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ORIGINAL CONTRIBUTIONS

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Abstract

Context Weight loss after bariatric surgery can be accurately predicted using an outcomes calculator; however, outliers exist that do not meet the 1 year post-surgery weight projections.

Objective Our goal was to determine how soon after surgery these outliers can be identified.

Design We conducted a retrospective cohort study.

Setting, Patients, and Intervention Using a bariatric surgery outcomes calculator formulated by the Michigan Bariatric Surgery Collaborative (MBSC), predicted weight loss at 1 year post-surgery was calculated on all patients who underwent primary bariatric surgery at a single-center academic institution between 2006 and 2015 who also had a documented 1-year follow-up weight ($n = 1050$).

Main Outcome Measures Weight loss curves were compared between high, low, and non-outliers as defined by their observed-to-expected (O:E) weight loss ratio based on total body weight loss (TBWL) %.

Results Mean predicted weight loss for the study group was 39.1 ± 9.9 kg, while mean actual weight loss was 39.7 ± 17.1 kg resulting in a mean O:E 1.01 (± 0.35). Based on analysis of the O:E ratios at 1 year post-surgery, the study group was sub-classified. Low outliers ($n = 188$, O:E 0.51) had significantly lower weight loss at 2 months (13.1% vs 15.6% and 16.5% TBWL, $p < 0.001$) and at 6 months (19% vs 26% and 30% TBWL, $p < 0.001$) when compared to non-outliers ($n = 638$, O:E 1.00) and high outliers ($n = 224$, O:E 1.46), respectively.

Conclusions Weight loss curves based on individually calculated outcomes can help identify low outliers for additional interventions as early as 2 months after bariatric surgery.

Keywords Bariatric surgery · Weight loss · Weight loss failure · Weight-related comorbidities · Patient-reported outcomes

Introduction

Bariatric surgery is the most effective treatment for patients with severe obesity and associated comorbid conditions [1–3]. While various mechanisms account for the impact of bariatric surgery on metabolic conditions, the degree of improvement correlates with the magnitude of weight and body mass index (BMI) reduction [1–3]. Consequently, optimization of weight loss after bariatric surgery is essential.

However, weight loss outcomes can vary considerably depending on patient-specific characteristics as well as procedure type [4]. Tools for predicting weight loss after bariatric surgery have evolved and account for patient age, sex, preoperative weight, and race [5]. Such tools provide important information for physicians to counsel patients about realistic expectations after bariatric surgery. In

Key Points

- Bariatric surgery weight loss calculators use key demographic and clinical parameters to provide individualized data to guide patient and provider post-surgical expectations.
- Despite the good overall accuracy of the weight calculator, some patients have weight results that fall below projections.
- Patients with less-than-expected weight response may be identified as early as two months post-surgery and potentially provides bariatric teams the opportunity for early, corrective intervention.

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addition, success and failure to achieve weight loss goals can be more accurately assessed by comparing actual weight loss to patient-specific predicted weight loss. Furthermore, prompt identification of suboptimal weight response to surgical therapy can lead to early implementation of evidenced-based weight control-enhancing treatments.

Using a statewide payer-funded bariatric-specific data registry that includes over 77,000 patients, the Michigan Bariatric Surgery Collaborate (MBSC) created a weight loss outcomes calculator that is publicly available as an app named "Weigh the Odds," which can be found on Google Play® and the App Store®. The app takes into account 30 different variables to predict weight loss outcomes after bariatric surgery. It also predicts 30-day complication rates and patient-reported discontinuation of medications associated with weight-related comorbidities. To date, there have been few reports of weight loss outcome calculations compared to actual weight loss [6, 7]. We previously published data from a smaller, multicenter cohort of patients who had surgery during an 18-month timespan [7]. We are now reporting on a larger group of patients from a single institution with data obtained over a 9-year span of time.

In this context, we utilized the MBSC outcomes calculator to compare predicted versus actual weight loss at 1 year after bariatric surgery at a single-center academic institution. Patients who did not meet the predicted weight loss target were compared to those who met or exceeded the target. Weight loss curves were also generated to characterize how soon after surgery the low-outlier cohort could be identified.

