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Original article

Predictors of pulmonary complications after bariatric surgery

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Abstract

Background: Postoperative pneumonia (PP) and respiratory failure (PRF) are known to be the most common nonwound complications after bariatric surgery. Our objective was to identify their current prevalence after bariatric surgery and to study the preoperative factors associated with them using data from the American College of Surgeons' National Surgical Quality Improvement Program.

Methods: Patients undergoing bariatric surgery were identified from the National Surgical Quality Improvement Program (2006–2008), a multicenter, prospective database. Univariate analysis and multivariate logistic regression analysis were performed.

Results: Of 32,889 patients, PP was diagnosed in 187 patients (.6%) and PRF in 204 patients (.6%). The overall 30-day morbidity rate was 6.4%, with PP and PRF accounting for 18.7%. The 30-day mortality rate was greater for the patients with PP and PRF than those without (4.3% versus .16% and 13.7% versus .10%, $P < .0001$). The hospital length of stay was also longer in patients with PP/PRF ($P < .0001$). On multivariate analysis, congestive heart failure (odds ratio 5.3, 95% confidence interval 1.20–23.26) and stroke (odds ratio 4.1, 95% confidence interval 1.42–11.49) were the greatest preoperative risk factors for PP. Previous percutaneous coronary intervention (odds ratio 2.8, 95% confidence interval 1.64–4.74) and dyspnea at rest (odds ratio 2.64, 95% confidence interval 1.13–6.13) were the factors most strongly associated with PRF. Bleeding disorder, age, chronic obstructive pulmonary disease, and type of surgery were risk factors for both ($P < .05$). Smoking also predisposed to PP, and diabetes mellitus, anesthesia time, and increasing weight also predisposed to PRF ($P < .05$ for all).

Conclusion: Although PP and PRF are infrequent, they account for one fifth of the postoperative morbidity and are associated with significantly increased 30-day mortality. They can be predicted by various risk factors, emphasizing the importance of patient optimization and careful selection before bariatric surgery. (Surg Obes Relat Dis 2012;8:574–581.)

Keywords: Bariatric surgery; Postoperative; Respiratory failure; Pneumonia; Reintubation; Wean from ventilator

American College of Surgeons National Surgical Quality Improvement Program (NSQIP) Disclaimer: the ACS NSQIP and hospitals participating in the ACS NSQIP were the source of the presented data; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by us; nor does this study represent the views or plans of the ACS or ACS NSQIP.

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The benefits of any surgical procedure are heavily influenced by the accompanying morbidity and mortality. The development of complications after surgery not only worsen the outcomes, but also prolong the hospital stay and are associated with a significantly increased cost in hospital care [1–3]. It has been estimated that nearly one fourth of deaths occurring within 6 days of all surgeries are related to postoperative pulmonary complications [4].

Postoperative respiratory failure (PRF) is commonly understood as failure to wean from the ventilator within 48 hours of surgery or unplanned intubation/reintubation, intraoperatively or postoperatively. PRF and postoperative pneumonia (PP) are among the most serious postoperative complications and have been shown to be associated with a marked increase in the postoperative length of stay, morbidity, and mortality in other surgical disciplines [5–7].

The number of bariatric surgeries being performed is increasing every year, with a 22-fold increase from 1996 to 2008 [8]. In 2008, 344,221 bariatric surgery operations were performed by 4680 bariatric surgeons; 220,000 of these operations were performed in United States or Canada by 1625 surgeons. The postoperative morbidity rate after bariatric surgery is about 5%, one fourth of which result from pulmonary complications [9–12]. PRF and PP are the most common postoperative nonwound complications in bariatric surgery [13,14]. Despite the prevalence of these 2 complications and their contribution to the overall postoperative morbidity after bariatric surgery, to our knowledge, no study has previously been undertaken to assess the preoperative factors associated with the development of these 2 complications.

