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Factors Associated With Achieving a Body Mass Index of Less Than 30 After Bariatric Surgery

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IMPORTANCE Achieving a body mass index (BMI, calculated as weight in kilograms divided by height in meters squared) of less than 30 is an important goal of bariatric surgery, given the increased risk for weight-related morbidity and mortality with a BMI above this threshold.

OBJECTIVE To identify predictors for achieving a BMI of less than 30 after bariatric surgery.

DESIGN, SETTING, AND PARTICIPANTS This retrospective study used data from the Michigan Bariatric Surgery Collaborative, a statewide quality improvement collaborative that uses a prospectively gathered clinical data registry. A total of 27 320 adults undergoing primary bariatric surgery between June 2006 and May 2015 at teaching and nonteaching hospitals in Michigan were included.

EXPOSURE Bariatric surgery.

MAIN OUTCOMES AND MEASURES Logistic regression was used to identify predictors for achieving a BMI of less than 30 at 1 year after surgery. Secondary outcome measures included 30-day postoperative complications and 1-year self-reported comorbidity remission.

RESULTS A total of 9713 patients (36%; mean [SD] age, 46.9 [11.3] years; 16.6% male) achieved a BMI of less than 30 at 1 year after bariatric surgery. A significant predictor for achieving this goal was a preoperative BMI of less than 40 (odds ratio [OR], 12.88; 95% CI, 11.71-14.16; $P < .001$). Patients who had a sleeve gastrectomy, gastric bypass, or duodenal switch were more likely to achieve a BMI of less than 30 compared with those who underwent adjustable gastric banding (OR, 8.37 [95% CI, 7.44-9.43]; OR, 21.43 [95% CI, 18.98-24.19]; and OR, 82.93 [95% CI, 59.78-115.03], respectively; $P < .001$). Only 8.5% of patients with a BMI greater than 50 achieved a BMI of less than 30 after bariatric surgery. Patients who achieved a BMI of less than 30 had significantly higher reported rates of medication discontinuation for hyperlipidemia (60.7% vs 43.2%, $P < .001$), diabetes (insulin: 67.7% vs 50.0%, $P < .001$; oral medications: 78.5% vs 64.3%, $P < .001$), and hypertension (54.7% vs 34.6%, $P < .001$), as well as a significantly higher rate of sleep apnea remission (72.5% vs 49.3%, $P < .001$) and higher satisfaction rate (92.8% vs 78.0%, $P < .001$) compared with patients who did not.

CONCLUSIONS AND RELEVANCE Patients with a preoperative BMI of less than 40 are more likely to achieve a BMI of less than 30 after bariatric surgery and are more likely to experience comorbidity remission. Policies and practice patterns that delay bariatric surgery until the BMI is 50 or greater can result in significantly inferior outcomes.

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Invited Commentary page 1065

Supplemental content

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It is estimated that more than 34% of adults in the United States are classified as obese, with a body mass index (BMI, calculated as weight in kilograms divided by height in meters squared) greater than or equal to 30.[1] Obesity is related to more than 40 diseases including type 2 diabetes, heart disease, hypertension, stroke, osteoarthritis, obstructive sleep apnea, and cancer.[1-4] Moreover, individuals with a BMI of 30 or greater have a 50% to 100% increased risk for premature death when compared with individuals of a healthy weight.[5]

Bariatric surgery has been shown to be the most effective treatment for morbid obesity, resulting in significant improvement of multiple weight-related comorbidities and a reduction in a person's risk for premature death.[2,4,6-14] However, given that weight loss after bariatric surgery varies depending on procedure type, age, and comorbid conditions, not all patients achieve a target weight that promotes optimal health.[15-17] Among patients with diabetes, Schauer et al[18] demonstrated a paradoxical effect in which the gain in life expectancy after bariatric surgery decreased as the preoperative BMI increased above 62.

In this context, we analyzed data from a statewide clinical registry to determine how many patients achieve a target BMI of less than 30 at 1 year after bariatric surgery and identified predictive factors for achieving this goal. We also compared 30-day postoperative complication rates and 1-year self-reported comorbidity remission between patients who did and did not achieve this goal.