Methods

Data Source and Study Population

This study analyzes data from the Michigan Bariatric Surgery Collaborative (MBSC), a payer-funded organization that uses a clinically rich bariatric-specific data registry used to improve the quality and safety of bariatric surgery. Thirty-eight hospitals, both teaching and non-teaching, submit data on primary and revisional cases. Bariatric procedures include laparoscopic sleeve gastrectomy (LSG), laparoscopic and open Roux-en-Y gastric bypass (RYGB-Open and RYGB-Lap, respectively), biliopancreatic diversion with duodenal switch (BPD/DS), and laparoscopic adjustable gastric banding (LAGB). Data abstraction from medical records includes a wide range of information on patient demographics, comorbid conditions, and postoperative outcomes that are described in greater detail elsewhere [6]. Centrally trained data abstractors review medical records and data variable definitions are standardized. Accuracy and completeness of MBSC data are also verified by annual visits to participating hospitals. Patient-reported outcomes (PROs) are captured via baseline and follow-up questionnaires. For this study, we identified all patients 18 years and older who underwent primary bariatric surgery at the University of Michigan between June 6, 2006, and July 29, 2015, who also had their weight documented at the time of their initial bariatric surgery consultation, the preoperative weight (defined as the last recorded preoperative weight), and at 2 weeks, 2 months, 6 months and 1 year after their procedure ($n = 1050$). This represented 91.5% of all patients undergoing bariatric surgery at the University of Michigan during the study period. Follow-up care was provided by the Post-Bariatric Endocrine Clinic, where patients are evaluated at 6 months and yearly after bariatric surgery to manage long-term care including obesity-related comorbidities, vitamin deficiencies, and weight regain as previously described in the literature [8].

Study Design and Data Collected

A weight loss prediction model was developed by the MBSC using data collected on all primary bariatric cases between June 2006 and January 2018 who also had a reported weight a one year after surgery ($n = 45{,}860$). The prediction model included variables that were obtained from patient's preoperative baseline survey and/or abstracted from their initial clinic visit, which included age, height, weight, sex, insurance type, comorbid conditions, mobility limitation, smoking history, and procedure type (Table 1).

Internal validation of the prediction model included 100% of the sample data to perform O:E ratio, calibrated curve, C-stastic, ROC, Hosmer-Lamershow, and cross-validation techniques. Using this prediction model, weight loss was calculated on all patients based on information obtained from the initial consult visit ($n = 1050$). Actual weight was collected on the day of surgery ($n = 1050$; 100%) as well as at 2 weeks ($n = 1038$; 98.9%), 2 months ($n = 1013$; 96.5%), 6 months ($n = 954$; 90.9%), and 1 year ($n = 1050$; 100%) after their procedure. An observed-to-expected weight loss ratio (O:E) was calculated using the predicted weight and actual weight at 1 year after surgery. Patients were then subdivided into one of three groups based on their O:E ratio: (1) High outlier (greater than predicted weight loss), mean O:E > 1.5; (2) low outlier (less than predicted weight loss), mean O:E < 0.5; and (3) non-outlier (achieved predicted weight loss), mean O:E = 1. Total body weight loss (TBWL) % was calculated for each group at each documented interval and compared. Preoperative characteristics, procedure type, and 1-year patient-reported outcomes were also compared.

Data on patient characteristics included age, sex, insurance type, race, preoperative body mass index (BMI), procedure type (institution-performed procedures include RYGB-Open, RYGB-Lap, LAGB, or LSG), and comorbidities including gastroesophageal reflux disease (GERD), hernia, liver disorder,

Table 1 Variables included in the weight loss calculator

Variable
Procedure type:
- RYGB-Open
- RYGB-Lap
- Laparoscopic sleeve gastrectomy
- LAGB
- BPD/DS
Demographics:
- Weight
- Height
- Private insurance (yes/no)
- Age
- Gender
- Race
Comorbidities
- GERD
- Hernia
- Liver disorder
- Hyperlipidemia
- Urinary incontinence
- Cholelithiasis
- Peptic ulcer disease
- Psychological disorder
- Sleep apnea
- Renal function disorder
- Musculoskeletal disorder
- Cardiovascular disease
• Peripheral vascular disease
• Heart rhythm disorder
• Chronic heart failure
• Hypertension
• Coronary artery disease
-Lung disease
• Chronic obstructive pulmonary disease
• Asthma
• Utilization of home oxygen
- Diabetes
•Insulin-dependent diabetes
• Non-insulin-dependent diabetes
Other risk factors
- Use of mobility aids
- History of VTE
- History of smoking