We used the National Surgical Quality Improvement Program (NSQIP) database to study the association of PP and PRF with the postoperative length of stay, morbidity, mortality, and other outcome parameters. We analyzed the database to assess the preoperative risk factors for PP and PRF. The knowledge of these risk factors could serve as a guide in patient selection and optimization of the preoperative medical condition of patients undergoing bariatric surgery, which could lead to additional improvement in the outcomes after bariatric surgery.

Methods

Database

Data were obtained from the 2006, 2007, and 2008 American College of Surgeons (ACS) NSQIP Participant Use Data Files [15]. These are multicenter, prospective databases with 121 (in 2006), 183 (in 2007), and 211 (in 2008) participant academic and community US hospitals. NSQIP collects data on 136 perioperative variables for patients undergoing major surgical procedures in both the inpatient and the outpatient setting. A participating hospital's surgical clinical nurse reviewer captures these data using a variety of methods, including medical chart abstraction. The data are collected using strict criteria formulated by a definition committee. To ensure the data collected are of the greatest quality, the ACS NSQIP has developed a host of different training mechanisms for the surgical clinical nurse reviewers and conducts an inter-rater reliability audit of the participating sites [15]. The process of surgical clinical nurse reviewer training and inter-rater reliability auditing has been previously described in detail [15]. The combined results of the audits completed to date revealed an overall disagreement rate of approximately 1.99% for all assessed program variables. The Participant Use Data File is a Health Insurance Portability and Accountability Act–compliant data file containing patient level, aggregate data and does not identify hospitals, healthcare providers, or patients. The sampling method of the NSQIP Participant Use Data Files has been previously described in detail [15–18].

Patients

Patients undergoing procedures with American Medical Association's Current Procedural Terminology codes 43,644, 43,645, 43,770, 43,842, 43,843, 43,845, 43,846, and 43,847 for morbid obesity were included. Sleeve gastrectomy did not have a Current Procedural Terminology code at the time the data were collected; thus, these patients were not included in the NSQIP data set. The preoperative variables analyzed included patient demographic variables of age, gender, and race. The lifestyle variables included smoking (within 1 yr of operation) and alcohol intake (>2 drinks daily within the past 2 wk). The co-morbidities included dialysis dependence, coronary artery disease (including angina within 30 d of surgery, myocardial infarction within 6 mo of surgery, percutaneous coronary intervention [PCI], and cardiac surgery), congestive heart failure (CHF), hypertension, peripheral vascular disease (including revascularization/amputation for peripheral vascular disease and pain at rest), history of chronic obstructive pulmonary disease (COPD), neurologic event or disease (including stroke with or without residual deficit and transient ischemic attack), diabetes mellitus, chronic corticosteroid use, weight loss (>10% in past 6 mo), bleeding disorders, and open wound. Other factors considered were the American Society of Anesthesiologists class, preoperative functional status (independent, partially dependent, totally dependent), dyspnea (none, moderate exertion, at rest), body mass index (BMI), previous surgery within 30 days, type of bariatric surgery, anesthesia time, operative time, intraoperative red blood cell transfusion, and wound classification. The preoperative laboratory variables examined included blood urea nitrogen, creatinine, albumin, bilirubin, serum glutamic oxaloacetic transaminase, hematocrit, platelet count, white blood cell count, partial thromboplastin time, and prothrombin time. The values were categorized using ACS NSQIP

definitions of normal and abnormal; missing data constituted a third categorical variable [19]. Except for the laboratory variables, for which clinical issues have substantial effect on the ordering of tests, missing values were virtually nonexistent for the ACS NSQIP variables.

Outcome

The outcomes were assessed ≤30 days after surgery. The outcomes of interest were PP and PRF. The patient was given the diagnosis of PP provided 1 of the following 2 criteria was met. The first criterion was rales or dullness to percussion on physical examination of chest and any of the following: new onset of purulent sputum or change in character of sputum, organism isolated from blood culture, or isolation of a pathogen from a specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy. The second criterion was chest radiograph showing new or progressive infiltrate, consolidation, cavitation, or pleural effusion and any of the following: new onset of purulent sputum or change in the character of the sputum; organism isolated from blood culture; isolation of a pathogen from a specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy; isolation of a virus or the detection of a viral antigen in respiratory secretions; diagnostic single antibody titer (IgM) or fourfold increase in paired serum samples (IgG) for pathogen; or histopathologic evidence of pneumonia. The patient must not have had preoperative pneumonia.

