The challenges of the obesity epidemic are not limited to concerns about bulk and weight but also to the associated physiologic, psychosocial, and economic disabil-
ities. A small amount of weight loss, approximately 10 kg, carries significant benefits. including resolution of comorbid conditions, and 10% of initial weight loss has been shown to improve long-term comorbidity control. The likelihood of comorbidity reso-
lation depends on many factors, including the length and severity of disease, the
amount of weight loss attained, and the contribution of obesity to the severity of the disease. Bariatric surgery (BS) can significantly reduce body weight, resolve
obesity-related comorbidities, and improve long-term survival. Overall mortality of BS in a meta-analysis was 0.28%, placing these procedures in the lowest category
of mortality for elective operations performed in the United States. An observational cohort study based on submitted claims for reimbursement of
services or medication showed that, after a mean of 5.3 years, BS was associated
with a mean excess weight loss (EWL) of 67.1%; produced significant relative risk
reductions in cardiovascular, endocrine, respiratory, infectious, and psychiatric
diseases, as well as cancers; and was associated with an 89% reduction in the relative
risk of mortality. These benefits improved patients’ quality of life and significantly
decreased (71.6%) obesity-related claims to insurance companies as early as 4
months following BS. The impact on comorbidities depends on the type of proce-
dure, amount of weight loss achieved, alterations in hormones and incretins, degree
of malabsorption, change in motility, and effect on eating habits.
This article reviews published literature on the impact of BS on some major obesity-
associated comorbidities.

The authors gratefully acknowledge the help of Mr Donald A. Risucci PhD in editing this
manuscript.

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doi:10.1016/j.suc.2011.08.003 surgical.theclinics.com
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TYPE 2 DIABETES MELLITUS

The prevalence of type 2 diabetes mellitus (DM) is increasing worldwide and, from an epidemiologic point of view, almost 90% of diabetes cases could be prevented by avoiding obesity. The estimated attributable risk of excess body weight leading to development of type 2 DM is extremely high and no other modifiable factor has such an impact on the health of the general population. Total costs of diabetes care were estimated to be $132 billion in 2002. Most (67%) people with type 2 DM have a body mass index (BMI) greater than or equal to 30, and thus diabetes is a key source of morbidity in the obese. Roux-en-Y gastric bypass (RYGB) greatly ameliorates obesity-related type 2 DM.

In the Swedish Obese Subjects (SOS) study, surgery, compared with nonsurgical interventions, decreased the risk of developing diabetes by more than 3 times, whereas resolution of diabetes was 3 times more frequent at 10 years. Other studies have shown similar significant, sustained advantages of BS compared with medical management. In a landmark article, Pories and colleagues found substantial and maintained long-term control of DM after RYGB in 121 of 146 patients (82.9%) with DM, and 150 of 152 patients (98.7%) with glucose impairment maintained normal levels of plasma glucose, glycosylated hemoglobin, and insulin.

A meta-analysis of all BS studies from 1990 to 2006 assessing type 2 DM resolution after BS found that 78.1% of diabetic patients had complete resolution, and diabetes improved or resolved in 86.6% of patients. Diabetes resolution was greatest for patients undergoing biliopancreatic diversion (BPD)/duodenal switch (95.1% resolved), followed by RYGB (80.3%), gastroplasty (79.7%), and adjustable gastric banding (AGB; 56.7%). The proportion of patients with diabetes resolution or improvement was constant at time points less than, equal to, and greater than 2 years. Insulin levels declined significantly after surgery, as did hemoglobin A1c and fasting glucose. Resolution of DM is related to weight loss after surgery but it is not a direct cause-and-effect relationship because resolution can occur within days after surgery, even before any significant weight loss. Mechanisms underlying these results are interesting, although only partially understood. These mechanisms include caloric reduction, appetite suppression, weight loss after surgery, decreased hepatic glucose production, increase in glucose uptake, changed gastric emptying, decreased leptin levels, increased leptin sensitivity, decreased insulin resistance, increased insulin levels, enhanced insulin sensitivity and β-cell responsiveness to glucose, reduction in ghrelin levels, change in gastric inhibitory peptide (GIP) levels, and increased levels of derivatives of L-cells (GLP-1, PYY). GLP-1 and its agonists promote β-cell replication and differentiation, increase β-cell mass, stimulate insulin secretion, and have an antiapoptotic effect on β-cells in the pancreas. In addition, peptide YY (PYY) might ameliorate insulin resistance. RYGB has been shown to decrease the activity of an incretin-inactivating enzyme called dipeptidyl peptidase-4 (DPP-4). This may result in higher incretin levels, and improved incretin levels may result in better blood sugar control. Both rat models and human studies have shown the role of nutrients being excluded from the foregut or rapidly delivered to the hindgut in controlling DM.