Key Points

Question Which patients achieve a body mass index (BMI) of less than 30 after bariatric surgery?

Findings In this study using a statewide clinical registry, 36% of patients achieved a BMI of less than 30 at 1 year after bariatric surgery. Significant predictors for success included a preoperative BMI of less than 40 and undergoing a metabolic procedure such as sleeve gastrectomy, gastric bypass, or duodenal switch.

Meaning Bariatric surgery is optimal in patients with a BMI of less than 40; delaying surgical treatment for obesity can lead to inferior results.

Methods

Study Design

This is a retrospective review of a payer-funded statewide clinical data registry that is used by the Michigan Bariatric Surgery Collaborative (MBSC) for quality improvement. In this study, patients who had achieved a BMI of less than 30 at 1 year after bariatric surgery were compared with patients who had not. Logistic regression was used to identify predictors for achieving a BMI of less than 30. Overall 30-day postoperative complications and 1-year self-reported comorbidity remission were also compared between the 2 groups. This study was approved by the institutional review board of the University of Michigan for the MBSC; written consent was obtained from participants.

Study Population

The MBSC is composed of 38 bariatric surgery programs and 70 surgeons across the state of Michigan and includes both teaching and nonteaching hospitals. The program administers a prospective, externally audited clinical outcomes registry and participating hospitals submit data on all patients who undergo primary and revisional bariatric procedures. Data include information on patient demographics, socioeconomic status, preoperative weight and comorbid conditions, postoperative complications, and weight loss outcomes. Patient data are obtained by data abstractors from in-hospital records 30 days after surgery as well as from patient surveys obtained at 1, 2, and 3 years after surgery. Centrally trained abstractors review medical records using a standardized and validated instrument and each hospital within the MBSC is audited annually by nurses from the coordinating center to verify that the data are complete and accurate.

For this study, we identified all patients 18 years and older who underwent primary bariatric surgery between June 2006 and May 2015 and had a weight reported at 1 year after surgery (N = 27 320), which represented 50% of all primary bariatric cases during the study period. Among these patients, we also identified patients who submitted both a baseline survey and a 1-year follow-up survey (n = 19 764). Bariatric procedures included laparoscopic adjustable gastric banding (LAGB), laparoscopic or open Roux-en-Y gastric bypass (RYGB), laparoscopic sleeve gastrectomy (LSG), and biliopancreatic diversion with duodenal switch (BPD/DS). Patients who had revisional bariatric surgery or did not have a reported weight at 1 year after surgery were excluded. Given that the study population represents 50% of the entire clinical registry, we compared demographic, socioeconomic, and preoperative comorbidities between those who did and did not have 1-year follow-up data (eTable in the Supplement).

Study Outcomes and Data Collected

The primary outcome variable was BMI at 1 year after bariatric surgery. Secondary outcome measures included 30-day postoperative complications and 1-year self-reported comorbidity remission. Data on patient characteristics included age, sex, preoperative and postoperative weight and BMI, weight loss percentage prior to surgery, race/ethnicity, income level, education, private insurance, and comorbidities including diabetes, cardiovascular disease, peripheral vascular disease, hypertension, hyperlipidemia, gastroesophageal reflux disease, obstructive sleep apnea, venous thromboembolism, history of smoking, lung disease, liver disease, kidney disease, peptic ulcer disease, mobility limitation, arthritis, psychological disorders, and urinary incontinence. Data on operative characteristics included procedure type (LAGB, RYGB, LSG, or BPD/DS) and 30-day complication rates were also collected. Complications included bowel obstruction, leak, abdominal abscess, wound complication, dehiscence, hemorrhage, venous thromboembolism, myocardial infarction or cardiac arrest, renal failure, pneumonia, reintubation, prolonged ventilator use, shock, hospital-acquired infections, and death. Serious complications were defined as potentially life-threatening complications including those that required invasive interventions such as percutaneous drainage or reoperation, blood transfusions of 4 or more units of blood, respiratory failure requiring more than 2 days of intubation, renal failure requiring in-hospital or long-term dialysis, venous thromboembolism, myocardial infarction or cardiac arrest, and death. Comorbidity remission was defined as self-reported discontinuation of treatment for the condition in patients receiving treatment on baseline surveys. Data on comorbidity remission included discontinuation of medication for hyperlipidemia, diabetes (oral medication and/or insulin), hypertension, and discontinuation of continuous positive airway pressure for obstructive sleep apnea.

