Surgery for Obesity and Related Diseases 13 (2017) 1590–1598

SURGERY FOR OBESITY AND RELATED DISEASES

Original article

Prospectively validated preoperative prediction of weight and co-morbidity resolution in individual patients comparing five bariatric operations

Gus J. Slotman, M.D., F.A.C.S., F.C.C.M., F.C.C.P., F.A.S.M.B.S.*

Inspira Health Network, Vineland, New Jersey

Received June 22, 2016; accepted April 11, 2017

Abstract

Background: No method preoperatively predicts the postoperative bariatric surgery outcomes in individual patients. Decisions for or against surgery and operation choice remain subjective. Only 1% of qualifying patients embrace bariatric surgery.

Objective: To predict preoperatively and validate prospectively the weight and co-morbidity resolution in individual patients after open Roux-en-Y gastric bypass (RYGB) and laparoscopic Roux-en-Y gastric bypass (LRYGB), laparoscopic adjustable gastric band (LAGB), sleeve gastrectomy (SG), and biliopancreatic diversion/duodenal switch (BPD/DS).

Setting: Surgical Review Corporation BOLD database, 2007–2010.

Methods: A total of 166,601 patients who had undergone RYGB (n = 5389), LRYGB (n = 83,059), LAGB (n = 67,514), SG (n = 8966), or BPD/DS (n = 1673) were randomized into modeling (n = 124,053) and validation (n = 42,548) groups. From preoperative data, multivariate linear and logistic regression predicted weight and co-morbidities at 2, 6, 12, 18, and 24 months postoperatively. Model fit was examined by R^2 and receiver operating characteristic/area under the curve and predicted versus observed results via Pearson correlation coefficient and sensitivity/specificity.

Results: Follow-up at 2/24 months was 120,909/11,014 for the modeling group and 41,528/3703 for validation. Weight models' R^2 was .910, .813, .725, .638, and .613 at 2, 6, 12, 18, and 24 months, respectively. The categorical receiver operating characteristic/area under the curve was .617 to .949 for 24-month predictions. Pearson continuous coefficients were .969 and .811 at 2 and 24 months, respectively. The median 24-month sensitivity and specificity of co-morbidity resolution were 79.2% and 97.42%, respectively.

Conclusions: Prospectively validated preoperative models predict, in individual patients, weight and obesity co-morbidities 2 years in advance for RYGB, LRYGB, LAGB, SG, and BPD/DS. This advance knowledge facilitates choosing the operation that is best for each individual and may encourage more patients to choose bariatric surgery. (Surg Obes Relat Dis 2017;13:1590–1598.)

Keywords: Bariatric surgery results prediction; Prognostic models; Outcomes

Presented, in part, at Obesity Week, November 11-16, 2013, Atlanta, GA

*Correspondence: Gus J. Slotman, M.D., F.A.C.S., F.C.C.M., F.C.C.P., F.A.S.M.B.S., Inspira Health Network, 1505 West Sherman Avenue, Suite B, Vineland, NJ 08360.

E-mail: slotmang@ihn.org

Morbid obesity affects 6.3% of the US population [1,2] with weight-related medical problems, doubling their medical expenses [3]. From the 2012 US census [4], over 19.8 million Americans meet the National Institutes of Health criteria for bariatric surgery [5]. Nevertheless, only about

http://dx.doi.org/10.1016/j.soard.2017.04.013

.97% of those who qualify for bariatric operations actually undergo surgery [6] and benefit from its weight loss and resolution of co-morbidities [7]. The relative efficacy of different operations may be debated [8], but the minimal penetration of bariatric surgery into the morbidly obese population leaves millions disabled. Characteristics of operative patients are understood [9], but why patients decide against bariatric surgery remains unknown. Certainly, variation in health insurance coverage for bariatric surgery and accompanying financial concerns are contributing factors [10]. Patient lack of knowledge and concerns over outcomes and complications may contribute [11,12]. Among obese patients who declined bariatric surgery, Fung et al. found fear of complications (51%), not needing weight loss surgery (32%), fear of surgery (24%), and costs (20%) to be the principal reasons against operation [13]. The open question is how to calm those concerns and encourage more patients to embrace surgical weight loss.

The lack of validated outcome predictions for individual morbidly obese patients may be another factor that discourages patients from having weight loss surgery. Calculators predicting the relatively rare complications of bariatric surgery [14–16] and nonvalidated weight loss calculators [17] are reported. Nevertheless, prospectively validated predictions for bariatric surgery that are applicable to individuals and compare the future results of the most common operations are not available. Thus, in counseling patients about bariatric surgery, physicians can reference only the published results for each operation, not individual outcomes. Ultimately, the choices of whether to have weight loss surgery and which procedure to undergo are left, subjectively, to the patient.

