Bariatric Surgery for Obesity

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KEYWORDS

• Obesity • Bariatric surgery • Metabolic surgery • Type 2 diabetes mellitus
• Gastric bypass • Sleeve gastrectomy

KEY POINTS

- Bariatric surgery is the most effective treatment for severe obesity. It is associated with significant and sustained weight loss and is more effective than lifestyle or medical management in achieving glycemic control and reductions in morbidity and mortality from cardiovascular disease and even cancer.
- The most commonly performed bariatric procedures are gastric banding, sleeve gastrectomy, Roux-en-Y gastric bypass, and biliopancreatic diversion (BPD), with or without duodenal switch. Most operations are successfully performed laparoscopically.
- Weight loss plays a major role in inducing improved glucose homeostasis following bariatric surgery, but there are several weight-independent mechanisms at play.
- Bariatric surgery has a very low mortality (0.04%–0.3%) and morbidity (4.3% incidence of major adverse events in the early postoperative period).
- Nutritional deficiencies are common following some bariatric procedures (gastric bypass and BPD). Lifelong supplementation of vitamins D and B12, folic acid, iron, and calcium, among others, is recommended.

INTRODUCTION

The rising prevalence of obesity, along with high numbers of nonresponders to medical weight-reduction programs, has led to the evolution and success of bariatric surgery.[1–3] Although this treatment was initially conceived purely for weight loss, bariatric surgery has since evolved into a treatment for health gain. Several randomized trials and prospective cohort studies have demonstrated that bariatric surgery is not only superior to usual medical care for weight loss but also, more importantly, translates into several health benefits, including improved glycemic control and reductions in

Disclosure Statement: The authors have no disclosures.
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Med Clin N Am 102 (2018) 165–182
https://doi.org/10.1016/j.mcna.2017.08.011 medical.theclinics.com
0025-7125/18/

morbidity and mortality from cardiovascular disease and even cancer.[4–9] Observing and investigating the significant metabolic impact of bariatric procedures have led to an understanding of several weight-independent mechanisms by which these procedures affect metabolic health. Indeed, many have embraced the term "metabolic surgery" to emphasize such effects.[10,11] Furthermore, surgical procedures have evolved and outcomes improved over the last decade, with the widespread adoption of minimally invasive techniques, enhanced recovery programs, and a commitment to data reporting.

Gastric banding, sleeve gastrectomy, Roux-en-Y gastric bypass (RYGB) and biliopancreatic diversion (BPD), with or without duodenal switch (DS), are the most commonly performed bariatric procedures at present. These operations have traditionally been categorized as restrictive (band and sleeve), malabsorptive (BPD, DS), or combined restrictive and malabsorptive (RYGB) procedures. However, this classification is unscientific, and an increasing body of literature demonstrates that mechanisms other than restriction and malabsorption are at play. It has emerged that procedure effects are largely determined by visceral signals, which occur as a result of anatomic alterations to the gut.[12,13] Gastric banding and sleeve gastrectomy only alter stomach anatomy, whereas RYGB and BPD involve anatomic alterations of both the stomach and the small bowel. The mechanism of action of each procedure results in unique outcomes and can give rise to a constellation of procedure-specific risks, merits, and limitations. In this review, the authors summarize the published outcomes of commonly performed bariatric procedures, including weight loss, perioperative morbidity and mortality, late complications, as well as the impact of bariatric surgery on comorbidities, cardiovascular risk, and mortality. The authors also briefly discuss the mechanisms by which bariatric/metabolic surgery causes such significant weight loss and health gain.

INDICATIONS FOR SURGERY

The eligibility criteria for bariatric surgery established by the National Institutes of Health in 1991 are widely used,[14] but are now being challenged. According to these criteria, patients are eligible if they have a body mass index (BMI) between 35 and 40 kg/m^2 as well as an obesity-related complication, such as diabetes mellitus, obstructive sleep apnea, or cardiovascular risk factors, or a BMI $\geq$40 kg/m^2, regardless of weight-related comorbidities. These criteria were based on risk-benefit evidence (risk of obesity vs surgical risk-benefit) at the time when most operations were not being done laparoscopically. The criteria reflect the consensus views of an expert group of surgeons, physicians, psychologists, and others that were expressed more than 25 years ago, whereas many of today's commonly used procedures were not in existence. Despite the time elapsed, many of the fundamental issues of bariatric surgery remain the same, although the widespread adoption of the laparoscopic approach to bariatric surgery and safer anesthetic techniques in these patients have reduced surgical risk significantly.