PRF was said to have occurred if a patient had been reintubated postoperatively once extubated or had a total duration of ventilator-assisted respiration during postoperative hospitalization for >48 hours. If the patient returned to the operating room for any reason and was intubated as a part of the anesthesia/surgery, it was not counted as reintubation. If a patient self-extubated and had to be reintubated that also was not counted as reintubation.

Statistical analysis

Statistical analyses were performed using SAS, version 9.1.3 (SAS Institute, Cary, NC). Univariate exploratory analysis was performed using the Pearson chi-square test or Fisher's exact test for categorical variables and the *t* or *F* test for continuous variables. Multivariate logistic regression modeling was performed to assess the factors associated with PP and PRF. The model selections were determined using a stepwise procedure, which alternates between removing the least significant variable from the model and then reconsidering all potential variables for reintroduction into the model until no more variables can be added. A variable that is individually predictive might not be selected by the stepwise procedure when adding the variable does not significantly improve the predictive power of the existing model. All preoperative variables were entered into both models.

We did not study the effect of other postoperative complications on PP and PRF, because some of the complications could have actually occurred after PP and PRF and thus might not be a risk factor for them. It would have been difficult to determine this. Thus, we restricted our analyses to the preoperative risk factors.

Model quality was evaluated using Hosmer-Lemeshow goodness-of-fit tests for calibration (correspondence in predictions and observations across the range of predictions) and the c-statistic for discrimination [20]. The c-statistic is considered the most relevant measure of model success and refers to the ability of the risk estimate to discriminate cases (e.g., death) from noncases (survival) [21]. Conceptually, it is the proportion of pairings among all possible pairings of cases and noncases, for which the predicted risk was estimated to be greater for the case than for the noncase. If discrimination is perfect, the predicted risk will be greater for the case than for the noncase for all pairs and the c-statistic will equal 1.0. If discrimination is no better than chance, the c-statistic will equal .50.

Results

Demographics and co-morbidities

Of the 32,889 patients who underwent bariatric surgery, 20.4% were men, with a median age of 45.0 years (interquartile range [IQR] 36–54). The overall median BMI was 47.0 kg/m^2 (IQR 42.6–52.8). The patient characteristics, comparing patients with and without PP and PRF, are listed in Table 1.

Outcomes

PP was diagnosed in 187 patients (.6%) and PRF in 204 (.6%). The patients with PP and PRF were older, had a greater BMI, and worse American Society of Anesthesiologists class (Table 1). Patients with PP and PRF had more complications than those without PP and PRF (Table 2). Also, the operative time was longer. The median hospital length of stay for patients with PP was 6 days (IQR 3–16) and was 2 days (IQR 1–3) for those not developing PP. The median hospital length of stay for patients with PRF was 9 days (IQR 4–26) and 2 days (IQR 1–3) for those not developing PRF. The overall 30-day morbidity rate for patients undergoing bariatric surgery was 6.4%, with PP and PRF accounting for 18.7%. Death within 30 days was seen in 4.3% of patients with PP compared with .16% of patients without PP. It was 13.7% for patients with PRF and .10% for patients without PRF ($P < .0001$ for all).