The present study hypothesized that the Systemic Mediator Associated Response Test (SMART) methodology could predict individual bariatric surgery outcomes from preoperative clinical data. Previous SMART models predicted qualitative and quantitative results in septic patients [18] and identified cohorts within failed clinical trials among which study drugs reduced septic mortality [19]. The objective of the present study, then, was to determine whether outcomes from the most frequently performed bariatric operations could be predicted in individual patients from preoperative data and then validated prospectively in a separate population.

Methods

With the approval of the Data Access Committee of the Surgical Review Corporation (SRC) and the Institutional Review Board of Our Lady of Lourdes Medical Center in Camden, New Jersey, Health Insurance Portability and Accountability Act–compliant data from the SRC's Bariatric Outcomes Longitudinal Database (BOLD) [20] on 166,601 patients who had undergone primary bariatric surgery between June 1, 2007 and December 31, 2010, and who had had at least one postoperative follow-up visit were analyzed. Business and validation rules were built into BOLD to flag or reject potential errors at the point of data entry, and automated data quality reports identify unacceptable trends after data capture. In addition, preoperative data, postoperative complications, and deaths entered into BOLD were verified 100% on-site by SRC monitors.

Long-term follow-up information was verified by random chart reviews in at least 15% of the cases [20]. Revisional operations were excluded from the present study. In the overall population, 5389 patients underwent open Roux-en-Y gastric bypass (RYGB); 83,059 had laparoscopic Roux-en-Y gastric bypass (LRYGB); 8966 received sleeve gastrectomy (SG); 67,514 had laparoscopic adjustable gastric band (LAGB); and 1673 had biliopancreatic diversion/duodenal switch (BPD/DS). Patients were randomized into a modeling group (n = 124,053) or a validation group (n = 42,548). Preoperative BOLD parameters with <5% missing data (n = 46) were screened as independent variables. Categorical preoperative variables subcategorized by severity of illness in BOLD using seminumerical scales of 1 to 5, 1 to 4, and so on were included in the statistical mix. Continuous dependent variables included weight and weight loss. Dichotomous dependent variables included diabetes, hypertension, obstructive sleep apnea (OSA), liver disease, cholelithiasis, gastroesophageal reflux disease (GERD), congestive heart failure (CHF), abdominal hernia, or surgeon/support group follow-up and adverse events, as defined by the Surgical Review Corporation's BOLD reporting definitions [20].

From a General Estimating Equation platform, multivariate linear regression identified preoperative independent variables that predicted weight and weight loss at 2, 6, 12, 18, and 24 months for each operation. Multivariate logistic regression identified preoperative independent parameters predicting co-morbidities at 2, 6, 12, 18, and 24 months for each operation, and adverse events at 0–6 and 0–12 months. All models were built using forward selection. Only independent variables with interaction coefficients at $P < .10$ were included in the models. Low-incidence variables causing quasicomplete separation of data points were not used. The coefficient of determination (R^2) tested model fit for continuous dependent variables. Receiver operating characteristics/area under the curve (ROC/AUC) examined dichotomous model fit [21]. Modeling was performed for each operation for each dependent variable at each observation point.

Linear models were tested by comparing validation group predicted values to the observed outcomes using Pearson correlation coefficients. Logistic models were validated by sensitivity and specificity [21].

Results

Preoperative variables that were screened as weighted independent variables (n = 46) and those included in the final prognostic models (n = 26) are listed in Table 1.

Table 1
Preoperative parameters screened and parameters identified as weighted independent variables for prognostic models

Pre-operative parameters screened as potential independent variables	
Height (cm)	IVC filter
Weight (kg)	Bariatric procedure planned
BMI	Age
Sex	Abdominal hernia
Black	Alcohol use
Asian	Angina
Caucasian	Asthma
Native American	Back pain
Hispanic	Cholelithiasis
Pacific islander/Hawaiian	Mental health diagnosis
Other race	Congestive heart failure
Cholecystectomy	Depression
Cholecystectomy with common	GERD
Bile duct exploration	Hypertension
Endoscopic examination	Liver disease
Gastrectomy partial	Musculoskeletal pain
Gastrectomy total	Obesity hypoventilation syndrome
Hiatal hernia repair	Psychological impairment
Liver biopsy	Pulmonary hypertension
Lysis of adhesions	Stress urinary incontinence
Small bowel resection	Tobacco use
Umbilical hernia repair	Full-time employment
Ventral hernia repair	
Final independent variables used in the SMART bariatric models	
Age	Hypertension
Abdominal hernia	Operation
Black	Liver disease
Alcohol use	Mental health diagnosis
Angina	Musculoskeletal pain
Asthma	Obesity hypoventilation syndrome
Back pain	Psychological impairment
Congestive heart failure	Employment
Caucasian	Pulmonary hypertension
Cholelithiasis	Stress urinary incontinence
Depression	Weight (kg)
GERD	Sex
Height (cm)	

IVC = inferior Vena Cava; BMI = body mass index; GERD = gastroesophageal reflux disease.