More recently, the International Diabetes Federation and more than 50 other organizations interested in the treatment of diabetes have recommended considering bariatric surgery for individuals with BMI less than 35 kg/m^2 and poorly controlled type 2 diabetes (T2D) despite best medical care.[15] If a candidate meets these eligibility criteria for surgery, then a multidisciplinary team assessment is made as to the suitability of the candidate. In some countries, this can be a complex process involving psychological, surgical, dietetic, and medical review to ensure that the individual is physically and psychologically fit to proceed to surgery[16]; however, many of these practices have evolved without an evidence base. There are also no evidence-based exclusion criteria, but the main contraindications in common use are psychological features that indicate that a patient would not be able to cope with the impact of the procedure, such as personality disorders, or that the procedures may put the patient at higher risk after surgery, such as alcohol addiction. Patient's fitness for surgery is assessed by the anesthetist on a case-by-case basis. The decision to operate will consider the candidate's potential benefit from surgery and the perioperative risks.

SURGICAL PROCEDURES

Over the last decade, bariatric surgical techniques have evolved and advanced. Recent data examining the utilization of laparoscopic bariatric procedures at academic medical centers in the United States reflect changing trends.[17] Vertical-banded gastroplasty was the prototype operation for many years, until acknowledgment of its high failure rates and long-term complications resulted in it being largely abandoned. Sleeve gastrectomy was initially used as the first component of a 2-stage DS procedure in high-risk patients, but has since been demonstrated to be effective as a stand-alone bariatric procedure and has now become the most commonly performed procedure in the United States, where it accounts for approximately 54% of all bariatric operations. Gastric bypass is the second most commonly performed procedure at present (approximately 23%), and gastric banding is much less commonly performed than previously (approximately 6% of all procedures). BPD and DS (**Fig. 1**) are infrequently performed in the United States (<1%), and revisional procedures are becoming increasingly common (13%) (ASMBS [American Society for Metabolic & Bariatric Surgery] data acquired from BOLD [Bariatric Outcomes Longitudinal Database], ACS/MBSAQIP [American College of Surgeons/Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program], National Inpatient Sample data https://asmbs.org/resources/estimate-of-bariatric-surgery-numbers).

Novel endoscopic procedures are proposed alternatives to bariatric surgery and include intragastric balloons, duodenojejunal bypass liners such as the EndoBarrier, and endoscopic suturing platforms.[18,19] These largely experimental procedures are associated with a mean weight loss of 5% to 15% in the short term, and a complication rate of up to 20%. Given the lack of long-term data at present, the role for such devices remains to be determined. Most recently, The AspireAssist System has received approval from the US Food and Drug Administration and is in clinical trials. This device is a novel endoscopic weight-loss device composed of an endoscopically placed percutaneous gastrostomy tube and an external device to facilitate drainage of approximately one-third of the calories consumed in a meal. Pilot data from patients with this device demonstrate a total body weight loss of 12% at 1-year follow-up.

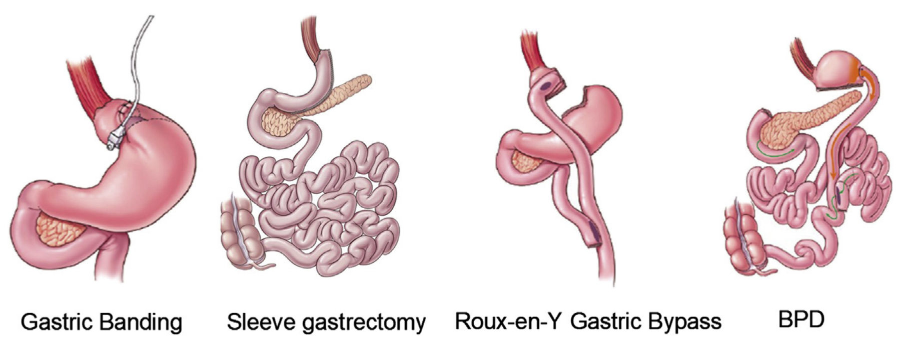

Fig. 1. Common bariatric procedures. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2017. All Rights Reserved.)

OUTCOMES OF BARIATRIC SURGERY: BENEFITS

Weight Loss

Previously, the primary goal of bariatric procedures has been weight loss. Although the various procedures achieve this to different extents, the overall weight loss is reported to be 15% to 30% in the long term.[11,20,21] RYGB and BPD achieve greater and more durable weight loss compared with sleeve gastrectomy and gastric banding, although at the expense of higher nutritional complications. Patients undergoing gastric banding and sleeve gastrectomy may also have a greater risk of weight regain in long-term follow-up.[22,23]