The cost of diabetic medications after BS is significantly lower compared with controls, likely because of decreased use. A retrospective review of reimbursement claims of 5502 obese patients comparing presurgery and postsurgery data reported a statistically significant decrease in DM at 3 years (19.9% vs 7.7%, respectively). In another cohort study at 12 months follow-up, diabetic medication use decreased 76% in patients undergoing surgery compared with an increase of 4% in the control.
Metabolic surgery is equally effective in patients with low BMI (<35 kg/m²) type 2 DM, producing postoperative euglycemia in a high proportion (85.3%) of these patients without undesirable weight loss. A desirable level of change was obtained with some patients moving from the overweight category into the normal weight category.46

Patients with DM typically have more preoperative comorbidities, despite having no difference in preoperative weight, than those without DM.47 Patients with preoperative DM had lower EWL after RYGB at 1 year (67.6% for those without DM, 63.5% for those with diet-controlled DM, 60.5% for those with DM controlled by oral hypoglycemic agents, and 57.5% for those requiring insulin). Nevertheless, DM resolved in 89.8% of those with diet-controlled DM, 82.7% of those taking oral hypoglycemic medication, and 53.3% of those requiring insulin.47 Duration of DM and preoperative C peptide levels also affect resolution rates. Subpopulations within the obese also have remission of DM after BS. For example, older populations have adequate resolution of type 2 DM after BS.48 Compared with RYGB, duodenal switch showed better DM resolution at 3 years in superobese patients, with BMI greater than 50 kg/m² (60% vs 100% respectively, \( P = .04 \)).49 Studies have also shown that type 2 diabetics who underwent an RYGB have fewer disease complications.50 Moreover, morbidly obese individuals after BS–induced DM resolution tend to have a longer lifespan.9,51 Case-control studies have reported late-onset severe hyperinsulinemic hypoglycemia after BS, implying that these procedures may have a β-cell stimulatory effect.52,53

BS is an effective and sustained treatment of obesity-induced type 2 DM. The best results are achieved with, in decreasing order, BPD, RYGB, gastroplasty, and AGB. BS reduces DM-induced complications and costs. Comorbidity remission rates are best if surgery is performed early in the disease process.

HYPERTENSION

Hypertension is one of the most common comorbidities associated with obesity. About 40% to 70% of patients undergoing BS are hypertensive.7,54 Mechanisms proposed to explain the contribution of obesity to the development of hypertension include an altered renin-angiotensin-aldosterone system, increased intra-abdominal pressure,55 increased sympathetic nervous system activity, development of insulin resistance, hyperleptinemia, leptin resistance, altered coagulation factors, as well as inflammation and endothelial dysfunction.54,56

The SOS study, in which most of the BS procedures were vertical-banded gastroplasty (VBG) and banding, showed a reduction of systolic blood pressure at 2 years in the surgical group. The pulse-pressure increase was less pronounced in the surgery group than in the control group even after 10 years.16 BS substantially improved and/or resolved hypertension in most patients (37%–53%) or reduced the need for antihypertensive agents (18%–36%).54,57–59 This trend persisted in people more than 60 years of age.58 Patients with vitamin D deficiency have significantly lower rates of resolution of hypertension compared with those with adequate vitamin D levels (42% vs 61%; \( P = .008 \)).59 Correction of deficiency with vitamin D supplementation (50,000 IU weekly) resulted in resolution of hypertension (75% vs 32%; \( P = .029 \)).60