Model fit for continuous and dichotomous dependent variables and validation results are displayed in Table 2. For weight/weight loss, R^2 values were .910, .813, .725, .638, and .613 in baseline models that predicted these continuous dependent variables at 2, 6, 12, 18, and 24 months postoperatively, respectively. ROC/AUC for dichotomous dependent variables ranged from .985 for cholelithiasis at 2 months to .599 for surgeon follow-up/support group attendance at 12 months. Models for the complications of nausea and vomiting, intra-abdominal complications, and organ failure and sepsis were not successful because low event rates caused a quasiseparation of points. Grouping all occurrences of these adverse events into an "Any AE" category resulted in an ROC/AUC of .683 for both the 0- to 6-month and 6- to 12-month periods.

Weight/weight loss models were validated at 2, 6, 12, 18, and 24 months after surgery with Pearson correlation coefficients of .959, .932, .875, .837, and .811, respectively. Validation of dichotomous models included median sensitivity of 79.2% (range 25.0%–98.30%) and median specificity of 97.42%% (range 80.27%–99.99%). For any adverse event, specificity for both 0–6 months and 6–12 months was 99.92%, but sensitivity was only .52% and .51%, respectively, for those intervals.

Discussion

This investigation describes a method that uses preoperative clinical data to predict, in individual patients, weight/weight loss and the presence or absence of the most serious obesity co-morbidities up to 24 months in advance after RYGB, LRYGB, LAGB, SG, or BPD/DS. These results individualize the choice of bariatric operation for morbidly obese patients. Weight/weight loss were validated at clinically useful accuracy. Diabetes was predicted with a 24-month specificity of 93.97% and clinically applicable sensitivities. Hypertension prognostication had consistently high sensitivity/specificity. OSA models achieved specificities >90% through 24 months. Preoperative predictions of liver disease also carried strong validation results, as did cholelithiasis models through 24 months. Presence/absence of GERD was forecast well from preoperative data. Abdominal hernia models had excellent sensitivity and specificity. In spite of high specificities, low event rates for CHF, any adverse event, and surgeon follow-up/support group attendance limited sensitivity in those models. Our review of the literature indicates that the prospectively validated predictions of weight/weight loss and of the presence or resolution of obesity co-morbidities in individual patients described here, comparing results from 5 different operations, have not been reported previously and represent a significant advance in the field of bariatric surgery. These predictive engines will enable physicians and morbidly obese patients to individualize objectively the choice of bariatric operation.

While previous reports described clinical formulae [22], quartile regression curves [23], artificial neural networks [24] and other correlations [25] to predict weight/weight loss, most applied to only one operation, were not validated prospectively, and used databases less comprehensive for each patient at preoperative baseline than BOLD. Baseline weight/weight loss models in the present investigation achieved Pearson correlation coefficients of .959, .932, .875, .837, and .811 at 2, 6, 12, 18, and 24 postoperative months, respectively. The results here, for the first time, enable data-based, individualized choice of weight loss operation.

Type 2 diabetes (T2D) afflicts 28%–52% of bariatric patients [26,27] and improves with weight loss [28,29]. Knowing what diabetes resolution will be in comparing 5 operations could increase patients' confidence in choosing bariatric surgery. In the current analysis, T2D in individual

Table 2
Modeling and validation results for continuous and categorical dependent variables