Overall, up to 20% of all bariatric patients lose less than 20% of their weight and are considered by some as surgical failures. The cause of failed bariatric procedures is complex and multifactorial. Contributing factors include technical complications (rare), patients with complex and chronic obesity syndromes that do not respond to surgery (common), and specific postsurgical causes that attenuate the usual profound effect of bariatric surgery on appetite (common).[24] Attempts to identify factors predictive of weight loss failure have been rather futile thus far.[24,25] Careful patient selection, preoperative education, meticulous operative technique, and routine follow-up have been thought to contribute to a lower incidence of failure, but most studies have failed to prove causation between these factors and outcomes. Clinical research endeavors are focused on identifying clinical, biochemical, or molecular factors that may influence bariatric surgery outcomes and therefore have utility as prognostic tools to better select the right procedure for the right patient. Thus, far very few prognostic markers have been identified. Revisional bariatric surgery is a growing subspecialty, in response to the rapid increase worldwide of the numbers of primary bariatric procedures, a proportion of which will be unsuccessful. RYGB is the most commonly practiced revisional bariatric procedure and has been documented to achieve excellent rescue rates with up to 25% weight loss from original presurgical weight.[26,27] The morbidity and mortality rates for revisional bariatric surgery are higher than those of primary procedures, but are deemed acceptable when considered alongside the restored benefits of weight loss and comorbidity resolution.[28,29]

Impact on Complications of Obesity

In addition to substantial weight loss, bariatric surgery is known to have profound metabolic effects, the most striking of which is the marked resolution of obesity-associated complications, such as diabetes, hypertension, and dyslipidemia. The various procedures differ in the degree of improvement they impart on an individual's state of metabolic disarray, with RYGB and BPD demonstrating greatest benefit in this regard overall.[20]

A substantial body of evidence, including data from 16 randomized controlled trials (summarized in **Table 1**),[4,5,30–48] demonstrates that bariatric/metabolic surgery achieves superior glycemic control and reduction of cardiovascular risk factors in patients with T2D compared with various medical and lifestyle interventions. The first of these to clearly report on weight loss and diabetic outcomes, by Dixon and colleagues,[49] compared the 2-year outcomes of conventional medical treatment with gastric banding for the management of type 2 diabetes mellitus (T2DM), in 60 obese patients. More recently, Schauer and colleagues[5] and Mingrone and colleagues[4] evaluated the 12-, 24-, 36-, and 60-month effects of bariatric surgery (gastric bypass, sleeve gastrectomy, or BPD) compared with intensive medical therapy on diabetes management.[35–37] All 3 groups demonstrated that weight loss surgery was far more effective than medical therapy at inducing remission or improvement of

Table 1
Summary of all randomized controlled trials in the field of bariatric and metabolic surgery to date

Authors	Study Group	N	Mean (SD) Age (y)	Female (%)	Mean (SD) Preop BMI (kg/m^2)	Follow-up Duration (mo)	Type 2 Diabetes		Mean Weight Loss (kg)	Diabetes Remission[a]	Mean Decrease in HbA1C (% Points)
							Prevalence (%)	Duration (y)			
Petry, 2015	Bariatric surgery (DJBm)	10	47 (8)	nr	29.7 (1.9)	12	100	6 (3)	8 (nr)	0.0%	1.2 (nr)
	Control	7	44 (5)	nr	31.7 (3.5)	12	100	5 (3)	1 (nr)	0.0%	0.6 (nr)
Ding, 2015	Bariatric surgery (LAGB)	18	50.6 (12.6)	50.0%	36.4 (3.0)	12	100	10.4 (5.6)	13.5 (1.7)	5.6%	1.23 (0.3)
	Control	22	51.4 (7.5)	41.0%	36.7 (4.2)	12	100	8.4 (4.2)	8.5 (1.6)	0.0%	1.0 (0.3)
Courcoulas, 2014; Courcoulas, 2015	Bariatric surgery (RYGB + LAGB)	41	46.6 (7)	80.0%	35.7 (3)	36	100	6.9 (4.5)	19.8 (2.1)	10.0%	1.1 (0.3)
	Control	20	48.9 (4.7)	85.0%	35.7 (3.3)	36	100	5.7 (5.6)	5.0 (2.5)	0.0%	0.21 (0.4) increase
Cummings, 2016	Bariatric surgery (RYGB)	15	52.0 (8.3)	80.0%	38.3 (3.7)	12	100	11.4 (4.8)	28.1 (15.8)	60.0%	1.3 (nr)
	Control	17	54.6 (6.3)	64.7%	37.1 (3.5)	12	100	6.8 (5.2)	7.2 (6.5)	5.9%	0.4 (nr)
Halperin, 2014	Bariatric surgery (RYGB)	19	50.7 (7.6)	68.0%	36.0 (3.5)	12	100	10.6 (6.6)	27.8 (nr)	58.0%	nr
	Control	19	52.6 (4.3)	53.0%	36.5 (3.4)	12	100	10.2 (6.1)	7.6 (nr)	16.0%	nr
Mingrone et al,[48] 2012; Mingrone et al,[4] 2015	Bariatric surgery (BPD&RYGB)	40	43.4 (7.8)	55.0%	45.0 (6.5)	60	100	6	40.9 (18.1)	50.0%	2.3 (1.7)
	Control	20	43.5 (7.3)	50.0%	45.1 (7.8)	60	100	6	10.0 (12.2)	0.0%	1.6 (1.0)
Schauer et al,[37] 2012; Schauer et al,[36] 2014; Schauer et al,[5] 2017	Bariatric surgery (RYGB & SG)	100	48.1 (8.1)	68.0%	36.6 (3.6)	60	100	8	20.9 (8.6)	26.0%	2.1 (1.8)
	Control	50	49.7 (7.4)	62.0%	36.8 (3.0)	60	100	9	5.3 (10.8)	5%	0.3 (2.0)
Reis, 2010	Bariatric surgery (RYGB)	10	36.7 (11.5)	0.0%	55.7 (7.8)	24	nr	nr	36.1 (3.8)	nr	nr
	Control	10	42.2 (11.0)	0.0%	54.0 (6.1)	24	nr	nr	0.8 (1.7)	nr	nr