RYBG, Roux-en-Y gastric bypass; *Lap*, laparoscopic; *LSG*, laparoscopic sleeve gastrectomy; *LAGB*, laparoscopic adjustable gastric banding; *BPD/DS*, biliopancreatic diversion with duodenal switch; *GERD*, gastroesophageal reflux disease; *VTE*, venous thromboembolism

hyperlipidemia, urinary incontinence, cholelithiasis, peptic ulcer disease, psychological disorder, renal function disorder, musculoskeletal disorder, cardiovascular disease (peripheral vascular disease, arrhythmia, chronic heart failure, hypertension, and coronary artery disease), lung disease (chronic obstructive pulmonary disease, asthma, and utilization of home oxygen), diabetes (non-insulin-dependent and -insulin dependent), use of mobility aids, history of venous thromboembolism (VTE), and smoking. Complications, reoperations, readmissions, and emergency department (ED) visits within 30 days of surgery were also captured. Complications within 30 days of surgery included bowel obstruction, leak, abdominal abscess, wound complication, dehiscence, hemorrhage, venous thromboembolism, myocardial infarction, renal failure, pneumonia, reintubation, prolonged ventilator use, shock, hospital-acquired infections, and death. Patient-reported discontinuation of medications for diabetes, hypertension, hyperlipidemia, and discontinuation of continuous positive airway pressure (CPAP) use for obstructive sleep apnea were obtain at 1 year after surgery from survey data. Finally, satisfaction rates were also obtained from survey data.

Statistical Analysis

Comparisons of patient characteristics, procedure type, and postoperative outcomes by outlier group were performed using analysis of variance (*F*-tests) for continuous variables and chi-squared tests for categorical variables. A linear mixed model was used to evaluate differences in percentage of total body weight loss between low-, high-, and non-outlier groups across six time points (initial bariatric consultation, day of surgery, and 2 weeks, 2 months, 6 months, and 1 year after surgery). Statistical significance was set at $p < 0.05$. All analyses were conducted using SAS v9.4.

Results

There were 1050 patients included in this study. For inclusion in the study, patients were required to have weight loss-related information at both baseline and 1 year after surgery. No other exclusion criteria were present. However, a few patients missed one or more interval follow-up visits within the first year. Characteristics of the missing patients and the comparison between these patients with the present ones can be found in Table 2.

Mean overall predicted weight loss was 39.1 kg ± 9.9 kg while mean actual weight loss was 39.7 kg ± 17.1 kg, resulting in a mean O:E 1.01 (±0.35). Predicted and actual weight loss outcomes for low-, high-, and non-outliers are presented in Table 3, while preoperative patient characteristics,

Table 2 Comparison between patients present or missed at each follow-up visit throughout the year after bariatric surgery

Factors		Time after surgery								
		2 weeks			2 months			6 months		
		Present ($N = 1038$)	Missing ($N = 12$)	P value	Present ($N = 1013$)	Missing ($N = 37$)	P value	Present ($N = 954$)	Missing ($N = 96$)	P value
Low outliers	Yes: N (%)	183 (17.6%)	5 (41.7%)	0.040*	179 (17.7%)	9 (24.3%)	0.370	162 (17.0%)	26 (27.1%)	0.002*
Weight loss parameters	Expected weight loss (kg): mean (SD)	39.1 (9.9)	42.9 (11.6)	0.190	39.1 (9.9)	39.7 (10.8)	0.750	39.1 (10.0)	39.6 (9.1)	0.670
	Observed weight loss (kg): mean (SD)	39.8 (17.1)	31.3 (14.9)	0.087	39.9 (17.1)	35.2 (14.7)	0.100	40.1 (17.0)	35.6 (17.4)	0.012*
	Observed-to-expected ratio: mean (SD)	1.0 (0.3)	0.8 (0.4)	0.011*	1.0 (0.4)	0.9 (0.3)	0.051	1.0 (0.3)	0.9 (0.4)	< 0.001*
Demographics	Age at procedure (years): mean (SD)	45.6 (10.7)	37.4 (11.8)	0.009*	45.6 (10.7)	41.6 (11.2)	0.027*	45.7 (10.8)	42.8 (10.1)	0.010*
	Male: N (%)	215 (20.7%)	3 (25.0%)	0.720	212 (20.9%)	6 (16.2%)	0.490	198 (20.8%)	20 (20.8%)	0.990
	Weight before surgery (pounds): mean (SD)	304.1 (62.8)	290.3 (83.7)	0.450	304.1 (62.6)	300.1 (75.0)	0.710	304.0 (63.1)	303.6 (63.4)	0.960
	BMI before surgery (kg/m^2): mean (SD)	48.7 (8.3)	48.1 (11.9)	0.820	48.7 (8.3)	48.4 (9.4)	0.830	48.7 (8.3)	48.8 (8.9)	0.920
	Private insurance: N (%)	926 (89.2%)	8 (66.7%)	0.013*	907 (89.5%)	27 (73.0%)	0.002*	858 (89.9%)	76 (79.2%)	0.001*
Key comorbidities	Hypertension: N (%)	523 (50.4%)	4 (33.3%)	0.240	510 (50.3%)	17 (45.9%)	0.600	480 (50.3%)	47 (49.0%)	0.800
	Hyperlipidemia: N (%)	533 (51.5%)	8 (66.7%)	0.300	521 (51.6%)	20 (54.1%)	0.770	497 (52.3%)	44 (45.8%)	0.230
	Diabetes: N (%)	355 (34.3%)	1 (8.3%)	0.059	346 (34.3%)	10 (27.0%)	0.360	334 (35.1%)	22 (22.9%)	0.016*
	CVD: N (%)	65 (6.3%)	0 (0.0%)	0.370	64 (6.3%)	1 (2.7%)	0.370	60 (6.3%)	5 (5.2%)	0.680
	Sleep apnea: N (%)	635 (61.2%)	4 (33.3%)	0.049*	621 (61.5%)	22 (59.5%)	0.800	592 (62.3%)	51 (53.1%)	0.080
Other risk factors	Mobility aids: N (%)	32 (3.1%)	0 (0.0%)	0.540	31 (3.1%)	1 (2.7%)	0.900	30 (3.2%)	2 (2.1%)	0.560
	VTE history: N (%)	52 (5.0%)	0 (0.0%)	0.430	52 (5.1%)	0 (0.0%)	0.160	46 (4.8%)	6 (6.3%)	0.540
	Smoking: N (%)	415 (40.1%)	3 (25.0%)	0.290	403 (39.9%)	15 (40.5%)	0.940	385 (40.5%)	33 (34.4%)	0.240