Model fit for continuous and categorical dependent variables					
Observation	2 mo	6 mo	12 mo	18 mo	24 mo
Number of patients	120,909	75,130	42,410	15,387	11,014
Continuous dependent variables (R^2)					
Weight/weight loss	.910	.813	.725	.638	.61
Dichotomous dependent variables (ROC/AUC)					
Cholelithiasis	.985	.975	.967	.957	.949
Diabetes	.956	.940	.933	.930	.926
GERD	.898	.860	.829	.818	.804
Hypertension	.913	.891	.874	.869	.858
Liver disease	.963	.956	.950	.940	.941
Obstructive sleep apnea	.887	.858	.837	.841	.827
Congestive heart failure	.881	.878	.883	.883	.872
Abdominal hernia	.971	.960	.947	.935	.921
Surgeon follow-up and support group attendance	.597	.600	.599	.603	.620
Any adverse event		.683	.683		
Predicted versus observed outcomes from validation group preoperative data entered into prognostic models built on the modeling group					
Observation	2 mo	6 mo	12 mo	18 mo	24 mo
Number of Patients	41,528	25,768	14,527	5,255	3,703
Continuous dependent variables (Pearson correlation coefficient)					
Weight/weight loss	.959	.932	.875	.837	.811
Dichotomous dependent variables					
Cholelithiasis					
Sensitivity	97.13	94.7	91.78	90.94	86.93
Specificity	98.83	98.34	97.62	97.42	97.21
Diabetes					
Sensitivity	98.39	74.87	72.14	69.14	60.28
Specificity	88.59	91.85	91.59	91.36	93.97
GERD					
Sensitivity	95.12	74.81	49.82	47.32	44.77
Specificity	81.05	80.27	87.07	87.25	86.65
Hypertension					
Sensitivity	92.44	92.61	77.91	79.15	79.56
Specificity	85.21	74.58	80.92	80.02	79.3
Liver disease					
Sensitivity	88.55	85.22	84.79	79.39	77.58
Specificity	99.2	98.86	98.41	98.47	98.05
Obstructive sleep apnea					
Sensitivity	73.99	87.57	64.06	59.05	50.76
Specificity	93.68	87.64	88.01	89.94	90.95
Abdominal hernia					
Sensitivity	93.31	90.03	85.99	79.2	75.27
Specificity	99.56	99.45	99.16	99.27	99.1
Congestive heart failure					
Sensitivity	40.35	40.62	37.61	42.47	25
Specificity	99.84	99.79	99.71	99.68	99.4
Postoperative surgeon follow-up and/or support group attendance					
Sensitivity	.38	.05	.19	0	.23
Specificity	99.87	99.98	99.94	99.89	99.9
Any adverse event					
Sensitivity		.52	.51		
Specificity		99.92	99.92		

ROC/AUC = receiver operating characteristic/area under the curve; GERD = gastroesophageal reflux disease.

patients was predicted accurately up to 24 months in advance. Diabetes sensitivity ranged from 98% to 60%, with specificity consistently >91%. Previous studies associated diabetes control with postoperative weight loss [28] and various clinical parameters, but did not predict individual outcomes [29]. The prognostic models reported here enable patients with T2D to know what their relative risk of diabetes persistence/resolution will be after bariatric surgery up to 24 months in advance, comparing future results from 5 weight loss operations.

Arterial hypertension frequently resolves after bariatric surgery [30,31]. However, before the present investigation, remission or persistence of hypertension after any weight loss procedure was not predicted but instead only associated statistically with baseline parameters and postoperative weight loss [30,31]. In the current report, prospectively validated models predicted the risk of hypertension for individual patients up to 24 months in advance, comparing outcomes for RYGB, LRYGB, SG, LAGB, and BPD/DS. Sensitivity/specificity were 92.44%/85.21% at 2 months and 79.56%/79.3% at 24 months. These models will enable individual hypertensive patients to choose objectively which procedure will control their high blood pressure most effectively.

OSA affects more than 40% of bariatric patients [27] and often resolves after weight loss surgery [32]. However, postoperative outcomes predictions do not apply to individuals. Models that predicted OSA in the present paper performed well, with all ROC/ACU values at .827 and higher and sensitivity/specificity ranging from 73.99%/93.6% at 2 months to 50.76%/90.95% at 24 months. Our review of the literature indicates that such validated advance knowledge of OSA persistence/resolution in individual bariatric surgery patients has not been reported previously and is an important finding of this study.

Nonalcoholic fatty liver disease and nonalcoholic steatohepatitis involve 7%–16% of bariatric surgery patients [26,27]. Although liver disease may resolve with weight loss, results vary among RYGB, LRYGB, LAGB, SG, and BPD/DS [31], adding decisional uncertainty for patients regarding which operation to undergo. For these patients, the liver disease models presented here add objectivity to the choice of bariatric procedure, with median sensitivity/specificity at 84.79%/98.41%. Thus, although the diagnosis of liver disease in BOLD was clinical only because liver biopsies were not required for all patients, the prognostic models here provide individual patients with weight-related liver dysfunction clinically significant guidance regarding its resolution by operation type.

At surgery, 9%–31% of bariatric patients have gallstones [26,27], and the incidence increases with postoperative weight loss [33]. However, preoperative factors that predict the incidence of cholelithiasis after weight loss operations are not established. In this investigation, preoperative cholelithiasis models were validated at sensitivity/specificity >86.93%/97.21% through 24 months, providing a reliable means of identifying the patients most at risk for gallstone formation. This advance knowledge could facilitate the decision regarding whether to perform incidental cholecystectomy at the time of primary bariatric surgery or, for high-risk patients without gallstones at operation, provide medical prophylaxis.