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Table 1
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Authors	Study Group	N	Mean (SD) Age (y)	Female (%)	Mean (SD) Preop BMI (kg/m^2)	Follow-up Duration (mo)	Type 2 Diabetes		Mean Weight Loss (kg)	Diabetes Remission[a]	Mean Decrease in HbA1C (% Points)
							Prevalence (%)	Duration (y)			
Ikramuddin et al, 2013; Ikramuddin et al, 2015	Bariatric surgery (RYGB)	60	49 (9)	63.0%	34.9 (3.0)	24	100	8.9 (6.1)	nr	25.0%	3.2 (nr)
	Control	60	49 (8)	34.0%	34.3 (3.1)	24	100	9.1 (5.6)	nr	0.0%	1.2 (nr)
Liang, 2013	Bariatric surgery (RYGB)	31	50.8 (5.4)	29.0%	30.5 (0.9)	12	100	7.4 (1.7)	nr	90.3%	4.5 (1.5)
	Control[b]	70	51.4 (6.2)	31.0%	30.3 (1.7)	12	100	7.2 (1.7)	nr	0.0%	3.6 (1.4)
O'Brien, 2006	Bariatric surgery (LAGB)	40	41.8 (6.4)	75.0%	33.7 (1.8)	24	nr	nr	21.6 (8.2)	nr	nr
	Control	40	40.7 (7.0)	77.0%	33.5 (1.4)	24	nr	nr	4.1 (8.0)	nr	nr
O'Brien, 2010	Bariatric surgery (LAGB)	25	16.5 (1.4)	64.0%	42.3 (6.1)	24	nr	nr	34.6 (7.5)	nr	nr
	Control	25	16.6 (1.2)	72.0%	40.4 (3.1)	24	nr	nr	3.0 (9.5)	nr	nr
Dixon et al,[49] 2008	Bariatric surgery (LAGB)	30	46.6 (7.4)	50.0%	37 (2.7)	24	100	<2	20.3 (6.5)	75.9%	1.8 (1.2)
	Control	30	47.1 (8.7)	57.0%	37.2 (2.5)	24	100	<2	5.9 (8.0)	15.4%	0.4 (1.3)
Dixon, 2012	Bariatric surgery (LAGB)	30	47.4 (8.8)	43.0%	46.3 (6.0)	24	33	nr	27.8 (10.7)	nr	nr
	Control	30	50.0 (8.2)	40.0%	43.8 (4.9)	24	33	nr	5.1 (6.6)	nr	nr
Mingrone, 2002	Bariatric surgery (BPD)	46	37.4 (4.6)	85.0%	48.2 (5.0)	24	nr	nr	40.6 (8.2)	nr	nr
	Control	33	37.4 (4.6)	88.0%	48.2 (7.7)	24	nr	nr	7.8 (8.0)	nr	nr
Heindorff, 1997	Bariatric surgery (LAGB)	8	Range 22–41	75.0%	Range 43–54	10	nr	nr	26.0 (2.0)	nr	nr
	Control	8	Range 21–43	15.0%	Range 40–56	10	nr	nr	1.0 (2.0)	nr	nr

Abbreviations: BPD, Biliopancreatic diversion; DJBm, duodenal-jejunal bypass surgery with minimal gastric resection; LAGB, Laparoscopic adjustable gastric banding; nr, not reported; RYGB, Roux-en-Y gastric bypass; SG, Sleeve Gastrectomy.

[a] The definition of diabetes remission varied in the different studies. Complete remission rates are listed here.