Statistical Analysis

Baseline characteristics between those achieving a BMI of less than 30 at 1 year and those who did not were compared using χ^2 square and *t* tests as appropriate. Logistic regression analysis was used to identify predictors of achieving a BMI of less than 30 among patient characteristics and procedure type. Logistic regression analysis was also used to compare comorbidity remission, complication rates, and patient satisfaction between patients who achieved a BMI of less than 30 at 1 year vs those who did not. The odds ratio (OR) and associated confidence intervals and *P* values are reported. To adjust for the effects of procedure type, age, and preoperative BMI on postoperative BMI, we fitted a multivariable logistic model with these factors as additional covariates. Rates are presented as percentages for categorical variables or means (SDs) for continuous variables.

Results

A total of 27 320 patients were included in the study. The overall mean (SD) BMI at 1 year after bariatric surgery was 33 (6.8) and the mean (SD) preoperative BMI was 48 (8.2). The most common procedure performed during the study period was RYGB (44%), followed by LSG (38%), LAGB (16%), and BPD/DS (1%). A total of 9713 patients (36%) achieved a BMI of less than 30 at 1 year after surgery. The mean (SD) age of these patients was 46.9 (11.3) years and the mean (SD) preoperative BMI was 42.66 (4.89). The most common procedure performed in this group was RYGB (57%) followed by LSG (36%).

Table 1 compares patient demographics, preoperative comorbidities, and procedure types between patients who did and did not achieve a BMI of less than 30 at 1 year after surgery. Significant predictors for achieving the target BMI included a preoperative BMI of less than 40 (OR, 12.88; 95% CI, 11.71-14.16; *P* < .001) and private insurance (OR, 1.09; 95% CI, 1.02-1.16; *P* = .002). Only 8.5% of patients with a BMI of 50 or greater achieved a BMI of less than 30 after bariatric surgery. Patients who underwent LSG, RYGB, or BPD/DS also had a higher likelihood of achieving a BMI of less than 30 when compared with those who underwent LAGB (OR, 8.37 [95% CI, 7.44-9.43]; OR, 21.43 [95% CI, 18.98-24.19]; and OR, 82.93 [95% CI, 59.78-115.03], respectively; *P* < .001).

Patients who achieved a BMI of less than 30 were significantly more likely to discontinue treatment for hyperlipidemia (60.7% vs 43.2%, *P* < .001), diabetes (insulin: 67.7% vs 50.0%, *P* < .001; oral medications: 78.5% vs 64.3%, *P* < .001), hypertension (54.7% vs 34.6%, *P* < .001), and sleep apnea remission (72.5% vs 49.3%, *P* < .001) and to report feeling highly satisfied with their surgery (92.8% vs 78.0%, *P* < .001) when compared with patients who did not (**Table 2** and **Table 3**). Overall and serious risk-adjusted 30-day complication rates were similar between the patients who did and did not achieve a BMI of less than 30 at 1 year after surgery (8.29% vs 7.08%, *P* = .87 and 2.28% vs 1.97%, *P* = .73, respectively).

Discussion

In this population-based study of morbidly obese patients undergoing bariatric surgery in Michigan, we found that 36% of patients achieved a BMI of less than 30 at 1 year after surgery. A key predictor of achieving this important weight loss goal was having a preoperative BMI of less than 40. Notably, the likelihood of achieving a BMI of less than 30 after surgery was only 8.5% when a patient's preoperative BMI was 50 or greater. Patients who achieved this weight loss goal demonstrated significant health benefits as they had a higher likelihood for comorbidity remission and were more likely to be satisfied with their surgery.

