shorter duration of disease prior to surgery. Like

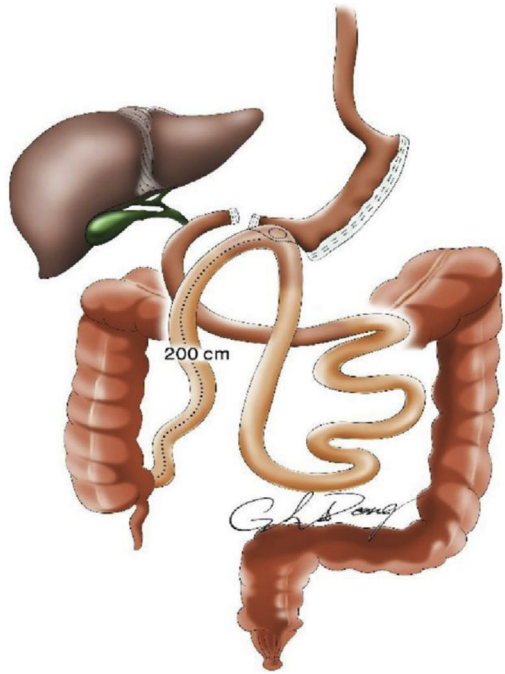

Fig. 5. SADI-S. (*From* Wu A, Tian J, Cao L, Gong F, Wu A, Dong G. Single-anastomosis duodeno-ileal bypass with sleeve gastrectomy (SADI-S) as a revisional surgery. *Surg Obes Relat Dis*. 2018;14(11):1686-1690; with permission.)

DS, the SADI-S appears to be an excellent procedure for superobese, diabetic patients; however, it is technically simpler and has some potential advantages. Concerns about afferent loop syndrome and gastroesophageal reflux remain, and long term, comparative studies are needed to identify the procedures best clinical application.

ECONOMIC IMPLICATIONS OF METABOLIC SURGERY FOR TYPE 2 DIABETES MELLITUS

As discussed previously, T2D is an insidious, chronic medical condition that is associated with a host of medical comorbidities, including microvascular complications (retinopathy, nephropathy, and neuropathy) as well as macrovascular disease states (myocardial infarctions, strokes, and amputations). Intense medical treatment of T2D has not demonstrated widespread effectiveness in halting the progression of the disease, and the cost of associated medical and surgical comorbidity continues to add to the financial burden on health care systems. Metabolic surgery halts the advancement of the disease process and, in 1 study, surgery was associated with a 65% decrease in microvascular and macrovascular complications related to T2D.[35] The Swedish Obesity Subjects Study (SOS), known for its extreme long-term follow-up, demonstrated a decrease in the cumulative incidence of microvascular and macrovascular complications with a mean follow-up of 17.6 years.[36] O'Brien and colleagues[37] also reported a significantly lower risk for the development of neuropathy, retinopathy, and nephropathy. In addition to decreases in the relative incidence of complications, hospitalizations, and surgeries associated with T2D, metabolic surgery has also shown a relative cost savings in medication usage. The SOS group also demonstrated decreased medication costs in the surgery group versus nonsurgical controls.[38]

In light of these savings, it should not be surprising that metabolic surgery affords an opportunity to decrease overall health care expenditures. Several studies have attempted to measure and predict the economic benefits of metabolic surgery in patients with T2D with encouraging results.[39–42] On a macroeconomic level, metabolic surgery may reduce direct costs for health care systems, but it may be more difficult to predict the economic benefits to society related to decreasing disability associated with T2D complications.

Despite the evidence of the economic benefits of metabolic surgery, it remains highly underutilized, perhaps due to preexisting bias and underappreciation of the metabolic effects of surgery.[43] As long as insurance policy barriers exist that prevent many patients from utilizing surgical treatments for T2D, the true economic benefit of metabolic surgery to society may not be fully realized.

SUMMARY

Since its inception as a procedure performed mainly for weight loss, metabolic surgery has evolved into a powerful weapon in the fight against metabolic disease. The physiologic impacts of these surgeries quickly are becoming more understood, leading to refinements in technique, bariatric program design, and utilization of pharmacologic adjuvant therapy. Patient access to surgical care for the management of T2D should be unrestricted, because most studies indicate a favorable cost/benefit ratio. Increasing the utilization of metabolic surgery as an early treatment option for T2D will slow the progression of the disease, decrease medical and surgical comorbidity, increase wellness and quality of life, and decrease overall health care expenditures over the lifetime of patients.

CLINICS CARE POINTS

- T2D incidence and prevalence are increasing in the United States.
- T2D is associated with microvascular comorbidity (nephropathy, neuropathy, and retinopathy) and macrovascular comorbidity (myocardial infarction, stroke, and limb ischemia).
- Metabolic surgery alters the levels of several key gut hormones that are responsible for maintaining energy metabolism.
- GLP-1 may play an important role in the remission of T2D after bariatric surgery.
- Metabolic surgery has variable effects on T2D, depending on the severity of disease and extend of comorbidity.
- The STAMPEDE trial demonstrated superiority of RYGB and VSG over medical management of T2D after 5 years.
- BPD may be more effective for the resolution of T2D compared with RYGB but may be associated with more potential complications.
- The SADI-S procedure is a modification of the BPD that has shown promise as a metabolic procedure.
- Several studies have indicated that metabolic surgery provides economic benefits compared with medical therapy for T2D.

DISCLOSURE

Authors have nothing to disclose.

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