[b] Control group consisted of a medical group with and without exenetide.

diabetes. A published meta-analysis of the data from 11 of these RCTs comparing multimodal medical therapy with bariatric surgery for management of T2DM indicates that weight loss was significantly greater in the surgical groups, and bariatric surgery patients had a higher remission rate of T2D (relative risk 22.1 [3.2–154.3]) and metabolic syndrome (relative risk 2.4 [1.6–3.6]), greater improvements in quality of life, and reductions in medicine use.[50] Other notable benefits in the surgical arms of these trials included significant decrease in plasma triglyceride concentrations and increase in high-density lipoprotein cholesterol concentrations.[50] Although not included in this meta-analysis because it was not a randomized trial, the noteworthy Swedish Obese Subjects (SOS) case-control study demonstrated a hazard ratio (HR) of 0.17 for diabetes incidence following assorted bariatric surgical interventions, illustrating how effectively bariatric surgery reduces progression from the prediabetic state.[51] The SOS studies have also shown that bariatric surgery is associated with a decreased incidence of diabetic microvascular complications (HR 0.44; 95% confidence interval [CI], 0.34–0.56; $P<.001$) and macrovascular complications (HR 0.68; 95% CI, 0.54–0.85; $P = .001$).[52]

The mechanisms by which gastrointestinal surgery leads to T2D remission are not completely understood. The contribution of weight loss to the metabolic benefits of bariatric surgery is critical. Observations supporting this statement include the fact that procedures, such as gastric banding and sleeve gastrectomy, achieve significant improvements in glycemic control, which correlate directly with the amount of weight lost. Buchwald's meta-analysis examining weight loss and diabetes resolution outcomes after bariatric surgery showed that diabetes mellitus resolution rates were proportional to the degree of weight loss.[11] It has also been observed that weight gain after bariatric surgery is associated with recurrence of metabolic comorbidities, including T2D. The reduction in volume of adipose tissue (particularly central adiposity), which occurs with weight loss, positively affects the inflammatory milieu and decreases intra-abdominal pressure, both of which are associated with metabolic benefits. Although weight loss certainly plays a major role in inducing improved glucose homeostasis following bariatric surgery, it appears that there are other mechanisms at play. Evidence to support this assertion includes the fact that leaner patients with T2D experience similar antidiabetic effects without significant weight loss, and most patients' glucose control improves or normalizes almost immediately after surgery, well before any significant weight loss takes place, but during the phase when calorie intake is significantly suppressed. Many patients with T2D can decrease, or even discontinue, insulin and oral hypoglycemic drugs just hours after undergoing RYGB.[53] Furthermore, the BPD and DS result in significantly greater remission of metabolic comorbidities such as T2DM, compared with other interventions with equivalent weight loss.

The various weight-independent mechanisms proposed to induce diabetes remission after bariatric/metabolic surgery include the following[54–56]:

- Increased postprandial secretion of gut hormones from intestinal L cells such as the incretin glucagon-like peptide 1 (GLP-1)
- Changes in intestinal nutrient-sensing mechanisms that affect insulin sensitivity
- Plasma bile acid alterations
- Changes in the gut microbiome
- Exclusion of the proximal duodenum and small intestine from nutrient flow, and possibly downregulation of an unidentified anti-incretin factor or factors

Diabetes remission is more likely in those with better preserved pancreatic function as indicated by lower glycosylated hemoglobin (HbA1c) levels preoperatively and shorter duration of diabetes (<5 years) and insulin independence at the time of surgery.[57,58] In those who do not achieve remission, bariatric procedures, including laparoscopic adjustable gastric banding (LAGB), facilitate better glycemic control and a reduced medication burden compared with intensive medical therapy.[4,37] Up to 25% of patients with initial resolution of their diabetes will have reoccurrence of glucose intolerance, insulin resistance, and T2D, although this phenomenon is often associated with failure to lose a significant amount of weight primarily, or with postoperative weight regain.[59] Bariatric surgery may also facilitate remission of diabetic microvascular complications.[60,61]

Impact on Cardiovascular Risk Profile

Obesity is associated with an increased risk of cardiovascular disease and increased cardiovascular mortality. Reducing this risk by pharmacologically targeting cardiovascular risk factors is effective, but also challenging, and usually involves evidenced-based multidrug regimens requiring high patient compliance. Weight loss of more than 10% may be an effective risk-reduction strategy,[62] but high rates of nonresponders to conventional weight management strategies have been disappointing. Bariatric surgery, by achieving significant and sustainable weight loss, has been shown to positively affect cardiovascular risk, by inducing resolution or improvement in cardiovascular disease risk factors, including T2D, hypertension, and dyslipidemia.[21,63] Indeed, a systematic review of 52 studies involving 16,867 patients who have undergone bariatric surgery demonstrated a reduction of 40% in Framingham risk (10-year cardiovascular disease risk score) following bariatric surgery, resolution, or improvement of 60% to 75% in traditional cardiovascular risk factors (T2DM, hypertension, and dyslipidemia) and significant reduction in novel risk factors, such as C-reactive protein and endothelial function.[63] No pharmacologic treatment has been shown to have so many patients that respond with such a marked positive impact on cardiovascular risk profile.