To our knowledge, this is the first study to assess what proportion of bariatric surgery patients achieve a BMI of less than 30 and to identify predictors for reaching this weight loss goal. Our results echo those of similar studies that have evaluated preoperative predictors of weight loss after bariatric surgery. In a systematic review of 115 articles between 1988 and 2010, Livhits et al[19] reported that baseline BMI was a significant predictor of weight loss and noted a 10.1% decrease in excess weight loss (EWL) for superobese patients (defined as BMI ≥50). Similarly, Ortega et al[20] found that younger individuals with a lower BMI had higher EWL and a higher rate of successful weight loss (defined as EWL ≥60%) after RYGB and LSG. Further, Lutfi et al[21] reported that weight loss at 1 year after gastric bypass was suboptimal in superobese patients and that patients with a BMI of less than 50 had the best chance of achieving greater weight loss. It is important to note that EWL percentage may appear exaggerated in relation to actual mass lost in patients with lower initial BMI in these studies. However, it also highlights the advantages of early surgical management of obesity in that smaller amounts of weight loss are required to achieve the desired effect. As with other studies, we also found that metabolic procedures, such as gastric bypass, sleeve gastrectomy, and duodenal switch, are more likely to achieve greater weight loss than gastric banding.[11,15,22] Moreover, metabolic procedures appear to have a more durable effect, particularly in patients with higher BMIs. Adams et al[12] demonstrated improved survival among gastric bypass patients only when comparing a control group with patients with a BMI of greater than 45.

Our results suggest that patients with morbid obesity should be targeted for surgery when their BMI is still less

Table 1. Comparison of Patient Demographics, Preoperative Comorbidities, and Procedure Types Between Patients Who Did and Did Not Achieve a BMI of Less than 30 at 1 Year After Bariatric Surgery

Characteristic	BMI <30 at 1 y After Surgery, No. (%)		Adjusted Odds of Achieving BMI <30 at 1 y After Surgery, Odds Ratio (95% CI)[a]	*P* Value
	No	Yes		
Patient totals	17 607 (64)	9713 (36)	NA	NA
Demographics				
Age at procedure, mean (SD), y	47.5 (11.7)	46.9 (11.3)	0.98 (0.98-0.98)	<.001
Preoperative weight, mean (SD), kg	140.17 (28.42)	117.97 (18.80)	0.99 (0.99-0.99)	<.001
Male	4089 (23.2)	1610 (16.6)	0.85 (0.78-0.92)	<.001
Preoperative BMI, mean (SD)	50.59 (8.50)	42.66 (4.89)	0.77 (0.76-0.77)	<.001
Preoperative BMI <40	1171 (6.7)	3036 (31.3)	12.88 (11.71-14.16)	<.001
Preoperative BMI category				
<40	1171 (6.7)	3036 (31.3)	1 [Reference]	NA
40-49	7974 (45.3)	5856 (60.3)	0.14 (0.12-0.15)	<.001
50-59	6269 (35.6)	782 (8.1)	0.02 (0.01-0.02)	<.001
≥60	2193 (12.5)	39 (0.4)	0 (0-0)	<.001
Race/ethnicity				
White, not of Hispanic origin	13 539 (76.9)	8264 (85.1)	1 [Reference]	NA
Black, not of Hispanic origin	2469 (14.0)	648 (6.7)	0.39 (0.35-0.44)	<.001
Other or unknown	916 (5.2)	446 (4.6)	0.71 (0.60-0.84)	<.001
Hispanic	563 (3.2)	295 (3.0)	0.76 (0.63-0.91)	.002
American Indian or Alaskan Native	100 (0.6)	47 (0.5)	0.72 (0.47-1.10)	.13
Asian or Pacific Islander	20 (0.1)	13 (0.1)	0.64 (0.28-1.47)	.29
Annual income level				
<$10 000	1300 (7.4)	386 (4.2)	0.86 (0.78-0.96)	.007
$10 000-$24 999	2524 (14.3)	405 (10.9)	0.94 (0.86-1.02)	.15
$25 000-$44 999	4152 (23.6)	1054 (21.5)	0.65 (0.56-0.75)	<.001
$45 000-$75 000	4765 (27.1)	2089 (28.8)	1 [Reference]	NA
>$75 000	4111 (23.4)	2800 (30.7)	1.15 (1.06-1.24)	.001
Education				
Some college or technical school	8094 (46.0)	4418 (45.5)	1 [Reference]	NA
8 grades or less	70 (0.4)	31 (0.3)	0.75 (0.42-1.35)	.34
Some high school	553 (3.1)	249 (2.6)	1.05 (0.96-1.14)	.93
High school graduate or GED	3573 (20.3)	1819 (18.7)	0.99 (0.81-1.21)	.30
College graduate (bachelor's degree)	3211 (18.2)	1917 (19.7)	1.03 (0.95-1.13)	.43
Graduate degree	1809 (10.3)	1124 (11.6)	1.02 (0.92-1.14)	.65
Private Insurance	9854 (56.0)	5556 (57.2)	1.09 (1.02-1.16)	.01
Comorbidities				
Hypertension	10 443 (59.3)	4797 (49.4)	0.73 (0.68-0.78)	<.001
Non-insulin-dependent diabetes	6445 (36.6)	2780 (28.6)	0.60 (0.56-0.64)	<.001
Insulin-dependent diabetes	2190 (12.4)	927 (9.5)	0.63 (0.57-0.70)	<.001
Hyperlipidemia	9179 (52.1)	5123 (52.7)	0.87 (0.82-0.93)	<.001
Coronary artery disease	10 773 (61.2)	5007 (51.6)	0.74 (0.69-0.80)	<.001
Obstructive sleep apnea	8855 (50.3)	3898 (40.1)	0.84 (0.79-0.89)	<.001