GERD is diagnosed preoperatively in 35%–52% of patients who undergo bariatric surgery [26,27]. Resolution of GERD is excellent with RYGB/LRYGB and DS and variable with LAGB, but GERD may increase after SG [34]. Our review of the literature suggests that the present investigation is the first to predict the relative risk of GERD in individual patients after weight loss procedures. Although sensitivity drifted below 50% at 12 months, specificity actually increased in the 12- to 24-month models. Considering the interprocedure variation among bariatric surgeries regarding postoperative GERD, the advance knowledge presented in this study may enable patients to compare the GERD effects of each technique in their individual cases.

At least 8% of bariatric surgery patients have preexisting inguinal and ventral abdominal wall hernias. How and when to repair these defects continues to be debated. However, the incidence of abdominal hernia can increase after bariatric surgery to 50% and higher [33]. The prognostic models reported here provide patients and surgeons reliable preoperative predictions of abdominal hernia development in individuals, comparing the 5 most common weight loss procedures. With ROC/AUCs all at .921 and higher and sensitivity/specificity consistently at clinically useful levels, these findings can facilitate objective preoperative bariatric surgery planning regarding relative risk of abdominal hernia.

CHF affects up to 9% of bariatric surgery patients preoperatively [26]. Although weight loss logically should ameliorate CHF severity, the rate of CHF after bariatric surgery can increase to >22% [33]. The ability to identify before surgery the individuals most at risk for CHF months and years after weight loss operations certainly could assist in preoperative planning and perisurgical management. In the present work, the CHF ROC/AUC model fit was excellent. However, although specificity was >99%, low event rates kept sensitivities in the 40% range and below. Nevertheless, these results are the first reported predictions of CHF in bariatric surgery.

Close long-term follow-up with bariatric surgeons and staff and regular support group attendance help to optimize surgical outcomes. In the present investigation, preoperative modeling ROC/AUCs were .620 and under and specificity was >99%, but sensitivity was <1%. In this modeling, then, one knows before surgery who will not follow-up, but not which patients will be compliant. Perhaps this at least identifies preoperatively patients who need the most encouragement for follow-up compliance.

Modeling for adverse events yielded ROC/AUC of .683, high specificity, and sensitivity <1%, clearly identifying problem-free patients but not those at highest risk of complications. Fortunately, complications after bariatric surgery have been addressed by previous authors. Sarela et al. developed the Obesity Surgery Mortality Risk Score, which predicts operative mortality [14]. Maciejewski and Arterburn stratified mortality risk for gastric bypass [8]. Ramanan et al. [15] developed a validated bariatric surgery mortality risk calculator, and Gupta et al. [16] generated a

Table 3
Example output of prognostic models predicting outcomes for 50-year-old female, 5 ft 4 in tall, 320 lb, with depression, diabetes, GERD, hypertension, and stress urinary incontinence

	2 mo	6 mo	12 mo	18 mo	24 mo
Weight					
LAGB	292	277	263	254	251
BPD/DS	275	230	194	183	182
LRYGB	277	234	208	200	200
RYGB	277	235	208	199	198
SG	280	245	222	217	211
Relative risk of having morbid obesity co-morbidities (%)					
Abdominal hernia					
LAGB	0	1	1	1	1
BPD/DS	0	2	9	16	13
LRYGB	0	1	1	1	1
RYGB	0	1	2	3	4
SG					
Congestive heart failure					
LAGB	0	1	1	1	0
BPD/DS	1	1	1	1	1
LRYGB	1	1	1	1	1
RYGB	0	1	0	1	0
SG	1	1	1	1	0
Cholelithiasis					
LAGB	1	1	2	2	2
BPD/DS	14	20	26	31	29
LRYGB	1	1	2	2	3
RYGB	1	1	1	2	2
SG	1	2	3	4	5
GERD					
LAGB	38	30	25	25	24
BPD/DS	47	41	26	31	32
LRYGB	36	23	17	18	16
RYGB	36	28	22	24	25
SG	41	32	34	25	25
Diabetes					
LAGB	23	20	17	15	14
BPD/DS	21	14	7	7	4
LRYGB	24	15	10	8	7
RYGB	24	17	13	11	10
SG	23	16	11	10	8
Hypertension					
LAGB	58	52	43	37	38
BPD/DS	39	25	14	14	13
LRYGB	42	27	19	16	16
RYGB	48	32	28	29	25
SG	46	33	24	23	21
Liver disease					
LAGB	1	1	1	1	1
BPD/DS	4	5	3	2	3
LRYGB	1	1	1	1	0
RYGB	3	2	2	1	2
SG	1	1	1	1	1
Obstructive sleep apnea					
LAGB	47	45	40	38	35
BPD/DS	55	45	34	33	31
LRYGB	48	38	28	26	23
RYGB	51	42	32	28	25
SG	49	42	32	30	26
Surgeon follow-up/support group attendance					
LAGB	12	13	11	11	9
BPD/DS	20	22	19	21	18
LRYGB	16	18	16	16	14

Table 3
Continued.

