Surg Endosc (2014) 28:3302–3309
DOI 10.1007/s00464-014-3606-7

Postoperative complications in bariatric surgery using age and BMI stratification: a study using ACS-NSQIP data

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Received: 5 February 2014 / Accepted: 3 May 2014 / Published online: 13 August 2014

Abstract
Background Bariatric surgery results in long-term weight loss and significant morbidity reduction. Morbidity and mortality following bariatric surgery remain low and acceptable. This study looks to define the trend of morbidity and mortality as it relates to increasing age and body mass index (BMI) in patients undergoing bariatric surgery.
Methods We queried the ACS/NSQIP 2010–2011 Public Use File for patients who underwent elective laparoscopic adjustable banding (LAGB), sleeve gastrectomy (LSG) and gastric bypass (LGBP). Total morbidity and 30-day mortality were evaluated. Logistic regression models were created to estimate the effect of increasing age and BMI on morbidity for these bariatric procedures.
Results A total of 20,308 laparoscopic bariatric procedures were reviewed (11617 LGBP, 3069 LSG and 5622 LAGB). Overall mortality and morbidity rates were 0.11 and 3.84 %, respectively. The odds of postoperative complications increased by 2 % with each additional year of age (OR 1.02, 95 % CI 1.02–1.03) and every point increase in BMI (OR 1.02, 95 % CI 1.01–1.03). Multiple logistic regression identified COPD, Diabetes, Hypertension, and Dyspnea as major risk factors for postoperative morbidity. Postoperative complications were three times more likely after LGBP (OR 2.87, 95 % CI 2.31–3.57) and two times more likely after LSG (OR 2.06, 95 % CI 1.57–2.72) when compared to patients undergoing LAGB.
Conclusion Morbidity and mortality increase on a predictable trend with increasing age and BMI. There is increased risk of morbidity for stapling procedures when compared to gastric banding, but this must be considered in context of surgical efficacy when choosing a bariatric procedure. These data can be used in preoperative counseling and evaluation of surgical candidacy of bariatric surgical patients.

Keywords Postoperative complications · Bariatric surgery · Age and BMI stratification · NSQIP data

Presented at the SAGES 2014 Annual Meeting, April 2–5, 2014, Salt Lake City, Utah.

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The World Health Organization describes obesity as the greatest threat to human life affecting one-third of adults in the United States [1, 2]. An estimated 400 million adults are classified as obese and 1.6 billion are overweight with estimated yearly deaths of about 300,000 attributable to complications of obesity such as heart disease, diabetes and high blood pressure [3, 4]. About 10 % of the US health care dollars are spent yearly on the treatment of medical conditions either caused or exacerbated by obesity [5].

Attempts at non-operative measures such as dietary modification, behavioral therapy, and increased physical activity have been shown to be ineffective in improving obesity related co-morbidities [6].

Bariatric surgery remains the only effective long term solution to weight loss and combating morbid obesity and its related co-morbidities [7]. Laparoscopy provides quick recovery and reduced perioperative complications enabling patient satisfaction [8].

The more commonly offered bariatric surgical procedures include laparoscopic gastric bypass (LGBP), laparoscopic sleeve gastrectomy (LSG), and laparoscopic gastric banding (LAGB). These procedures can reduce mortality by 35–89 % through significant improvement or resolution of chronic co-morbid conditions such as diabetes, hypertension, obstructive sleep apnea, and other cardiovascular risk factors [9]. They also improve the quality of life and psychosocial outcome in a substantial proportion of patients [5].

Morbidity and mortality rates following bariatric surgery remain low and have been reported in the literature to range from 9–25 %, and 0.1–2 %, respectively [5]. The most frequently reported perioperative complications after a LGBP include wound infection (2.98 %), anastomotic leak (2.05 %), bowel obstruction (1.73 %), pulmonary embolism (0.41 %), and late complications such as stomal stenosis (4.73 %), bowel obstruction (3.15 %), and incisional hernia (0.47 %) [10].

Patients undergoing LSG are more prone to developing staple line leaks (1.17 %) and postoperative hemorrhage (3.57 %) [5].

Overall complications are more common with the LAGB placement than with LGBP or LSG [8]. Gastric band related complications such as slippage/pouch dilatation (24 %), esophageal dilatation (8 %), stomal obstruction (14 %), failure rate of 44 % and revisional surgery in up to 30 % of patients [11] have decreased the popularity of this procedure recently.

Several risk factors for increased morbidity and mortality following bariatric surgery have been reported. A history of deep venous thrombosis (DVT)/pulmonary embolism (PE), obstructive sleep apnea (OSA), impaired functional status, and extreme obesity (BMI > 60) were all associated with increased morbidity [12]. Patients with a history of chronic renal insufficiency (on dialysis), low preoperative serum albumin, and a history of bleeding disorders had a higher chance of return to the operating room [13, 14].. Higher mortality was found in patients that were male, super-obese (BMI > 50) and elderly (age > 65 years) [15].