*Statistically significant

Table 3 Predicted vs actual weight loss among low, high, and non-outliers

	All patients ($n=1050$)	Low outliers ($n=188$)	Non-outliers ($n=638$)	High outlier ($n=224$)	*p*-value
1-year weight loss					
Predicted weight loss (kg): mean ± SD	39.1 ± 9.9	36.9 ± 10.6	39.9 ± 9.7	39.1 ± 9.7	$p=0.002$
Actual weight loss (kg): mean ± SD	39.7 ± 17.1	19.1 ± 12.5	39.8 ± 10.8	56.8 ± 15.9	$p<0.001$
O:E: mean ± SD	1.0 ± 0.4	0.5 ± 0.3	1.0 ± 0.1	1.5 ± 0.2	$p<0.001$

SD, standard deviation

procedure type, and postoperative outcomes for each group is presented in Table 4.

Low outliers had a mean overall weight loss of 19.1 kg (O:E 0.5 ± 0.3) at 1 year and were significantly more likely to be older (47.2 years vs 45.1 years, $p=0.04$), have a lower preoperative BMI (47.5 vs 48.7 kg/m^2), were more likely to smoke (45.2% vs 36.9%, $p<0.04$), and undergo gastric banding (6.4% vs 1.6%, $p<0.001$) when compared to non-outliers. Low outliers also had significantly lower percentage of total body weight loss (TBWL%) at 2 months (13.1%),

Table 4 Analysis of demographics, comorbidities, and procedure type between, low, high, and non-outliers

	Low outliers ($n=188$)	Non-outliers ($n=638$)	High outlier ($n=224$)	*p*-value
Patient demographics				
Age: mean (years), ± SD	47.2 ± 10.7	45.1 ± 10.6	44.9 ± 11.0	0.04
Preoperative weight (kg): mean ± SD	131.5 ± 28.3	136.9 ± 27.8	146.0 ± 29.4	< 0.001
Preoperative BMI (m/kg^2); mean ± SD	47.5 ± 9.2	48.7 ± 8.2	49.6 ± 7.9	0.03
Male: *n* (%)	40 (21.3%)	135 (21.2%)	43 (19.2%)	0.81
White race: *n* (%)	145 (77.1%)	500 (78.4%)	170 (75.9%)	
Black/African American: *n* (%)	19 (10.1%)	75 (11.8%)	30 (13.4%)	
Hispanic: *n* (%)	9 (4.8%)	15 (2.4%)	13 (5.8%)	
Other race: *n* (%)	15 (8.0%)	48 (7.5%)	11 (4.9%)	
Private insurance: *n* (%)	165 (87.8%)	568 (89.0%)	201 (89.7%)	0.81
Comorbidities; *n* (%)				
Hypertension	101 (53.7%)	316 (49.5%)	110 (49.1%)	0.56
Hyperlipidemia	102 (54.8%)	325 (51.0%)	114 (50.9%)	0.63
Non-insulin-dependent diabetes	45 (23.9%)	132 (20.7%)	49 (21.9%)	0.63
Insulin-dependent diabetes	32 (17.1%)	71 (11.2%)	28 (12.6%)	0.10
Gastroesophageal reflux disease	99 (52.7%)	328 (51.4%)	118 (52.7%)	0.92
Coronary artery disease	15 (8.0%)	36 (5.6%)	14 (6.3%)	0.50
Obstructive sleep apnea	121 (64.4%)	376 (58.9%)	142 (63.4%)	0.28
Mobility limitation	4 (2.1%)	23 (3.6%)	5 (2.2%)	0.43
Asthma	55 (29.3%)	148 (23.2%)	53 (23.7%)	0.23
Psychological disorder	125 (66.5%)	425 (66.6%)	161 (71.9%)	0.32
History of VTE	12 (6.4%)	29 (4.6%)	11 (4.9%)	0.59
Urinary incontinence	47 (25.0%)	183 (28.7%)	59 (26.3%)	0.55
History of smoking	84 (45.2%)	235 (36.9%)	99 (44.2%)	0.04
Kidney disease	3 (1.6%)	4 (0.6%)	2 (0.9%)	0.45
Liver disease	40 (21.3%)	120 (18.8%)	33 (14.7%)	0.21
Lung disease	61 (32.5%)	155 (24.3%)	57 (25.5%)	0.08
Procedure type: *n* (%)				
Adjustable gastric banding: *n* (%)	12 (6.4%)	10 (1.6%)	7 (3.1%)	
Gastric bypass: *n* (%)	73 (38.8%)	286 (44.8%)	70 (31.3%)	
Sleeve gastrectomy: *n* (%)	103 (54.8%)	342 (53.6%)	147 (65.6%)	