Obesity and hypertension places patients at a higher cardiovascular risk, which can be markedly reduced (risks of coronary arterial disease [CAD] decreased by 39% in men and 25% in women) after weight loss–induced resolution of hypertension.61 BS decreases CAD risk to rates lower than the age-adjusted and gender-adjusted estimates for the general population.61
Cremieux and colleagues\textsuperscript{10} found that the incidence of hypertension decreased from 38.8\% in the preoperative period to 21.1\% in the postoperative period (up to 4 months) and was only 12.3\% at 3 years after surgery ($P<.05$). Sjostrom and colleagues\textsuperscript{62} reported that the postoperative prevalence of hypertension after 8 years of follow-up was no different between VBG cases and controls, whereas a statistically significant decrease in hypertension occurred in the group that underwent RYGB compared with the control group. Magee and colleagues\textsuperscript{63} found a 25\% reduction or improvement of hypertension at 1 year in patients who had sleeve gastrectomy (SG). Reported rates of hypertension resolution differed across studies depending on the procedure. In the literature, after AGB resolution, rates of hypertension ranged between 48\% and 62.95\% in different studies\textsuperscript{64,65}; after SG, between 78\% and 93.8\%\textsuperscript{57,64,66,67}; after RYGB, between 65\%\textsuperscript{54} and 90.7\%\textsuperscript{68}; and, after duodenal switch in super morbid obese patients, resolution rates were more than 68\%.\textsuperscript{49}

Significant reduction in blood pressure can be seen within 1 month after surgery, with up to 25\% showing resolution and 36\% having improvement of hypertension.\textsuperscript{54} In superobese patients (BMI $>$ 50 kg/m$^2$), similarly to DM patients, duodenal switch shows better resolution of hypertension at 3 years compared with RYGB (68\% vs 38.6\%).\textsuperscript{49} An insurance data review showed a 51\% decrease in hypertensive medication use at 12 months for patients undergoing surgery, compared with an increase of 8\% in the patients who did not have surgery.\textsuperscript{45}

Normotensive patients who were not on any blood pressure medications showed no reduction in systolic BP after surgery and only a small, gradual decline in diastolic pressure.\textsuperscript{69} The best results were seen in hypertensive patients not on active treatment.\textsuperscript{69} Resolution rates of hypertension are dependent on length of preexisting hypertension, with better results in those having hypertension for less than 4 years.\textsuperscript{54,70}

In conclusion, hypertension is one of the most common morbid obesity–associated comorbidities and BS is an effective and sustained treatment. Resolution results are the best in BPD, followed by RYGB, gastroplasty, and AGB. These procedures reduce hypertension-induced complications and costs. Remission rates are best if surgery is performed early.

HYPERLIPIDEMIA

Hyperlipidemia is present in up to 50\% of morbidly obese patients and is a major modifiable risk factor in development of atherosclerosis and CAD.\textsuperscript{71} Hyperlipidemia refers to high levels of low-density lipoprotein (LDL), triglycerides (TG), and/or total cholesterol, as well as low high-density lipoprotein (HDL). BS greatly improves secondary hypercholesterolemia and mixed forms of hyperlipidemia. There is a relationship among measures of central obesity, insulin resistance, and impaired glucose metabolism with dyslipidemia in severely obese subjects.\textsuperscript{72} Nonsurgical weight loss may lead to a decrease in serum TG and only a modest increase in HDL; however, serum total cholesterol (TC) and LDL remain unchanged.\textsuperscript{73–75}