Impact on Other Obesity Complications

Bariatric surgery positively affects many other weight-related conditions, including obstructive sleep apnea, nonalcoholic steatohepatitis, gastroesophageal reflux disease, arthritis and back pain, urinary incontinence, gout, thyroid and parathyroid function, subfertility, asthma, and others (**Fig. 2**).[64] There is emerging evidence that bariatric surgery may reduce the incidence of cancer, with a stronger protective effect reported in women than men.[6,65] The mechanisms underlying the reduced risk of cancer after bariatric surgery are unclear, but may involve mediation of inflammatory pathways and attenuation of obesity-associated hyperinsulinism.

Impact on Mortality

Several nonrandomized studies have demonstrated that bariatric surgery significantly reduces mortality. The SOS study showed a 30% decrease in mortalities after 10 years of follow-up, mainly from decreases in deaths due to cancer and myocardial infarction.[8] Interestingly, the only predictor of mortality benefit was fasting insulin levels above the median. Similar results were reported by Adams and colleagues,[9] showing a 40% reduction in mortalities for the entire group, but a 92% reduction in mortality for patients with diabetes. Again, the benefit was driven by reduction in death due to cancer and cardiovascular disease. A recent systematic review and meta-analysis has identified 8 studies that reported on long-term mortality, involving 23,647 operated patients and 89,628 nonoperated obese controls. These

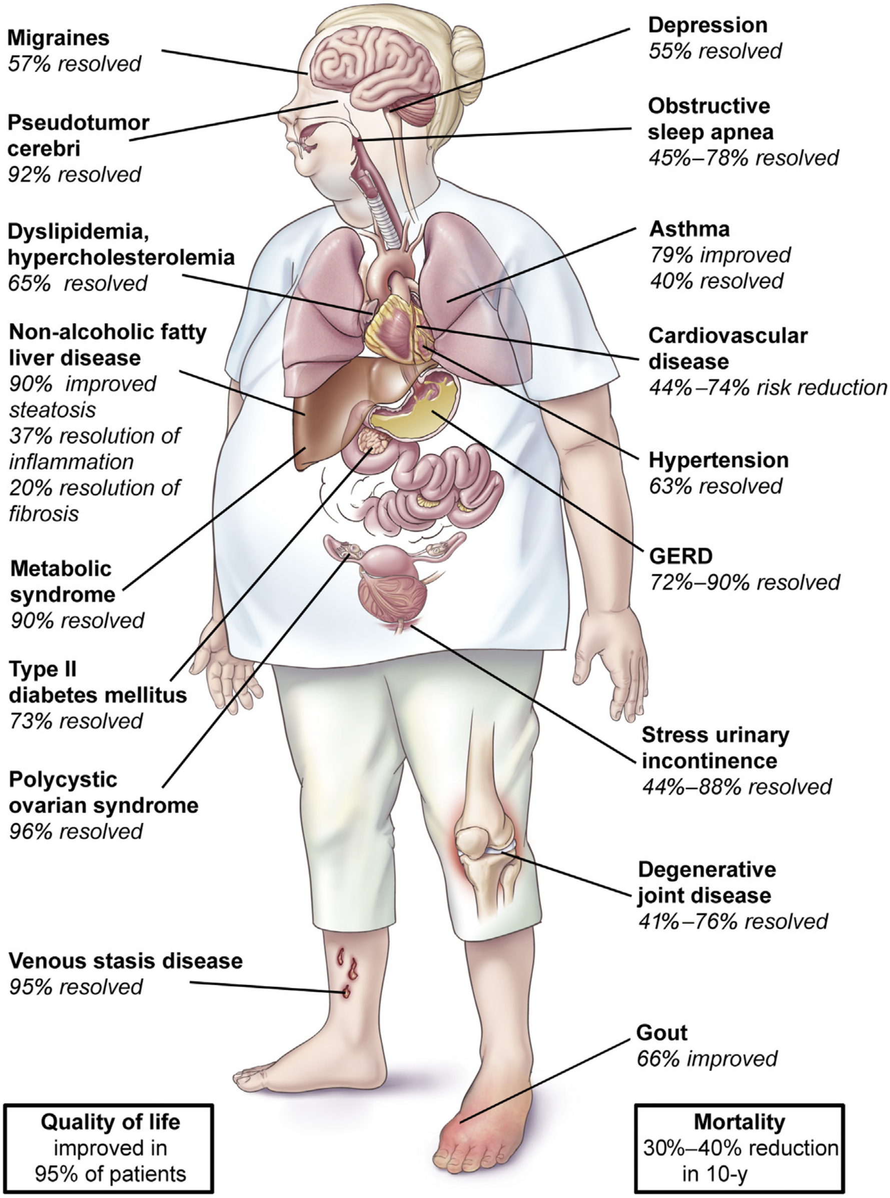

Fig. 2. Obesity-associated comorbidities and their resolution rates after bariatric surgery. GERD, gastroesophageal reflux disease. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2017. All Rights Reserved.)

data showed a reduction of 41% in all-cause mortality after bariatric surgery. Furthermore, bariatric surgery patients were 0.42 times less likely and 0.47 times less likely as nonoperated obese controls to die from cardiovascular diseases and cancer, respectively.[66]