6 months (18.5%), and 1 year (14.5%) when compared to non-outliers (15.6, 25.6; 29.2%) and high outliers (16.5%, 29.7%, 38.9%), respectively (Table 4, Table 5; Fig. 1).

Preoperative weight loss and duration of time between the initial evaluation and day of surgery were similar among all groups. Finally, low outliers experienced lower rates of comorbidity resolution and lower satisfaction rates but had similar 30-day risk adjusted complication rates when compared to non-outliers and high outliers (Tables 4 and 5). To assess whether or not the starting BMI could account for the findings, a separate analysis was conducted for individuals with a BMI > 45 kg/m^2. There were 652 patients who had a baseline BMI > 45 kg/m^2. Among them, 106 were low outliers, 392 were non-outliers, and 154 were high outliers. Results for this subgroup were comparable to the group, as a whole (Fig. 2).

Discussion

This is one of a few reports of a bariatric surgery outcomes calculator derived entirely from a statewide bariatric-specific data registry that includes the most common procedures used today. Our data provided several insights regarding accuracy of the outcomes calculator, limitations in the calculator's ability to identify a "low-outlier" subset of patients, potential factors that may affect weight outcomes, and timing of insufficient weight loss identification.

Accurate predication of weight outcomes after bariatric surgery is important both to patients and providers. To achieve this goal, weight outcome prediction calculators have been developed to account for various demographic, anthropometric, and clinical factors that can affect post-surgical weight trajectory. Prior studies have demonstrated that weight loss outcomes can vary considerably after bariatric surgery depending on procedure type as well as preoperative patient characteristics [9]. Notably, results from the MBSC published in 2013 demonstrated that weight loss was greatest for RYGB-Lap followed by LSG and then LAGB [4]. In addition, older patients also experienced less weight loss. Identifying risk factors that affect weight loss after bariatric surgery has been integral to generating statistical models that predict patient-specific outcomes. For example, Wise et al. noted that male gender, black race, higher starting BMI, hypertension, and diabetes were associated with less weight loss and these variables were utilized to create a weight loss prediction model for laparoscopic gastric bypass [10]. Sczepaniak et al. also developed a predictive weight

Table 5 Analysis of weight loss, complication rates, discontinuation of treatment for comorbidities and satisfaction rates between, low, high, and non-outliers