Ten-year follow-up in the SOS study revealed that TG reduction was 18\% after AGB, 15\% after VBG, and 28\% after RYGB. TC reduction was 5\% after AGB, 5\% after VBG, and 12.6\% after RYGB. The increase in HDL cholesterol was 20.4\% after AGB, 23.5\% after VBG, and 47.5\% after RYGB. These findings were more significant in the surgically treated group than the control group.\textsuperscript{16} In another study,\textsuperscript{72} 1 year after AGB, mean TG concentration decreased by 23\% and mean TC by 3.3\%. Percentage EWL was not an important predictor of lipid profile improvement in this study. Those with insulin resistance and its associated metabolic problems had less weight loss, but greater improvement in dyslipidemia.\textsuperscript{72}
SG results in marked improvement in hyperlipidemia, with improvement or resolution rates of more than 70% in most studies.\(^\text{57-67,68,76}\) By causing malabsorption of fats to reduce enterocolic circulation and reabsorption of cholesterol, both RYGB and BPD lead to marked improvement in lipid profile.\(^\text{48,77,78}\) A retrospective study\(^\text{73}\) of 94 patients who had RYGB and who were diagnosed with hyperlipidemia showed optimization of serum TC, TG, and LDL profiles in all patients within 6 months after surgery. The HDL cholesterol levels improved more slowly, reaching desirable levels within 12 months after surgery, and reached the greatest level at 4 years. None of the patients taking lipid-lowering agents required the medication at the end of the study period. The overall improvement in serum lipid levels included a 27% improvement in serum TC, 47% improvement in serum TG, 40% improvement in serum LDL cholesterol, and a 12% increase in serum HDL cholesterol at the end of the 6-year follow-up period.\(^\text{73}\) A Veterans Affairs study\(^\text{48}\) of 298 patients with hyperlipidemia found a 40% medication discontinuation rate at 1 year after BS. The veterans with hyperlipidemia were more likely to discontinue medication if they had only been taking fibrates (odds ratio [OR] 6.15, \(P < .01\)) as opposed to statins and fibrates. Another insurance data review showed a 59% reduction of hyperlipidemia medication use in patients undergoing BS compared with a 20% increase in those without surgery at 12 months.\(^\text{45}\) When comparing SG with RYGB, some studies showed comparable results (75% and 78%, respectively),\(^\text{67}\) whereas others found that the improvement/resolution rate was significantly higher in the RYGB group (100%) than in the SG group (75%). BPD with duodenal switch shows marked improvement, if not complete resolution, of hyperlipidemia after surgery in most cases.\(^\text{77,79}\) In superobese patients (BMI > 50 kg/m\(^2\)), duodenal switch shows better resolution of dyslipidemia at 3 years compared with RYGB (72% vs 26.3%, \(P = .01\)).\(^\text{49}\) Even in mildly obese or nonobese patients, duodenal switch without gastric resection has shown better results.\(^\text{80}\)

In conclusion, hyperlipidemia is a major modifiable factor in development of atherosclerosis, and BS greatly improves secondary hypercholesterolemia and mixed forms of hyperlipidemia and leads to improved HDL cholesterol levels. This is associated with significant reduction in need of medications for hyperlipidemia.

**CARDIOVASCULAR DISORDER**

**Congestive Heart Failure**

The combination of increased adipose cells and increased lean muscle mass in obese patients results in high cardiac output and an increased circulating volume. Weight loss caused by caloric restriction or surgery promotes favorable hemodynamic changes referred to as reverse remodeling. Regression of left ventricle (LV) mass and chamber size has been shown universally.\(^\text{81}\)

BS in morbidly obese patients decreases the thickness of the LV wall and the overall ventricular mass,\(^\text{82,83}\) promotes both structural and functional myocardial changes that improve cardiac performance,\(^\text{84}\) improves the right ventricle (RV) end-diastolic area, and might prevent progression to RV dysfunction.\(^\text{85}\) The benefits of BS on LV mass continue even when weight loss has stopped, and these effects may be caused by neurohumoral factors. These factors may contribute to improved long-term survival.\(^\text{86}\)

In patients undergoing BS with left ventricular ejection fraction (LVEF) less than or equal to 35%, mean LVEF at 6 months had significantly improved from 23% (±2%) to 32% (±4%) \((P = .04)\) with subjective and objective improvement in cardiac function.\(^\text{87}\) Surgical weight loss could therefore provide a bridge to heart transplantation
in patients with morbid obesity. Some evidence suggests that the greatest regression of LV mass and hypertrophy may occur when weight loss is combined with β-adrenergic blocker therapy.