Multivariate analysis for PP

The preoperative risk factors associated with a greater incidence of PP included new CHF or exacerbation of chronic CHF within 30 days of surgery, stroke with neuro-

Table 1
Univariate analysis of preoperative variables

Preoperative demographic and co- morbidity variables	PP			PRF		
	Yes (n = 187)	No (n = 32,702)	*P* value	Yes (n = 204)	No (n = 32,685)	*P* value
Median age (yr)	49	45	.0005	50.5	45.0	<.0001
Median anesthesia time (min)	208.0	160.0	<.0001	227.0	160.0	<.0001
Angina within 1 mo	.0	.16	.74	.0	.16	.73
Bleeding disorder	5.35	2.10	.002	7.84	2.08	<.0001
Median BMI (kg/m2)	50.10	46.97	<.0001	52.48	46.95	<.0001
CHF within 1 mo	1.07	.10	.02	.98	.10	.02
COPD with FEV_1 <75% or causing functional disability or hospitalization	9.09	1.78	<.0001	8.33	1.78	<.0001
Diabetes						
Insulin dependent	21.39	16.34	<.0001	28.43	16.29	<.0001
Oral medications	19.25	10.93		21.08	10.92	
Dialysis	.53	.10	.16	.98	.10	.02
Dyspnea						
At rest	1.07	.65	.002	3.43	.64	<.0001
With moderate exertion	40.64	29.31		45.59	29.27	
Alcohol >2 drinks/d within 2 wk of surgery	.53	.28	.31	.49	.28	.32
Functional status						
Independent	98.40	99.27	.32	94.12	99.30	<.0001
Partially dependent	1.60	.70		5.88	.67	
Totally dependent	.0	.03		.0	.03	
Hypertension	66.31	53.20	.0003	73.04	53.16	<.0001
Male gender	26.74	20.31	.03	35.78	20.25	<.0001
Myocardial infarction within 6 mo	.0	.03	.95	.49	.02	.05
Median operative time (min)	140.0	108.0	<.0001	154.5	108	<.0001
Previous PCI	5.35	2.24	.004	9.31	2.21	<.0001
Previous cardiac surgery	3.21	1.31	.02	3.43	1.31	.008
Previous operation within 30 d	.0	.21	.67	.98	.20	.06
Race						
Black	17.11	12.31	.24	13.24	12.33	.69
Hispanic	4.81	5.54		7.35	5.53	
White	68.45	74.01		72.06	73.99	
Smoker within previous year	18.18	12.56	.02	17.16	12.56	.048
Stroke with neurologic deficit						
Yes	2.14	.42	.007	.98	.43	.16
No	1.07	.42	.14	.98	.42	.16
TIA history	1.07	.65	.22	.49	.65	.35
Surgery type						
LRYGB	55.08	56.71	<.0001	50.49	56.74	<.0001
LAGB	6.95	29.30		4.41	29.33	
ORYGB	31.55	10.12		35.78	10.08	
VBG	1.07	.81		.49	.81	
Other GP	2.14	2.17		2.94	2.17	
BPD-DS	3.21	.89		5.88	.87	
Median weight (lb)	292.0	278.0	<.0001	307.0	278.0	<.0001
>10% weight loss within 6 mo	.53	.05	.09	.0	.05	.90
Creatinine (abnormal)	3.74	1.87	.04	5.88	1.85	.0001
Albumin (abnormal)	6.42	4.16	.21	8.82	4.14	.002
Hematocrit (abnormal)	12.30	9.18	.31	10.29	9.19	.86

PP = postoperative pneumonia; PRF = postoperative respiratory failure; BMI = body mass index; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; PCI = percutaneous coronary intervention; PVD = peripheral vascular disease; TIA = transient ischemic attack; BPD-DS = biliopancreatic diversion with duodenal switch; LRYGB = laparoscopic Roux-en-Y gastric bypass; ORYGB = open Roux-en-Y gastric bypass; LAGB = laparoscopic adjustable gastric banding; GP = other gastroplasty; VBG = vertical banded gastroplasty.

P value reflects univariate analysis: Pearson chi-square test or Fisher's exact test was used for categorical variables and *t* or *F* test for continuous variables, comparing the presence and absence of PP and PRF.

Binomial variables expressed as percentages.

One *P* value provided for American Society of Anesthesiologists class, diabetes, dyspnea, functional status, type of surgery, and wound class, because they are multilevel variables.