(continued)

Table 1. Comparison of Patient Demographics, Preoperative Comorbidities, and Procedure Types Between Patients Who Did and Did Not Achieve a BMI of Less than 30 at 1 Year After Bariatric Surgery (continued)

Characteristic	BMI <30 at 1 y After Surgery, No. (%)		Adjusted Odds of Achieving BMI <30 at 1 y After Surgery, Odds Ratio (95% CI)[a]	*P* Value
	No	Yes		
Mobility limitation	1307 (7.4)	321 (3.3)	0.70 (0.60-0.82)	<.001
Asthma	3854 (21.9)	1899 (19.6)	0.91 (0.85-0.99)	.02
Psychological disorder	8744 (49.7)	5094 (52.5)	0.92 (0.86-0.98)	.006
History of venous thromboembolism	844 (4.8)	314 (3.2)	0.84 (0.72-0.99)	.04
Urinary incontinence	4081 (23.2)	2511 (25.9)	1.09 (1.01-1.17)	.03
Arthritis	13 404 (76.1)	7245 (74.6)	1.00 (0.93-1.07)	.89
Kidney disease	45 (0.3)	18 (0.2)	1.15 (0.60-2.22)	.68
Liver disease	1074 (6.1)	608 (6.3)	0.93 (0.82-1.05)	.25
GERD	8571 (48.7)	8175 (53.3)	1.04 (0.98-1.10)	.24
Procedure Type				
LAGB	3956 (22.5)	533 (5.5)	1 [Reference]	NA
SG	6988 (39.7)	3492 (36.0)	8.37 (7.44-9.43)	<.001
RYGB	6542 (37.2)	5513 (56.8)	21.43 (18.98-24.19)	<.001
BPD/DS	121 (0.7)	175 (1.8)	82.93 (59.78-115.03)	<.001

Abbreviations: BPD/DS, biliopancreatic diversion with duodenal switch; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); GED, General Education Development; GERD, gastroesophageal reflux disease; LAGB, laparoscopic adjustable gastric banding; NA, not applicable; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

[a] All variables (except procedure, age, preoperative BMI, and BMI <40) are adjusted for procedure, age, sex, and preoperative BMI category. Values for procedure type are adjusted for age, sex, and preoperative BMI category. Values for preoperative BMI and BMI less than 40 are adjusted for procedure, age, and sex. Comorbidities are adjusted for procedure, age, sex, and preoperative BMI category.

Table 2. Comparison of Self-reported Medication or Treatment Discontinuation Between Patients Who Did and Did Not Achieve a BMI of Less Than 30 at 1 Year After Bariatric Surgery

Discontinuation Type	BMI <30 at 1 y After Surgery, No. (%)		Odds of Resolving Medication at 1 y After Surgery, Odds Ratio (95% CI)[a]	*P* Value
	No (n = 12 236)	Yes (n = 7528)		
Cholesterol medication	1705 (43.2)	1258 (60.7)	2.03 (1.82-2.26)	<.001
Insulin medication	747 (50.0)	434 (67.7)	2.10 (1.73-2.55)	<.001
Oral diabetes medication	1997 (64.3)	1075 (78.5)	2.03 (1.75-2.35)	<.001
Hypertensive medication	2108 (34.6)	1565 (54.7)	2.28 (2.09-2.50)	<.001
CPAP for sleep apnea	2103 (49.3)	1414 (72.5)	2.71 (2.42-3.0)	<.001

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CPAP, continuous positive airway pressure.