Coronary Artery Disease

Morbid obesity is an independent risk factor for CAD and, after BS, these risks have been shown to decrease. Both coronary microvascular function and peripheral vascular dilator function were found to significantly improve after BS. Coronary microvascular function was assessed by measuring coronary blood flow velocity response to intravenous adenosine and to cold pressor test in the left anterior descending coronary artery by transthoracic Doppler echocardiography. Peripheral vascular dilator function was assessed by brachial artery diameter changes in response to postischemic forearm hyperemia (ie, flow-mediated dilation). The favorable vascular effects of BS were independent of the presence and changes of other known cardiovascular risk factors and of basal values and changes of serum C-reactive protein levels.

Ventricular repolarization abnormalities are significantly increased in subjects with morbid obesity. These QT abnormalities (QT interval and QT interval dispersion) improve substantially after BPD. This change is independent of weight loss and may be related to surgical interruption of the enteroinsular axis. These changes may also be the cause of the survival advantage seen after BS. For patients less than 65 years of age, this survival advantage started at 6 months after surgery and, for patients more than 65 years of age, at 11 months. Donadelli and colleagues reported a significant overall reduction of 10-year cardiovascular disease (CVD) risk starting 1 year after RYGB surgery, with a 1.1% reduction of absolute risk and a 2.3% reduction of percent risk as a result of surgery in patients being observed for 2 years after the operation. The SOS study, comparing a control with a surgical group, found that BS seemed to be a safe and feasible treatment in improving cardiovascular risk factors and may be used as a strategy for secondary prevention in CVD. Recent data suggest that vitamin D might also reduce CVD risk through BP-independent mechanisms.

Atherosclerosis

BS results in significant improvements in inflammatory, structural, and functional markers of coronary atherosclerosis. By reversing some of the risk factors for development of atherosclerosis, including insulin resistance, lipid levels, diabetes, and hypertension, BS can reverse or decrease plaque progression. Eighteen months after BS, carotid intima media thickness diminished from 0.56 to 0.53 mm (n = 37; P = .004), whereas brachial flow-mediated dilation improved from 5.81 to 9.01 (n = 25; P<.001). A growing body of evidence suggests that the broadly acting neurotrophic adipokine pigment epithelium–derived factor (PEDF) is associated with visceral adiposity, metabolic syndrome, diabetes, and atherosclerosis. BS reduces levels of PEDF. Similarly, the increase in serum nitric oxide levels and decrease in elevated l-arginine concentration, as well as decreasing C-reactive proteins, may contribute to the diverse beneficial effects of weight loss after BS, especially in the context of atherosclerosis risk.

BS causes significant improvements in LVEF, leads to regression of left ventricular mass and chamber size, decreases risk factors for CAD, and improves ventricular repolarization abnormalities. BS also results in significant improvements in inflammatory, structural, and functional markers of coronary atherosclerosis. All these improvements may contribute to improved long-term survival.
OBSTRUCTIVE SLEEP APNEA AND ASTHMA

Obstructive sleep apnea (OSA) is a common problem among obese patients, with a prevalence rate as high as 77%. Neck circumference more than 17 inches in men and 16 inches in women is a good predictor of OSA. Some studies suggest that, despite availability of prediction models, the diagnosis of OSA cannot be made easily without routine polysomnography testing for all patients considering BS. Chronic obstructive pulmonary disease (COPD) and other pulmonary disorders (including OSA) decrease significantly after BS (from 57.7% to 16.2% after surgery at 3 years).