Table 2
Univariate analysis of postoperative variables

Postoperative variable	PP			PRF		
	Yes (n = 187)	No (n = 32,702)	*P* value	Yes (n = 204)	No (n = 32,685)	*P* value
Transfusion >4 U within 72 h	5.88	.23	<.0001	9.31	.21	<.0001
Cardiac arrest	4.81	.11	<.0001	14.71	.04	<.0001
Myocardial infarction	1.60	.01	<.0001	2.45	.0	<.0001
Deep venous thrombosis	1.07	.27	.08	2.45	.26	<.0001
Pulmonary embolism	2.67	.18	<.0001	1.47	.19	.007
Pneumonia	100.0	.0	<.0001	32.84	.37	<.0001
Reintubation/unplanned intubation	21.39	.32	<.0001	71.08	.00	<.0001
Ventilator >48 h	32.09	.20	<.0001	60.78	.00	<.0001
Renal insufficiency with increase in creatinine by 2 (no dialysis)	5.88	.18	<.0001	11.76	.14	<.0001
Renal failure requiring dialysis	4.81	.12	<.0001	15.20	.05	<.0001
Superficial site infection	6.95	1.76	<.0001	4.41	1.78	.005
Deep incisional infection	4.28	.32	<.0001	2.45	.33	<.0001
Organ/space infection	20.32	.53	<.0001	25.0	.49	<.0001
Urinary infection	6.42	.72	<.0001	5.39	.73	<.0001
Septic shock	26.20	.24	<.0001	43.14	.12	<.0001
Sepsis	18.18	.62	<.0001	17.16	.62	<.0001
Wound and fascia disruption	5.88	.21	<.0001	7.84	.19	<.0001
Coma	1.07	.02	<.0001	2.45	.01	<.0001
Stroke	.53	.02	.04	1.47	.01	<.0001
Peripheral nerve injury	.53	.06	.10	.0	.06	.88
Return to operating room	43.85	2.29	<.0001	59.80	2.17	<.0001
Median interval from surgery to discharge (d)	6.0	2.0	<.0001	9.0	2.0	<.0001
Morbidity	100.0	5.83	<.0001	100.0	5.79	<.0001
Death within 30 d	4.28	.16	<.0001	13.73	.10	<.0001

PP = postoperative pneumonia; PRF = postoperative respiratory failure.

P value reflects univariate analysis: Pearson chi-square test or Fisher's exact test for categorical variables, and *t* or *F* test for continuous variables, comparing presence and absence of PP and PRF.

Binomial variables expressed as percentages.

logic deficit, COPD with forced expiratory volume in 1 second <75% or causing functional disability or hospitalization, bleeding disorder, smoking cigarettes within 1 year of surgery, age, and type of bariatric surgery (Table 3). The other preoperative variables were not selected using the stepwise logistic regression algorithm.

Multivariate analysis for PRF

The preoperative risk factors associated with a greater incidence of PRF included previous PCI, dyspnea at rest or moderate exertion, bleeding disorder, COPD with forced expiratory volume in 1 second <75% or causing functional disability or hospitalization, diabetes, age, weight, anesthesia time, and type of bariatric surgery (Table 4). The other preoperative variables were not selected using the stepwise logistic regression algorithm.

Discussion

In their adjusted analysis of all surgeries, taking into account procedure complexity, patient characteristics, and other complications, Dimick et al. [22] found respiratory complications to be associated with the largest attributable cost ($52,466), followed by thromboembolic ($18,310) and cardiovascular complications ($7789). The median hospital costs were lowest for patients without complications ($4487) [22]. Analyzing the length of stay, they found respiratory complications to significantly increase the length of stay (by 5.5 d), followed by thromboembolic complications (by 2.8 d), and infectious complications (by 2.8 d) for a median of 4 days. This demonstrates that pulmonary complications are deleterious to outcomes after surgery and consume resources.