OUTCOMES OF BARIATRIC SURGERY: RISKS

Perioperative Mortality and Morbidity

Over the last 2 decades, the safety of bariatric surgery has been greatly improved and well documented. Developments in surgical innovations, in the medical device industry, coupled with increased experience in minimally invasive surgery have enabled this. In addition, advances in surgical technique and implementation of enhanced recovery after surgery programs have contributed to reduced operative time, length of stay, and complications. The rate of conversion to open surgery is now 1%, occurring most often in the setting of revisional surgery or for complex malabsorptive procedures.[67]

Short-term mortality after bariatric surgery is low, ranging from 0.04% to 0.3%.[68] In a meta-analysis of published mortality data after bariatric surgery, Buchwald and colleagues[69] reported an overall 30-day postoperative mortality of 0.28% (n = 84,931), and total mortality from 30 days to 2 years was 0.35% (n = 19,928). The Longitudinal Assessment of Bariatric Surgery (LABS) study subsequently reported a similarly low 30-day mortality (0.3%) among 4776 patients.[70] More recently, a population-based, nationwide study from Finland reported 30-day, 90-day, and 1-year mortalities following bariatric surgery compared with mortalities after other common operations (cholecystectomy, hysterectomy, prostatectomy, knee and hip arthroplasty, colorectal and gastric resections, coronary artery bypass graft). This study demonstrated that mortality within the first year after surgery was lowest for bariatric surgery in comparison to these other procedures.[68]

Early and long-term complications after bariatric surgery are lower than might be expected for this medically comorbid population; the LABS consortium reported a 4.3% incidence of major adverse events in the early postoperative period.[70] Although these reports are encouraging, a few complications associated with bariatric surgery are potentially fatal and merit careful consideration. These complications include sepsis from an anastomotic dehiscence, shock secondary to postoperative hemorrhage, or cardiopulmonary events in this high-risk group. The leading cause of death after bariatric surgery is thromboembolic disease, with an incidence of 0.34%.[71,72] Perhaps the most dreaded complication is sepsis secondary to an anastomotic or staple line leak, with rates ranging from 1% to 2% for primary gastric bypass and sleeve gastrectomy.[73–75] Early identification and an aggressive approach to management of leaks improve the outcome. Conservative management is only indicated for leaks that are controlled by a surgical drain, in a hemodynamically stable patient. Otherwise, a prompt and aggressive surgical approach is recommended.[76] Early postoperative bleeding complicates 1% to 4% of bariatric surgeries. Most postoperative bleeds can be treated nonoperatively with volume resuscitation and blood transfusions, but any evidence of hemodynamic instability necessitates surgical intervention.[77,78] Other complications unique to the most commonly performed bariatric procedure (RYGB) are illustrated in **Table 2**.

Several risk factors for postoperative morbidity and mortality have been identified; these include male gender, age greater than 50 years, congestive heart failure, peripheral vascular disease, and renal impairment.[79,80] Although these factors may increase risk, they do not necessarily preclude an individual from bariatric surgery and need to be considered in the individual clinical context.

Late Complications of Bariatric Surgery

Long-term complications of bariatric surgery are unique to the specific procedure. Operations such as gastric bypass, which has a narrow gastrojejunal anastomosis,

Table 2
Complications associated with Roux-En-Y gastric bypass

Frequency	Mild	Moderate	Severe
>5%	Nausea and vomiting without consequence, up to 100%	Anastomotic ulcer (8%) Anastomotic stricture (7%) Malnutrition of vitamins or minerals (up to 50%) Dumping syndrome (up to 75%)	Nausea and vomiting leading to dehydration and requiring readmission (~5%) Reoperation (for any reason, <5%)
1–5%	Self-limiting impairment in renal function (2%)	Abdominal hemorrhage or anemia without a clear source, requiring blood transfusion (5%) Pneumonia (4%) Herniation or small bowel obstruction (4%) Wound infection (3%) Arrhythmia without hemodynamic instability (2%) Gallstones (symptomatic in 2%)	Reoperation for abdominal hemorrhage (2%) Anastomotic leak (1%)
<1%			Unstable arrhythmia, myocardial infarction, or cardiac arrest (<1%) Pulmonary embolus, respiratory failure, or other potentially fatal medical complication (0.5%) Overall risk of surgical mortality approximately 0.3%