	Low outliers (*n* = 188)	Non-outliers (*n* = 638)	High outlier (*n* = 224)	*p*-value
Total body weight loss (TBWL) %				
- Preoperative: mean ± SD	1.9 ± 5.0	1.2 ± 4.0	0.7 ± 5.0	0.29
- 2 week postop: mean ± SD	8.2 ± 5.0	9.0 ± 4.9	9.0 ± 5.3	0.16
- 2 month postop: mean ± SD	13.1 ± 5.5	15.6 ± 4.7	16.5 ± 5.9	< 0.001
- 6 month postop: mean ± SD	18.5 ± 6.2	25.6 ± 5.6	29.7 ± 6.9	< 0.001
- 1 year postop: mean ± SD	14.5 ± 8.6	29.2 ± 6.0	38.9 ± 6.9	< 0.001
Time from initial evaluation to surgery (months) ± SD	6.2 ± 3.4	6.2 ± 5.7	6.0 ± 3.6	0.83
30-day complication rates				
Any complication: *n* (%)	12 (6.4%)	58 (9.1%)	20 (8.9%)	0.50
Surgical complication: *n* (%)	10 (5.3%)	37 (5.8%)	13 (5.8%)	0.97
Medical complication: *n* (%)	0 (0.0%)	3 (0.5%)	1 (0.5%)	0.64
Discontinuation of treatment for comorbidities				
Hypertension: *n* (%)	25 (40.3%)	126 (56.0%)	48 (61.5%)	0.04
Hyperlipidemia: *n* (%)	13 (34.2%)	61 (48.0%)	26 (59.1%)	0.08
Diabetes: *n* (%)	26 (50.0%)	98 (66.7%)	45 (80.4%)	0.004
Obstructive sleep apnea: *n* (%)	25 (35.7%)	118 (59.0%)	64 (71.1%)	< 0.001
Satisfaction rate				
Very satisfied: *n* (%)	74 (64.4%)	397 (87.1%)	155 (93.4%)	< 0.001
Somewhat satisfied: *n* (%)	21 (18.3%)	47 (10.3%)	9 (5.4%)	
Neutral: *n* (%)	7 (6.1%)	6 (1.3%)	0 (0.0%)	
Somewhat dissatisfied: *n* (%)	7 (6.1%)	4 (0.9%)	1 (0.6%)	
Very dissatisfied: *n* (%)	6 (5.2%)	2 (0.4%)	1 (0.6%)	

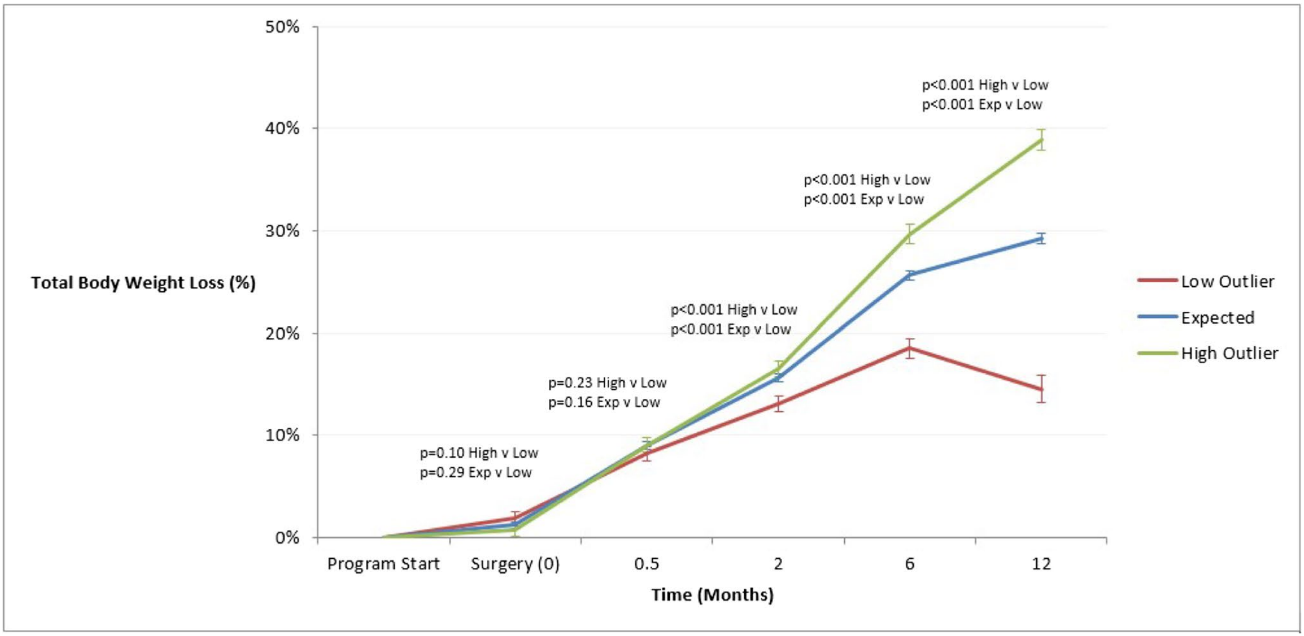

Fig. 1 Comparison of total body weight loss % (TBWL%) between the non-outliers, high outliers, and low outliers from time of program start to 12 months post-surgery