Of the 6.4% postoperative morbidity rate (among NSQIP-reported complications) seen after bariatric surgery, PRF and PP accounted for 18.7%, second only to wound infection. In comparison, renal complications accounted for 7.0% and cardiac complications accounted for 2.1% of the postoperative morbidity [13]. Not only are PRF and PP common problems after bariatric surgery, but they are also associated with greater mortality in patients developing these complications. We found a 30-day mortality rate of 4.3% and 13.7% among patients developing PP and PRF, respectively, compared with .16% and .10% among patients not developing these complications. These 2 complications were also associated with a significantly longer length of

Table 3
Risk factors for postoperative pneumonia (multivariate analysis)

Preoperative risk factor	Adjusted OR	95% CI
CHF—new or exacerbation of chronic within 30 d of surgery	5.26	1.20–23.26
Stroke with neurologic deficit	4.05	1.42–11.49
COPD with FEV_1 <75% or causing functional disability or hospitalization	3.19	1.87–5.46
Bleeding disorder	1.99	1.03–3.85
Smoking cigarettes within 1 yr of surgery	1.56	1.06–2.29
Increasing age (yr)	1.02	1.007–1.035
LRYGB versus LAGB	2.90	1.60–5.27
ORYGB versus LAGB	8.62	4.61–16.13
VBG versus LAGB	4.54	1.02–20.41
Other GP versus LAGB	3.85	1.25–11.90
BPD-DS versus LAGB	8.06	2.92–22.22

OR = odds ratio; CI = confidence interval; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; LRYGB = laparoscopic Roux-en-Y gastric bypass; ORYGB = open Roux-en-Y gastric bypass; LAGB = laparoscopic adjustable gastric banding; GP = other gastroplasty; VBG = vertical banded gastroplasty; BPD-DS = biliopancreatic diversion with duodenal switch.

stay. To better understand these 2 complications and their role in contributing significantly to poor outcomes after bariatric surgery, we analyzed the preoperative risk factors for these complications.

CHF was associated with the greatest risk of PP with an odds ratio of 5.3, and patients with previous PCI had a 2.8 times greater association with PRF. To our knowledge, CHF and previous PCI have previously not been shown to be risk factors for PP and PRF, respectively, after all surgeries [5,7,23]. The reason for CHF and PCI (a marker for cardiac disease) being associated with these pulmonary complications after bariatric surgery could be perioperative fluid overload, leading to worsening of the cardiopulmonary function. However, the precise reasons are unclear from the data set and need to be investigated further. We recommend approaching elective bariatric surgery very cautiously in these patients. It might be prudent to optimize the CHF and cardiac status before proceeding with the surgery.

Table 4
Risk factors for postoperative respiratory failure (multivariate analysis)

Preoperative risk factor	Adjusted OR	95% CI
Previous PCI	2.79	1.64–4.74
Dyspnea at rest versus no dyspnea	2.64	1.13–6.13
Bleeding disorder	2.49	1.45–4.27
COPD with FEV_1 <75% or causing functional disability or hospitalization	2.01	1.16–3.47
Insulin-dependent diabetes versus no diabetes	1.75	1.24–2.47
Oral medication-dependent diabetes versus no diabetes	1.49	1.01–2.19
Dyspnea on moderate exertion versus no dyspnea	1.45	1.08–1.95
Increasing age (yr)	1.019	1.005–1.034
Increasing anesthesia time (min)	1.006	1.005–1.008
Increasing weight (lb)	1.004	1.002–1.006
LRYGB versus LAGB	3.29	1.64–6.60
ORYGB versus LAGB	9.71	4.74–20.00
VBG versus LAGB	3.21	.40–25.64
Other GP versus LAGB	5.35	1.75–16.39
BPD-DS versus LAGB	13.89	5.56–34.48
C-statistic	.830	—

PCI = percutaneous coronary intervention; COPD = chronic obstructive pulmonary disease; LRYGB = laparoscopic Roux-en-Y gastric bypass; LAGB = laparoscopic adjustable gastric banding; GP = other gastroplasty; BPD-DS = biliopancreatic diversion with duodenal switch; OR = odds ratio; CI = confidence interval; FEV1 = Forced expiratory volume in 1st second.