A study investigating the effects of surgical weight loss on inflammatory biomarkers associated with OSA reported that BS resulted in significant decrease in apnea-hypopnea index, cytokines (eg, interleukin-6, soluble tumor necrosis factor [sTNF] αR1, and sTNFαR2), and leptin levels. Of all the biomarkers, BS-related amelioration of sleep apnea independently determined the decrease in sTNFαR2. These results suggest that sTNFαR2 may be a specific OSA biomarker.

High rates of OSA resolution after BS have been shown in many studies. Continuous positive airway pressure (CPAP) use ceased in 52.9% of patients with OSA who had undergone SG at 1 year. Two retrospective studies found complete resolution of OSA after BS in an Indian morbidly obese population at 1 or 3 years after surgery.

Obesity and increased neck circumference lead to difficult intubation and management of the airway. After BS, patients had an increased interincisor gap, thyromental distance, and reduction in neck circumference. A meta-analysis to identify the effects of surgical weight loss on the apnea-hypopnea index showed a reduction from a random-effects pooled baseline value of 54.7 events/h to 38.2 events/h and subsequent final value of 15.8 events/h. BS thus significantly reduces the apnea-hypopnea index, but postoperative apnea-hypopnea index was consistent with moderately severe OSA. Thus, these patients likely need continued treatment to minimize their future OSA-associated morbidity and complication rate.

Excess BMI increases both the risk and severity of asthma. In a follow-up questionnaire, BS was found to decrease the number of medications required to control patients’ asthma symptoms, although AGB seems to produce less significant effects. BS thus shows significant improvement in OSA and other pulmonary diseases.

RENAI DISORDERS

The pathophysiology underlying obesity-associated renal disorders includes insulin resistance, adiponectin deficiency, hyperaldosteronism, and many other pathogenetic factors. The abnormalities of renal structure in obese and morbidly obese individuals include increased kidney weight, glomerulomegaly, disorder of podocytes, mesangial expansion, and abnormalities of the renal interstitium. These abnormalities are accompanied by functional abnormalities like renal hyperperfusion, increased renal plasma flow, increased filtration fraction, and albuminuria. Both obesity and metabolic syndrome have been identified as powerful predictors of chronic kidney disease and end-stage renal disease.

Obesity is an independent risk factor for developing chronic or end-stage renal disease with 23% increased odds in patients with high BMI (>30 kg/m²). The mechanism and mediators of obesity’s effects on renal function are not yet well known. A possible mechanism may be that obesity leads to a proinflammatory milieu, renal lipotoxicity, and altered renal hemodynamics, causing glomerulosclerosis and
hyperfiltration.\textsuperscript{108} Obesity seems to magnify the effect of hypertension on albuminuria.\textsuperscript{112} This overall kidney dysfunction improves after BS, which may prevent the development of overt obesity-related glomerulopathy.\textsuperscript{108–110} Moreover, these improvements, mainly observed in the first year after surgery with most of the weight loss, seem to occur in patients both with and without established chronic renal impairment.

Twenty-four hour albuminuria continues to improve during the second year of follow-up after BS. Agrawal and colleagues\textsuperscript{113} found significant reduction in the median urine albumin/creatinine ratio and microalbuminuria in obese diabetic patients 1 year after RYGB. Saliba and colleagues\textsuperscript{114} found that creatinine clearance decreased 15\% in diabetics ($P = .02$) and 21\% in nondiabetics ($P = .03$) 12 months after RYGB. A significant change in glomerular filtration rate was seen earlier in the nondiabetics (−29\% after 6 months, $P = .003$). Tubular function remained unchanged in the nondiabetic subjects, but worsening occurred in the diabetic subjects. These results underscore the importance of reversal of excessive obesity before the onset of frank diabetes.\textsuperscript{108,114}