[a] BMI of 30 or greater is the reference category.

Table 3. Satisfaction Rate Between Patients Who Did and Did Not Achieve a BMI of Less Than 30 at 1 Year After Bariatric Surgery

BMI Category at 1 y After Surgery	Satisfaction at 1 y After Surgery, No. (%)		Odds of Being Very Satisfied at 1 y After Bariatric Surgery, Odds Ratio (95% CI)	*P* Value
	Less Than "Very Satisfied"	"Very Satisfied"		
≥30	2672 (22.0)	9463 (78.0)	1 [Reference]	NA
<30	537 (7.2)	6953 (92.8)	3.653 (3.313-4.028)	<.001

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); NA, not applicable.

than 40, as these patients are more likely to achieve a target BMI that results in substantial reduction in weight-related comorbidities. Our findings are supported by a recent study of bariatric surgery outcomes by Schauer et al.[18] They examined patients undergoing bariatric surgery at a single center and demonstrated that the gain in life expectancy after bariatric surgery decreases with increasing BMI. Furthermore, they found no increase in life expectancy for patients with a BMI greater than 62.[18] Although it stands to reason that patients with the highest BMI benefit the most from bariatric surgery, they may remain morbidly obese even after excellent weight loss and thus still have the same weight-related comorbidities.

Despite evidence that patients with lower BMI may have the most success from bariatric surgery, the mean BMI in our cohort was 48, which is well above the National Institutes of Health–established threshold for bariatric surgery (ie, BMI >40 or BMI >35 with weight-related comorbidities). There are several likely reasons that patients are not being referred for surgery at a lower BMI. Bariatric surgery is commonly considered as an intervention for morbid obesity only after all other methods have failed and patients are at high risk for morbidity and mortality from weight-related comorbidities.[23,24] Limited knowledge about the safety and efficacy of bariatric surgery by both patients and referring physicians have also been noted in prior studies.[25,26] Patients may also wait until they experience worsening of health issues or low energy levels that limit their activities.[27] In turn, this may contribute to additional weight gain prior to considering surgery.

Weight loss requirements prior to bariatric surgery may also serve as a barrier for earlier referral. Currently, most insurance carriers mandate 3, 6, or 12 months of medically supervised weight loss. Although preoperative weight loss is typical of most surgery programs, its practice is still unproven.[28-31] In some cases, the medically supervised weight loss requirement is waived if the BMI is 50 or greater. This may serve as an incentive for patients and referring physicians to pursue bariatric surgery only after they have met this BMI threshold. Our data suggest that these practices may have a detrimental effect on outcomes.

This study should not be interpreted to mean that patients with a higher BMI should be excluded from surgery. While many of these patients will not achieve a BMI of less than 30, surgery continues to offer substantial benefits in terms of weight loss, comorbidity reduction, and quality of life for these patients when compared with medical management alone.[6,8,10,11] In fact, without bariatric surgery, the annual probability of achieving a healthy weight when the BMI is between 40 and 44.9 is 1 in 1290 for men and 1 in 677 for women.[32] Instead, we interpret our data as demonstrating the benefits of earlier surgical intervention for obesity as well as appropriate counseling of expectations postoperatively. We also recognize the impact of certain regulations, such as mandatory weight documentation, which may fail to optimize patient selection.