are susceptible to stricture formation leading to partial or complete luminal obstruction either in the acute setting secondary to edema or in the long term due to fibrosis and scar tissue formation. Complicating up to 8% of laparoscopic RYGB cases, and usually presenting in the first postoperative month, anastomotic strictures can often be managed endoscopically with balloon dilatations, rarely complicated by perforation.[81,82] Obstructive symptoms following gastric banding are usually the result of band slippage or overinflation and are often easily corrected by band adjustment in the clinic. Obstructive symptoms following sleeve gastrectomy usually present immediately following surgery and may indicate an excessively "tight" sleeve exacerbated by postoperative edema. As the edema resolves, symptom resolution usually ensues. Another frequently reported delayed complication of bariatric surgery, usually presenting later in the postoperative course, is ulceration in proximity to the gastrojejunal anastomosis of a gastric bypass or BPD. These "marginal ulcers" are consequent to exposure of the unprotected jejunal mucosa to gastric acidity, and the incidence is reported to be approximately 7%. Medical treatment with proton-pump inhibitors is sufficient for most cases, although there is a select group of patients who continue to suffer from symptomatic, nonhealing ulcers, despite appropriate medical treatment, who require surgical intervention (resection and revision of the ulcerated gastrojejunal anastomosis).[83] Incisional and internal herniation can complicate both open and laparoscopic bariatric procedures. The reported incidence for internal herniation ranges from 2.5% to 6.2% (4% on average); given that presenting symptoms and clinical signs associated with this phenomenon may be subtle and the potential for life-threatening bowel ischemia to occur because of the problem, a high index of suspicion is critical for early diagnosis and timely intervention.[84–86] Abdominal computed tomography is the most sensitive investigation for the identification of an internal hernia, often demonstrating the classic “swirl” sign of the herniated bowel mesentery. Prompt surgical exploration, reduction of the hernia, and resection of any nonviable bowel, and closure of the internal hernia space, are the mainstays of treatment.

Gastric band patients are predisposed to developing several band-related complications, including band slippage, band erosion, and significant esophageal dysmotility, resulting in reintervention rates as high as 48%.[87,88]

Special attention must always be given to the nutritional status of patients following bariatric procedures, particularly after malabsorptive operations. Deficiency of essential vitamins and minerals is highly likely following RYGB and BPD, and on rare occasions, may be life threatening, as with thiamine deficiency encephalopathy. The multidisciplinary team managing bariatric patients must be mindful of micronutrient deficiencies, and dietary supplementation following these procedures is essential. Lifelong supplementation of vitamins D and B12, folic acid, iron, and calcium, among others, is recommended.[89] Scheduled surveillance of the nutritional parameters by blood tests is recommended on a regular basis, at 3-month intervals for the first postoperative year, 6 monthly for the second postoperative year, and annually thereafter.[90]

Another diet-related problem after bariatric surgery, specifically after gastric bypass, is dumping syndrome, which occurs immediately after eating in approximately 50% of patients after RYGB at some stage postoperatively.[91] It is characterized by symptoms such as nausea, tremors, sweating, diarrhea, dizziness, flushing, tachycardia, and occasionally syncope, resulting from the ingestion of food containing large quantities of refined sugars and from food eaten too quickly. Although this was initially considered a desirable deterrent from such behaviors, particularly in patients who are partial to sweets, no association between symptoms and weight loss has ever been shown. Moreover, dumping syndrome can be very problematic in approximately 1% of patients.[92] Another group of patients suffer with postprandial hyperinsulinemic hypoglycemia with neuroglycopenia potentially due to changes in the gut hormonal milieu.[93] Strict dietary alteration is required, with patients eating more low glycemic index carbohydrates and protein and avoiding any medium or high glycemic index carbohydrates. Patients may require a trial of diazoxide, octreotide, or calcium-channel antagonists, among other drugs,[94] whereas GLP-1 analogues have also recently been tested as partial agonists.

Other late complications of bariatric surgery, related to significant weight loss, include gallstone formation (approximately 10% of patients), hair thinning, and excess skin. The latter can significantly affect body image and satisfaction with the surgical outcome. In addition to the aesthetic problem, it can lead to functional problems, dermatoses, and difficulties in maintaining satisfactory personal hygiene. Treatment is mainly with body contouring surgery, for which there are guidelines from international Plastic and Reconstructive Surgery associations.[95] The most troublesome complication is nonspecific abdominal pain, which can occur in 5% to 10% of patients.[53] Although the symptoms are real, the diagnosis and treatment can be very challenging.

SUMMARY

In addition to achieving substantial and durable weight loss, bariatric surgery is associated with favorable metabolic effects far beyond those achieved by lifestyle modifications and pharmacologic treatments. Perioperative morbidity and mortality have decreased significantly over the last decade such that the safety profile of bariatric surgery is better than many well-accepted procedures, such as cholecystectomy and hysterectomy. In fact, the 0.3% mortality risk of bariatric surgery is one-tenth that of coronary artery bypass surgery with significantly greater improvement in long-term mortality. Much of the improvement in perioperative morbidity and mortality can be attributed to advances in laparoscopic surgery as well as establishment of a nationwide center of excellence network and required outcome reporting. The current extensive evidence demonstrating the safety and efficacy of bariatric surgery supports it as the current standard of care for treatment of severe obesity and its related complications.

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