	2 mo	6 mo	12 mo	18 mo	24 mo
RYGB	16	17	15	14	15
SG	15	17	14	15	12

GERD = gastroesophageal reflux disease; LAGB = laparoscopic adjustable gastric band; BPD/DS = biliopancreatic diversion/duodenal switch; LRYGB = laparoscopic Roux-en-Y gastric bypass; RYGB = open Roux-en-Y gastric bypass; SG = sleeve gastrectomy

morbidity risk calculator, both of which are available online: http://www.surgicalriskcalculator.com/bariatric-surgery-risk-calculator. These clinical aides complement the prognostic models described in the present study.

A practical hypothetical demonstration of the outcomes models described here as applied to individual patients may be illustrative. In this clinical example, consider a 50-year-old Caucasian female who is 5 feet, 4 inches tall; weighs 320 lb; is employed full-time; drinks socially; takes ibuprofen for back and musculoskeletal pain; has stress urinary incontinence occasionally; has OSA; and takes antidepressants, proton pump inhibitors for GERD, one medication for hypertension, and oral agents for T2D. She does not have angina, asthma, CHF, cholelithiasis, liver disease, obesity hypoventilation syndrome, psychological impairment, pulmonary hypertension, abdominal hernia, or other mental health diagnoses. This baseline information was entered into the prognostic models, and the program provided outcomes predictions of weight and relative risk of abdominal hernia, CHF, cholelithiasis, GERD, diabetes, hypertension, liver disease, and surgeon follow-up/support group attendance. Predicted outcomes for this patient are listed in Table 3.

To be clear, the prognostic models in this report use preoperative clinical data, without laboratory or radiology results, to predict outcomes for individual morbidly obese patients within the validation predicted versus observed statistical analyses presented that would result if individuals were to choose RYGB, LRYGB, LAGB, SG, or BPD/DS. Prediction of the relative probability of a patient choosing one bariatric surgery approach over another was not attempted because no database, including BOLD, can support statistical modeling for the ultimately subjective choices individuals make for their healthcare. Similarly, statistically comparing the outcomes after one operation versus another was not part of this study. Variation in results among these procedures has been well described in the literature [5–9]. The concept underlying the present investigation was that preoperative clinical characteristics of morbidly obese patients could be linked statistically to known bariatric surgery outcomes in the modeling cohort and that the accuracy of those models could be validated in a separate, similar population. The goal thus achieved was to give morbidly obese individuals and their healthcare providers additional advance knowledge of the potential outcomes if they were to choose one of the operations analyzed.

This study has several limitations. First, the definitions of obesity co-morbidities in BOLD were entirely clinical. For example, that liver biopsies were not performed universally may have made the BOLD data incomplete academically. Second, BOLD contains no preoperative laboratory or radiology information, all of which might have facilitated even more accurate predictive models. However, as a serendipitous benefit, the data on which the models here were based comprise common clinical information that enables every patient to benefit from the bariatric surgery prognostications presented. Third, the decrease in patient follow-up visits over time may have contributed to sub-optimal modeling/validation for some conditions. Finally, the possible inconsistencies of a retrospective analysis on a prospectively collected database apply, which was the rationale for randomizing the entire BOLD population into modeling and validation databases at the beginning of this study.

Conclusions

Statistical models in this investigation provide individual morbidly obese patients clinically usable predictions of what their weight and relative risk of the presence/absence of diabetes, hypertension, OSA, liver disease, cholelithiasis, GERD, and abdominal hernia would be up to 24 months in advance, comparing results from RYGB, LRYGB, LAGB, SG, and BPD/DS. Such advance knowledge may help facilitate optimized bariatric surgery outcomes. The clinical predictions described here are intended to supplement the knowledge and judgment of bariatric surgeons in recommending the best operation for each patient. Certainly, medical and anatomic conditions can render the predicted best procedure from these models suboptimal for individual patients. In addition, it may be that, in spite of this objective advance knowledge and the surgeon's counseling, some patients still will choose bariatric procedures that are not optimal for them. For example, although Schauer et al. reported superiority of LRYGB over SG in controlling T2D [35], in the current wave of public popularity for SG, the latter may be chosen in spite of the published data. Also, some patients who could benefit from bariatric surgery still might not choose operative treatment for their obesity even with the individualized preoperative outcomes predictions afforded by this research because, ultimately, it remains a personal, individual decision. Nevertheless, in the net effect, one hopes that the new predictive methodology presented here will become accessible to patients and physicians so that it might facilitate optimized patient care and possibly encourage more morbidly obese patients to embrace the benefits of weight loss surgery. The next step in this research, then, is to identify and engage formats that will enable use of the predictive models described in this report, so as to put into practice the clinical benefits for which they were developed.