Limitations

Our study has several limitations. First, it is a retrospective study that is limited to bariatric procedures performed in a single state. In addition, we only had 1-year weight data on 50% of patients in the MBSC registry, which can lead to selection bias. Despite these limitations, this study uses the largest data set (>27 000 patients), to our knowledge, to evaluate predictors for weight loss to date. Our bariatric-specific registry also provides a more accurate assessment than administrative data as the data are captured prospectively and are audited annually for accuracy. It also includes hospitals from a variety of settings (teaching and nonteaching hospitals) with a diverse patient population. Also, our study population was found to have similar mean BMI, distribution of BMI categories, and rates of diabetes, mobility limitations, and gastroesophageal reflux disease when compared with the remaining patients in the data registry. Another limitation is that our study does not measure patient behavioral characteristics that may be associated with weight loss after bariatric surgery, according to Mitchell et al.[33] Data on binge eating behaviors, support group attendance, level of physical activity, and social support are not captured within the MBSC owing to concerns that survey length may impact response rate. Our data did reveal that patients who achieved a BMI of less than 30 reported less mobility limitations, indicating that they may be more likely to engage in physical activity, which may improve weight loss. Furthermore, given the known alterations in neuroendocrine signaling after bariatric surgery, it is unclear whether weight loss through a change in energy intake is simply a matter of "will power" or compliance alone.

Conclusions

Patients who achieved a BMI of less than 30 at 1 year after bariatric surgery had a significantly higher rate of comorbidity remission and were more satisfied than those who did not. Patients with a preoperative BMI of less than 40 were more likely to reach the weight loss goal, while less than 9% of patients achieved this goal when their preoperative BMI was 50 or greater. Metabolic procedures, such as sleeve gastrectomy, gastric bypass, and duodenal switch, were more successful than purely restrictive ones, such as gastric banding. Patients should be counseled appropriately with respect to weight loss expectations after bariatric surgery. Furthermore, policies and practice patterns that delay or incentivize patients to pursue bariatric surgery only once the BMI is highly elevated can result in inferior outcomes.

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Study concept and design: Varban, Carlin, Finks.
Acquisition, analysis, or interpretation of data: Varban, Cassidy, Bonham, Carlin, Ghaferi.
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Statistical analysis: Cassidy, Bonham, Ghaferi.
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REFERENCES

1. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA*. 2014;311(8):806-814.

2. Chikunguwo SM, Wolfe LG, Dodson P, et al. Analysis of factors associated with durable remission of diabetes after Roux-en-Y gastric bypass. *Surg Obes Relat Dis*. 2010;6(3):254-259.

3. Kaplan LM. Body weight regulation and obesity. *J Gastrointest Surg*. 2003;7(4):443-451.

4. Sjöström L. Bariatric surgery and reduction in morbidity and mortality: experiences from the SOS study. *Int J Obes (Lond)*. 2008;32(suppl 7):S93-S97.

5. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. *WMJ*. 1998;97(9):20-21, 24-25, 27-37.

6. Schauer PR, Bhatt DL, Kirwan JP, et al; STAMPEDE Investigators. Bariatric surgery versus intensive medical therapy for diabetes: 3-year outcomes. *N Engl J Med*. 2014;370(21):2002-2013.

7. Kim J, Eisenberg D, Azagury D, Rogers A, Campos GM. American Society for Metabolic and Bariatric Surgery position statement on long-term survival benefit after metabolic and bariatric surgery. *Surg Obes Relat Dis*. 2016;12(3):453-459.

8. Carlsson LM, Peltonen M, Ahlin S, et al. Bariatric surgery and prevention of type 2 diabetes in Swedish obese subjects. *N Engl J Med*. 2012;367(8):695-704.

9. Ganguly S, Tan HC, Lee PC, Tham KW. Metabolic bariatric surgery and type 2 diabetes mellitus: an endocrinologist's perspective. *J Biomed Res*. 2015;29(2):105-111.

10. Puzziferri N, Blankenship J, Wolfe BM. Surgical treatment of obesity. *Endocrine*. 2006;29(1):11-19.

11. Sjöström L, Narbro K, Sjöström CD, et al; Swedish Obese Subjects Study. Effects of bariatric surgery on mortality in Swedish obese subjects. *N Engl J Med*. 2007;357(8):741-752.

12. Adams TD, Gress RE, Smith SC, et al. Long-term mortality after gastric bypass surgery. *N Engl J Med*. 2007;357(8):753-761.

13. Adams TD, Mehta TS, Davidson LE, Hunt SC. All-cause and cause-specific mortality associated with bariatric surgery: a review. *Curr Atheroscler Rep*. 2015;17(12):74.