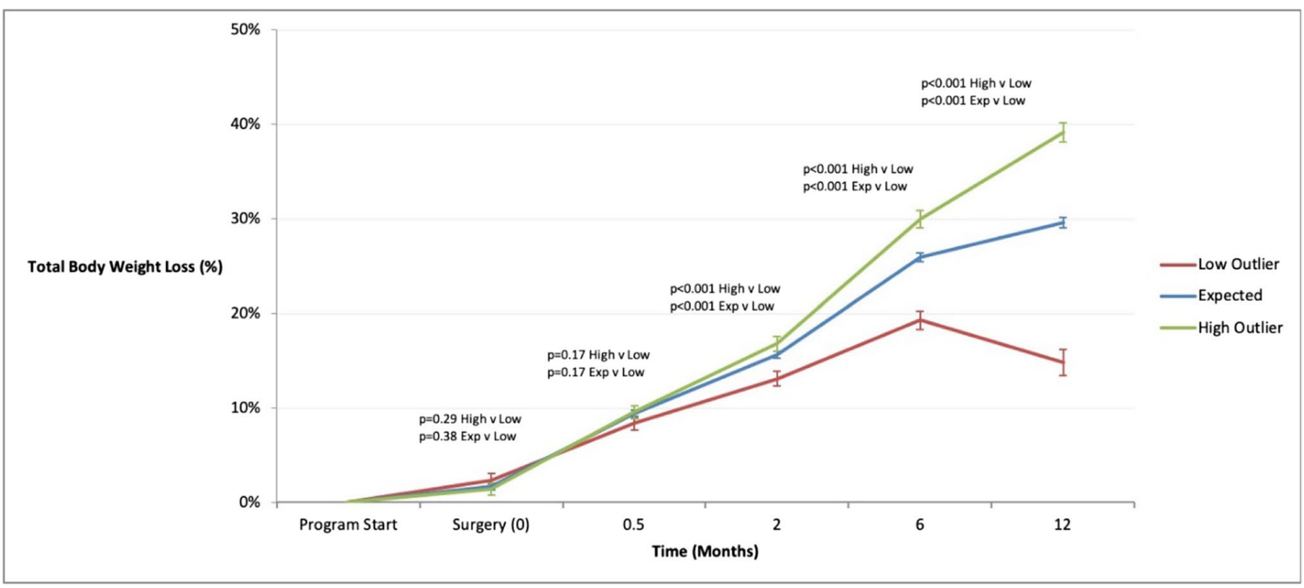

Fig. 2 Comparison of total body weight loss % (TBWL%) between the non-outliers, high outliers, and low outliers among patients with a baseline BMI > 45 kg/m^2 from time of program start to 12 months post-surgery

loss curve for laparoscopic and open gastric bypass utilizing data from a single surgeon's experience at a community hospital [11]. They note that the patient's initial weight was the single most important predictor of weight loss after surgery. Likewise, when creating a weight loss prediction tool for gastric bypass, Wood et al. noted that preoperative BMI and age had the highest correlation with weight loss success [5]. Their weight loss prediction model utilized 2986 patients which has been the largest reported to date. By comparison, the MBSC outcomes calculator utilizes over 45,000 patients and includes 30 different variables including multiple procedure types, not only gastric bypass.

This study demonstrates that the MBSC weight loss outcomes calculator was accurate when applied to our overall patient population (overall mean O:E = 1.01) by using information that is easily obtained during their initial clinic visit (i.e., demographics, comorbidities, and desired procedure type). However, even after accounting for various demographic, anthropometric, and clinical factors (such as diabetes mellitus), there were still patients identified that fell outside the predictions: the low and high outliers. Use of this classification may allow for a more individualized and effective approach when counseling patients. Unfortunately, a lack of standardized definitions for weight loss success and failure for bariatric surgery remains an obstacle when setting appropriate expectations for patients. Interestingly, there appears to be a higher incongruence between patient's perceived and calculated weight status classification among post-surgery patients when compared to pre-surgery patients [12]. Commonly cited outcome measures in the scientific literature used to define primary non-response include percentage excess body weight loss (%EBWL), percentage total body weight loss (%TBWL), and body mass index (BMI). However, there is no consensus regarding the cutoffs or chronology (i.e., outcomes at 1 year post-surgery versus 2 years post-surgery) [13]. Additionally, most definitions do not account for the presence of comorbid conditions [14]. To address these issues, we chose to compare actual weight loss to patient-specific predicted weight loss using an outcomes calculator. In doing so, we were able to identify patients who fell below their individual predicted weight loss targets (i.e., low outliers, O:E < 0.5). Low outliers had significantly lower rates of medication discontinuation for weight-related comorbidities as well as lower satisfaction rates.