Disclosures

Supported, in part, by a research grant from the Lourdes Foundation, Camden, NJ. The author has no commercial associations that might be a conflict of interest in relation to this article.

References

[1] Hedley AA, Ogden CL, Johnson CL, Carroll MD, Curtin LR, Flegal KM. Prevalence of overweight and obesity among US children, adolescents and adults, 1999–2002. JAMA 2004;291(23):2847–50.
[2] Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999–2010. JAMA 2012;307(5):491–7.
[3] Arterburn DE, Maciejewski ML, Tsevat J. Impact of morbid obesity on medical expenditures in adults. Int J Obes (Lond) 2005;29 (3):334–9.
[4] United States Census Bureau. U.S. and World Population Clock [homepage on the Internet]. Washington, D.C.: U.S. Department of Commerce. Available from: http://www.census.gov/popclock. Accessed July 4, 2016.
[5] Gastrointestinal surgery for severe obesity: National Institutes of Health Consensus Development Conference Statement. Am J Clin Nutr 1992;55(2 Suppl.):615S–9S.
[6] Ponce J, Nguyen N, Hutter M, Sudan R, Morton JM. American Society for Metabolic and Bariatric Surgery estimation of bariatric procedures in the United States, 2011-2014. Surg Obes Relat Dis 2015;11(6):1199–200.
[7] Buchwald H, Avidor Y, Braunwald E, et al. Bariatric surgery: a systematic review and meta-analysis. JAMA 2004;292(14):1724–37.
[8] Maciejewski ML, Arterburn D. Cost-effectiveness of bariatric surgery. JAMA 2013;310(7):742–3.
[9] Jakobsen GS, Hofsø D, Røislien J, Sandbu R, Hjelmesaeth J. Morbidly obese patients—who undergoes bariatric surgery? Obes Surg 2010;20(8):1142–8.
[10] Lee JS, Sheer JL, Lopez N, Rosenbaum S. Coverage of obesity treatment: a state-by-state analysis of Medicaid and state insurance laws. Public Health Rep 2010;125(4):596–604.
[11] Maciejewski ML, Winegar DA, Farley JF, Wolfe BM, DeMaria EJ. Risk stratification of serious adverse events after gastric bypass in the Bariatric Outcomes Longitudinal Database. Surg Obes Relat Dis 2012;8(6):671–7.
[12] 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.
[13] Fung M, Wharton S, Macpherson A, Kuk JL. Receptivity to bariatric surgery in qualified patients. J Obes 2016;2016:5372190.
[14] Sarela AI, Dexter SP, McMahon MJ. Use of the obesity surgery mortality risk score to predict complications of laparoscopic bariatric surgery. Obes Surg 2011;21(11):1698–703.
[15] Ramanan B, Gupta PK, Gupta H, Fang X, Forse RA. Development and validation of a bariatric surgery mortality risk calculator. J Am Coll Surg 2012;214(6):892–900.
[16] Gupta PK, Franck C, Miller WJ. Development and validation of a bariatric surgery morbidity risk calculator using the prospective, multicenter NSQIP dataset. J Am Coll Surg 2011;212(3):301–9.
[17] Campos GM, Rabl C, Mulligan K, et al. Factors associated with weight loss after gastric bypass. Arch Surg 2008;143(9):877–83.
[18] Slotman GJ. Prospectively validated prediction of physiologic variables and organ failure in septic patients: The Systemic Mediator