14. Arterburn DE, Olsen MK, Smith VA, et al. Association between bariatric surgery and long-term survival. *JAMA*. 2015;313(1):62-70.

15. Carlin AM, Zeni TM, English WJ, et al; Michigan Bariatric Surgery Collaborative. The comparative effectiveness of sleeve gastrectomy, gastric bypass, and adjustable gastric banding procedures for the treatment of morbid obesity. *Ann Surg*. 2013;257(5):791-797.

16. Schauer PR, Burguera B, Ikramuddin S, et al. Effect of laparoscopic Roux-en Y gastric bypass on type 2 diabetes mellitus. *Ann Surg*. 2003;238(4):467-484.

17. Giordano S, Victorzon M. Bariatric surgery in elderly patients: a systematic review. *Clin Interv Aging*. 2015;10:1627-1635.

18. Schauer DP, Arterburn DE, Livingston EH, et al. Impact of bariatric surgery on life expectancy in severely obese patients with diabetes: a decision analysis. *Ann Surg*. 2015;261(5):914-919.

19. Livhits M, Mercado C, Yermilov I, et al. Preoperative predictors of weight loss following bariatric surgery: systematic review. *Obes Surg*. 2012;22(1):70-89.

20. Ortega E, Morínigo R, Flores L, et al. Predictive factors of excess body weight loss 1 year after laparoscopic bariatric surgery. *Surg Endosc*. 2012;26(6):1744-1750.

21. Lutfi R, Torquati A, Sekhar N, Richards WO. Predictors of success after laparoscopic gastric bypass: a multivariate analysis of socioeconomic factors. *Surg Endosc*. 2006;20(6):864-867.

22. Buchwald H, Buchwald JN, McGlennon TW. Systematic review and meta-analysis of medium-term outcomes after banded Roux-en-Y gastric bypass. *Obes Surg*. 2014;24(9):1536-1551.

23. Colquitt J, Clegg A, Sidhu M, Royle P. Surgery for morbid obesity. *Cochrane Database Syst Rev*. 2003;(2):CD003641.

24. Tork S, Meister KM, Uebele AL, et al. Factors influencing primary care physicians' referral for bariatric surgery. *JSLS*. 2015;19(3):e2015.00046.

25. Afonso BB, Rosenthal R, Li KM, Zapatier J, Szomstein S. Perceived barriers to bariatric surgery among morbidly obese patients. *Surg Obes Relat Dis*. 2010;6(1):16-21.

26. Funk LM, Jolles S, Fischer LE, Voils CI. Patient and referring practitioner characteristics associated with the likelihood of undergoing bariatric surgery: a systematic review. *JAMA Surg*. 2015;150(10):999-1005.

27. Roberson DW, Neil JA, Pories ML, Rose MA. Tipping point: factors influencing a patient's decision to proceed with bariatric surgery. *Surg Obes Relat Dis*. 2016;12(5):1086-1090.

28. Gerber P, Anderin C, Thorell A. Weight loss prior to bariatric surgery: an updated review of the literature. *Scand J Surg*. 2015;104(1):33-39.

29. Brethauer S. ASMBS position statement on preoperative supervised weight loss requirements. *Surg Obes Relat Dis*. 2011;7(3):257-260.

30. Becouarn G, Topart P, Ritz P. Weight loss prior to bariatric surgery is not a pre-requisite of excess weight loss outcomes in obese patients. *Obes Surg*. 2010;20(5):574-577.

31. Conaty EA, Bonamici NJ, Gitelis ME, et al. Efficacy of a required preoperative weight loss program for patients undergoing bariatric surgery. *J Gastrointest Surg*. 2016;20(4):667-673.

32. Fildes A, Charlton J, Rudisill C, Littlejohns P, Prevost AT, Gulliford MC. Probability of an obese person attaining normal body weight: cohort study using electronic health records. *Am J Public Health*. 2015;105(9):e54-e59.

33. Mitchell JE, Christian NJ, Flum DR, et al. Postoperative behavioral variables and weight change 3 years after bariatric surgery. *JAMA Surg*. 2016;151(8):752-757.