In patients with established renal disease, 20\% resolution, improvement, or stabilization of renal disease was seen at 1 year after RYGB, with complete resolution in 1 patient followed for 9 years.\textsuperscript{115} Several case reports describing patients with established renal dysfunction have also shown either improvement or stabilization in proteinuria and creatinine at several months follow-up after RYGB.\textsuperscript{116–120}

BS can lead to postoperative acute kidney injury (AKI) in up to 8.5\% of all cases undergoing BS. Risk factors predisposing to AKI include higher BMI, hyperlipidemia, and preoperative use of angiotensin-converting enzyme inhibitors (ACE-I) or angiotensin receptor blockers.\textsuperscript{121} However, BS in morbidly obese patients on dialysis can improve their comorbidities and prepare them for transplantation.\textsuperscript{122}

Thus, BS has recently emerged as a successful intervention for obesity-associated renal disease for both prevention of further damage and improvement/resolution of renal dysfunction.

### DIGESTIVE DISORDERS

Obese patients have up to 2.4 times more gastroesophageal symptoms compared with nonobese patients.\textsuperscript{123} They also have higher distal esophageal acid exposure\textsuperscript{124} and a higher number of gastroesophageal reflux episodes.\textsuperscript{125} Cremieux and colleagues\textsuperscript{10} found a significant decrease (39.4\% before surgery vs 13.5\% after BS) in medication use for gastroenterologic disorders after BS.

As expected, different BS procedures have varying effects on gastroesophageal reflux disease (GERD). A recent meta-analysis\textsuperscript{126} found decrease in reflux symptoms (from 32.9\% to 7.7\%), decrease in antireflux medications (from 27.5\% to 9.5\%), and decreased prevalence of erosive esophagitis (from 33.3\% to 27\%) after AGB. However, they reported new reflux symptoms in 15\% and new esophagitis in 22.9\%.

SG seems to increase reflux compared with both banding\textsuperscript{127} and silastic ring–banded RYGB.\textsuperscript{128} The shape of the remaining stomach has an impact because preservation of the antrum may decrease reflux in contrast with a tubular pattern or a superior pouch.\textsuperscript{129} RYGB significantly improves heartburn, acid regurgitation, eructation, flatus, and abdominal pain.\textsuperscript{130} RYGB has shown excellent results in recalcitrant GERD in morbidly obese patients\textsuperscript{131} and has been used to salvage reflux symptoms after restrictive surgery. A prospective study in which SG and RYGB were used as staged procedures found 78\% of patients after stage I and 80\% patients after stage II had resolution or improvement of GERD symptoms.\textsuperscript{76} In superobese patients
(BMI > 50 kg/m²), RYGB showed better resolution of GERD at 3 years compared with duodenal switch (76.9% vs 48.6%, \(P = .04\)).

To summarize, SG may increase GERD symptoms, whereas AGB shows conflicting results, but RYGB seems to have significant positive effects on GERD.

Obesity is a significant risk factor for the development of hepatic steatosis, nonalcoholic steatohepatitis (NASH), and nonalcoholic fatty liver disease (NAFLD). Steatosis of the liver is exacerbated with hyperlipidemia. Obesity surgery improves steatosis, necroinflammatory activity, and hepatic fibrosis in patients with morbid obesity and NASH.132,133 NAFLD-related increases in hepatic lipid peroxidation and enzyme cytochrome P450 2E1 expression also improve significantly with BS-induced weight loss.134

MUSCULOSKELETAL DISORDERS

Obesity is associated with a range of mobility problems, musculoskeletal pains, osteoarthritis and gout, all of which significantly affect quality of life.135 For every 2-unit increase (5 kg) in BMI, there is a 36% increase in the risk of developing painful joint conditions such as osteoarthritis.136 Disease of the musculoskeletal and connective system, such as arthropathies, osteoporosis, and rheumatism, decreased significantly after BS.10,16,63 There is also sustained improvement in physical function and reduction of pain following BS.137 Cottam and colleagues76 reported 85% resolution of degenerative joint disease after stage I SG and 88% resolution or improvement after stage II RYGB.