COPD, as in studies in other surgical disciplines, was a risk factor for PP and PRF after bariatric surgery [5,7]. Cigarette smoking was also seen as a risk factor for PP. Chumillas et al. [24] found in their randomized trial that preoperative and postoperative respiratory rehabilitation can reduce postoperative pulmonary complications (19.5% in the control and 7.5% in the rehabilitation group) offering a viable strategy to address this risk factor in bariatric surgery. The use of improvement bundles with incentive spirometry, head of bed elevation, ambulation, and oral hygiene has also shown potential to reduce these complications [25,26].

With 25% of the patients undergoing bariatric surgery aged >54 years, analysis of the effect of age on PP and PRF was important. As in many other surgical disciplines, increased age was associated with these complications after bariatric surgery. Increased age was associated with impaired oropharyngeal motor function, laryngopharyngeal sensitivity, and increased risk of atelectasis; all of which might contribute to the increased risk [27].

Patients with a history of stroke with neurologic deficit were associated with 4 times the risk of PP. These patients might have had an increased risk of aspiration owing to stroke. Greater weight was a risk factor for PRF, and efforts to promote preoperative weight loss might be instrumental in reducing this factor. Diabetes was also found to be a risk factor for PRF. Although these diseases cannot be cured, knowledge of these factors might aid in patient selection and counseling.

Overall, the type of bariatric surgery performed had the greatest difference in terms of the risk of PP and PRF. Open Roux-en-Y gastric bypass and biliopancreatic diversion with duodenal switch were associated with a greater risk than laparoscopic Roux-en-Y gastric bypass, and laparoscopic adjustable gastric bypass was associated with a lower risk than all bariatric surgeries. This might have been because of the more invasive nature of open Roux-en-Y gastric bypass and biliopancreatic diversion with duodenal switch.

The present NSQIP database study had many strengths compared with other studies. The large sample size enabled smaller confidence intervals in the assessment of the risk factors. Also, it included data from both academic and community hospitals (data that have been independently validated and audited) and included multiple preoperative variables. This was in contrast to many registry and Medicare-based analyses, which were pri-

marily administrative discharge data sets, not limited by the concerns of accuracy, because these data sets were not validated, as was NSQIP [28]. In addition to accuracy, administrative data sets are also usually limited by the number of variables they contain, frequently omitting information on important parameters, such as the BMI [29]. In administrative data sets, it is also sometimes difficult to distinguish between diagnoses present at admission and diagnoses that occurred as complications. The real-time data acquisition and hospital mix of NSQIP provides a platform in which the data reported are the most current and representative of collective care in the United States. It has been widely suggested that the discriminative ability of a predictive model should be >.75 for a prediction model to be considered clinically relevant [30,31]. The c-statistic for the PRF and PP model was .83 and .77, respectively, demonstrating excellent discrimination/predictive ability.

Despite many strengths, the study had some limitations. First, NSQIP was developed with consideration for all surgeries and not specifically for bariatric surgery. Despite being fairly comprehensive, with >50 preoperative variables, obstructive sleep apnea is not included as a co-morbidity. Similarly, pulmonary function test results might be relevant but were not available. The presence of these variables in the data set would have probably improved the predictive ability of the risk models further; however, it must be realized that the predictive ability is still excellent (c-statistic >.8). The risk factors were obtained using the NSQIP data set and might not apply to nonparticipating hospitals. However, given the diversity of NSQIP, this is unlikely.

Conclusion

PP and PRF are the most common nonwound complications after bariatric surgery, account for approximately one fifth of the morbidity, and are associated with a 30-day mortality rate of 4.3% and 13.7%, respectively. The NSQIP database provides an accurate real-time measure of outcome after bariatric surgery. Several modifiable and nonmodifiable factors associated with PP and PRF were identified. Through the development of specific strategies to address and optimize the modifiable risk factors in bariatric patients and careful patient selection, the incidence of PP and PRF can be controlled, thereby further improving the surgical outcomes after bariatric surgery.

Disclosures

The authors have no commercial associations that might be a conflict of interest in relation to this article.

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