The factors contributing to these groups' results are unclear. Although low outliers tended to be slightly older, with a lower BMI and more likely to undergo LAGB, there were no major differences in the prescreened comorbid health conditions that would suggest an error in the weight loss outcomes calculator algorithm. No other obvious pre-surgical modifiable factors were identified, either. Obesity-related genetic testing was not a part of typical practice during the time of the study period, and we did not collect this information. Factors contributing to weight loss failure (aka: "primary non-response") to bariatric surgery are incompletely understood [15, 16]. However, we found that preoperative weight loss was not predictive of achieving expected or greater-than-expected weight loss at 1 year after surgery. This is an important finding given that preoperative medically supervised weight loss mandated by insurance carriers may have no proven benefit and, instead, represent a barrier to obesity care. To date, the association between preoperative and postoperative weight loss remains mixed. A systematic review by Livhits et al. identified seven studies with a positive association, one study with a negative association and six studies with no association whatsoever [9]. Our study further demonstrates a lack of correlation between preoperative weight loss and expected postoperative weight loss success and does so by using a predictive model to identify patient-specific weight loss targets to account for the known variation in outcomes.

Of considerable clinical interest, our data found that low outliers could be identified as early as 2 months after surgery. Early identification of patients who did not meet their predicted weight loss target is important as it can allow for earlier implementation of weight optimization strategies rather than waiting to treat secondary non-response (aka "weight regain") [17]. This is also advantageous for the patient since secondary non-response to surgery can lead to significant psychological and emotional distress [18]. While there is no standard early-intervention methodology, there are emerging data investigating assessment and treatment protocols. Though limited, studies have examined intervention strategies [19]. During clinic visits, careful questioning may reveal potentially modifiable weight barriers such as behavioral control issues, dietary non-adherence, uncontrolled hunger/craving, mental health instability, and/or anatomic surgical failure [19]. Based on the assessed need(s), evidenced-based treatment strategies could be implemented such as enrollment in a structured behavioral program [20, 21], intensification of dietary visit structure and frequency [22–25], utilizing weight control pharmacotherapy [26–29], identification and treatment of psychiatric disorder (including binge eating disorder) [30], and/or consideration of surgical intervention [31]. These data should also prompt investigation as to whether early implementation of these interventions can improve the rate of comorbidity resolution in low-outlier patient groups.

We recognize that our study has several limitations. First, the study population includes patients that were treated at a single-center academic center and the case distribution included mostly RYGB-Lap and LSG procedures, with a low volume of LAGB and no BPD/DS. As such, it is unclear whether the study is generalizable to all patient populations. Nevertheless, the study included over 1000 patients with a follow-up rate of over 90%, which matches or exceeds similar studies evaluating weight loss outcomes. Furthermore, our previously published study examined 658 patients who underwent bariatric surgery at 35 different bariatric surgery programs between 2015 and 2017 and results aligned with the results presented here [7]. Another concern may be that the MBSC outcomes calculator has not been externally validated as a tool for predicting weight loss accurately and may not be reliable for extreme weights (i.e., BMI > 90 kg/m^2). Furthermore, the MBSC data, upon which the model is built, is inclusive of the patient data from our center. However, it should be noted that our patient data ($n = 1050$) represent only 2% of the total data ($n = 45{,}860$). Additionally, we are working to achieve external validation and the calculator is currently being tested using a data registry from a different country. However, 100% of the sample data was used for internal validation, which included O:E ratio, calibrated curve, C-statistic, ROC, Hosmer-Lamershow, and cross-validation techniques. It is unclear which patients underwent medically supervised weight loss preoperatively and this may bias results. We do not think the study was biased by the use of weight loss medications since this was not part of practice at our center during the time of study (i.e., prior to 2017).

Conclusions

Weight loss calculators that account for multiple, easily accessible patient characteristics and procedure type are useful when setting appropriate expectations for patients after bariatric surgery. Using a weight loss calculator formulated from a robust statewide bariatric-specific clinical registry, we were able to identify patients who failed to meet their predicted weight loss as early as 2 months after surgery. These patients may benefit from additional interventions to help achieve their expected weight loss potential.

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Declarations

Ethics Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

For this type of study, formal consent is not required.

Conflict of Interest Dr. Elif A. Oral reports receiving grant support from GI Dynamics and having IP related to bariatric medicine. Dr. Oral served as a consultant and receives grant support from Rhythm Pharmaceuticals developing new products for treatment of monogenic forms of morbid obesity. Unrelated to this manuscript, Dr. Oral also provides consulting and advising services to several companies developing therapeutics or who own therapeutics in lipodystrophy space and has patents in the lipodystrophy and nonalcoholic steatohepatitis spaces. Dr. Varban reports receiving salary support from Blue Cross Blue Shield of Michigan for leadership and participation in the Michigan Bariatric Surgery Collaborative. All the other authors report nothing to disclose.

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