A review of all studies on BS and joint pain from 1965 to 2009 reported a subjective improvement in, or resolution of, general joint pain, arthralgia, or osteoarthritis ranging from 32% to 100% at 1 year after surgery.136 Load-bearing joints like ankle, hip, and knee showed significant improvement. Moreover, joint pain improvement usually occurred within the first 6 months and continued to improve throughout the year.136

BS before joint surgery has shown favorable outcomes in joint replacement and arthroplasty.138 Morbidly obese individuals with severe degenerative joint disease, who are considered unsuitable for arthroplasty because of excess weight, should be considered for BS. Total joint arthroplasty after surgical treatment of obesity has an excellent outcome with an acceptable complication rate.138

BS thus shows promise in improving mobility, relieving joint pain, and reducing pain medication use, particularly for the load-bearing joints, in morbidly obese patients. It should also be considered before joint replacement and arthroplasty surgery in the morbidly obese.

PSYCHOLOGICAL, NEUROLOGIC, AND SEXUAL DISORDERS

Psychological factors are intimately connected with morbid obesity and food may be used to satisfy certain cravings. Weight loss greatly improves depression caused by obesity.76,139 A Greek study140 surveying 59 obese women before and after bariatric procedures found significant reductions in depression (\(P < .001\)) and sexual pain levels (\(P = .014\)) as well as significant improvements in sexual desire, arousal (\(P = .001\)), lubrication (\(P = .003\)), satisfaction (\(P = .012\)), and total sexual function (\(P = .003\)) 1 year after surgery.

Menstrual irregularities are common in morbidly obese women and may lead to anemia. Polycystic ovary syndrome (PCOS) is frequently (30%–70%) associated with obesity, which significantly modifies both clinical and laboratory expression of the syndrome.141 BS may resolve obesity-associated PCOS.142 A decrease in
hirsutism, total and free testosterone, androstenedione and dehydroepiandrosterone sulfate, and restoration of regular menstrual cycles and/or ovulation paralleled weight loss after BS. Testosterone levels in men also improved after surgery.

**Intracranial Hypertension**

Morbid obesity is associated with increased intracranial hypertension, which responds well to BS. Ninety-seven percent of patients having BS were found to have resolution of papilledema after surgery, 92% had complete or nearly complete resolution of visual field deficits, and the remaining patient had stabilization of previously progressive vision loss. BS may thus be an effective treatment of increased intracranial hypertension in obese patients, both in symptom resolution and visual outcome.

In addition, migraine may be exacerbated by obesity and there is marked alleviation of symptoms and reduced incidence and severity of migraine headaches after BS.

**CANCER**

In the United States, approximately 85,000 new cancer cases per year are related to obesity. Recent research has found that, when the BMI increases by 5 kg/m², cancer mortality increases by 10%. The cancer-protective role of metabolic surgery is strongest for obesity-related tumors in women; however, the underlying mechanisms may involve both weight-dependent and weight-independent effects. These effects include the improvement of insulin resistance with attenuation of the metabolic syndrome as well as decreased oxidative stress and inflammation and beneficial modulation of sex steroids, gut hormones, cellular energetics, immune system, and adipokines.

After 13 years of follow-up in the SOS study, BS has been shown to significantly decrease the incidence of first cancer in women \( P = 0.0009 \). One proposed mechanism for cancer reduction is that RYGB-induced weight loss modifies the production of cytokines related to natural killer cell function and improves their activity.

**SUMMARY**

Published data show that BS not only leads to significant and sustained weight loss but also resolves or improves multiple comorbidities associated with morbid obesity. Evidence suggests that the earlier the intervention the better the resolution of comorbidities. Patients with metabolic syndrome and comorbidities associated with morbid obesity should be promptly referred for consideration for BS earlier in the disease process.

**REFERENCES**