Associated Response Test (SMART). Crit Care Med 2002;30(5):1035–45.
[19] Slotman GJ. The systemic mediator-associated response test identifies patients in failed sepsis clinical trials among whom novel drugs reduce mortality. J Trauma 2011;71(5):1406–14.
[20] DeMaria EJ, Pate V, Warthen M, Winegar DA. Baseline data from American Society for Metabolic and Bariatric Surgery-designated Bariatric Surgery Centers of Excellence using the Bariatric Outcomes Longitudinal Database. Surg Obes Relat Dis 2010;6(4):347–55.
[21] SAS Institute Inc. SAS/STAT® 9.22 User's Guide. Cary, NC: The SAS Institute; 2009.
[22] Sczepaniak JP, Owens ML, Garner W, Dako F, Masukawa K, Wilson SE. A simpler method for predicting weight loss in the first year after Roux-en-Y gastric bypass. J Obes 2012;2012:195251.
[23] Wood GC, Benotti P, Gerhard GS, et al. A patient-centered electronic tool for weight loss outcomes after Roux-en-Y gastric bypass. J Obes 2014;2014:364941.
[24] Wise ES, Hocking KM, Kavic SM. Prediction of excess weight loss after laparoscopic Roux-en-gastric bypass: data from an artificial neural network. Surg Endosc 2016;30(2):480–8.
[25] 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.
[26] Raisdana B, Slotman G. Cardiopulmonary, metabolic, and hepatobiliary dysfunction varies by insurance status in the mega-obese. Crit Care Med 2013;41(12):A132–3.
[27] Adams M, Slotman G. The effect of race on the distribution of demographics, body mass, and medical comorbidities in morbid obesity – an analysis of 83,059 patients from the BOLD database. Am J Gastroenterol 2013;108(Suppl 1):S479.
[28] Coupaye M, Sabaté JM, Castel B, et al. Predictive factors of weight loss 1 year after laparoscopic gastric bypass in obese patients. Obes Surg 2010;20(12):1671–7.
[29] Park JY, Kim YJ. Prediction of diabetes remission in morbidly obese patients after Roux-en-Y gastric bypass. Obes Surg 2016;26(4):749–56.
[30] Våge V, Nilsen RM, Berstad A, et al. Predictors for remission of major components of the metabolic syndrome after biliopancreatic diversion with duodenal switch (BPDDS). Obes Surg 2013;23(1):80–6.
[31] Hatoum IJ, Blackstone R, Hunter TD, et al. Clinical factors associated with remission of obesity-related comorbidities after bariatric surgery. JAMA Surg 2016;151(2):130–7.
[32] Ashrafian H, le Roux CW, Rowland SP, et al. Metabolic surgery and obstructive sleep apnoea: the protective effects of bariatric procedures. Thorax 2012;67(5):442–9.
[33] Gomez JP, Davis MA, Slotman GJ. In the superobese, weight loss and resolution of obesity comorbidities after biliopancreatic bypass and/or duodenal switch vary according to health insurance carrier: Medicaid vs Medicare vs private insurance vs self-pay in 1681 Bariatric Outcomes Longitudinal Database patients. Am J Surg 2016;211(3):519–24.
[34] El-Hadi M, Birch DW, Gill RS, Karmali S. The effect of bariatric surgery on gastroesophageal reflux disease. Can J Surg 2014;57(2):139–44.
[35] 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):2002–13.

Editorial comment

Prospectively validated preoperative prediction of weight and co-morbidity resolution in individual patients comparing five bariatric operations

Obesity is evolving into an epidemic in the United States, and it is estimated that it will affect more than half of the world population by 2030 [1]. Therefore, obesity-related co-morbidities, including diabetes, hypertension, liver disease, among others, has become a significant area of interest. Obesity is considered a modifiable risk factor for cardiovascular, respiratory, and other diseases. Consequently, new alternatives have been sought to control this disease. Bariatric surgery is a safe and effective procedure that offers improved outcomes and proven weight loss. However, the bariatric procedure that provides better outcomes and co-morbidities resolution is still debatable in the literature, especially when related to long-term clinical and surgical outcomes.

Studies have shown that 65% of patients who undergo Roux-en-Y gastric bypass (RYGB) achieve at least 50% of excess weight loss in the long term, whereas 78% of patients receiving sleeve gastrectomy (SG) sustained the same goal [2]. Moreover, patients with a body mass index lower than 40 kg/m^2 and younger patients are more likely to lose weight after bariatric procedures [3]. A Veterans Affairs Surgical Quality Improvement Program analysis found that female and Caucasian patients are more likely to lose 30% or more of their baseline weight [4]. An International Federation for the Surgery of Obesity and Metabolic Disorders–European Chapter analysis revealed that more than half of the patients have hypertension resolution after RYGB or SG [5]. Moreover, at 1 year postoperatively, 64% of the patients who underwent RYGB had improvement in their diabetes versus 54% in the SG groups. The rates for obstructive sleep apnea resolution at 1 year were 68% and 60%, for RYGB and SG, respectively [5]. A randomized controlled trial found that the mean GerdQ score 12 months after bariatric surgery was higher (6.63 ± 2.26) for SG patients, compared with RYGB (5.60 ± 1.07) [6]. A meta-analysis showed that there is no significant difference in long-term co-morbidity resolution between SG and RYGB, although the authors found