The effectiveness of these different bariatric procedures is as important as the complication rates. The stapling procedures (LSG & LGBP) have been noted to produce an excess body weight loss of about 60–70 %, respectively, when compared to the LAGB at <50 % [27, 28].

Prior reports have reported on bariatric outcomes above and below certain BMI cutoffs. In practice, increasing age and BMI occur over a continuum, and quite likely as age and BMI increase so does the risk profile, irrespective of arbitrary cutoffs. Possibly, inflection points may exist above which bariatric surgical risk profiles do not warrant conduction of the procedure. To our knowledge, these risk curves have not been described, but is critical as increasing numbers of patients, at higher BMI's and more elderly ages, are referred for bariatric evaluation.

This study defines the trend of morbidity as it relates to increasing age and BMI in patients undergoing bariatric surgery using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database.

Materials and methods

We utilized the 2010–2011 ACS-NSQIP Participant Use File, which represents a large prospective, multi-hospital database that collects data from patients undergoing inpatient and outpatient surgical procedures from over 250 participating medical centers. ACS-NSQIP collects information on 136 variables including preoperative risk factors, laboratory values, intra-operative variables, and 30-day postoperative mortality and morbidity outcomes. The data were collected by a certified clinical reviewer who had received training regarding the definitions, data extraction, continuing education, and monitoring through the ACS-NSQIP. The ACS-NSQIP has had a 95 % success rate to date in capturing the 30-day outcomes for all cases in the database. The accuracy and reproducibility of the data have been previously published [16].

We identified patients over the age of 18 who underwent bariatric surgery using specific current procedure terminology (CPT) codes which included laparoscopic adjustable gastric banding (43770), laparoscopic sleeve gastrectomy (43775), and laparoscopic Roux-en-Y gastric bypass (43644). Patients with a body mass index (BMI) < 35 kg/m^2, emergency procedures, a history of cancer, and combined procedures, were excluded.

Patients were then stratified by age and BMI to assess their effect on short-term operative outcomes (morbidity) following bariatric surgery. There were too few deaths to analyze the effect of increasing age and BMI on risk factors for mortality.

Statistical analysis

All demographics were summarized, by procedure, in descriptive statistics tables. For continuous variables, mean and standard deviation were calculated. For categorical variables the number per procedure and percent of the procedure group were reported.

Demographics, preoperative co-morbidities, and operative factors (ASA class and inpatient status) were compared between subjects with and without complications, within each procedure, using univariate tests. Continuous measures were compared using independent two-sample-tests and categorical variables with χ^2 test. In some cases,

Table 1 Demographics ($N = 20{,}308$)

Variable	LGBP ($N = 11{,}617$)	LSG ($N = 3{,}069$)	LAGB ($N = 5{,}622$)	P value
Age, mean year (sd)	43.8 (11.5)	43.7 (11.2)	44.0 (12.1)	0.6308
BMI, mean kg/m^2 (sd)	46.6 (7.8)	46.7 (8.4)	44.2 (6.5)	**<0.0001**
Gender: male n (%)	2,365 (20.6 %)	746 (24.6 %)	1,318 (23.7 %)	**<0.0001**
Race: white n (%)	8,382 (82.2 %)	2,104 (75.9 %)	4,115 (80.6 %)	**<0.0001**
Inpatient, n (%)	11,469 (98.7 %)	2,848 (92.8 %)	3,121 (55.5 %)	**<0.0001**
ASA class				**<0.0001**
1	51 (0.4 %)	12 (0.4 %)	37 (0.7 %)	
2	4,097 (35.3 %)	1,048 (34.2 %)	2,325 (41.4 %)	
3	7,199 (62.1 %)	1,924 (62.8 %)	3,179 (56.6 %)	
4	247 (2.1 %)	81 (2.6 %)	76 (1.4 %)	

Bold values are statistically significant ($P < 0.05$)

Fisher's exact test was used to compare categorical groups due to small sample sizes. Out of the co-morbidities captured in the NSQIP data, only those with a prevalence of at least 1 % are presented in the Tables. All statistical tests used two-tailed P values. Specific complications and other outcomes are summarized in separate Tables using basic descriptive statistics.

Finally, binary logistic regression was used to model the effect of age and BMI on the rate of complications while controlling for possible confounders. Variables were selected as possible confounders if they appeared to have a significant effect on complications on univariate analysis. If the P value for at least two of the three procedures was less than 0.05, variables were included in the model. Interaction terms between age and BMI and the rest of the variables were tested by adding them to the base model one at a time. Second order (squared terms) for age and BMI were also added to the base model in this manner, to check for non-linear associations between the variables and the log-odds of complications. Linear splines for BMI with knots at 55 and 60 were also tested. The year of surgery was tested in the model as a confounder to ensure complication rates did not change significantly based on technical expertise between 2010 and 2011.

All analyses were performed with SAS 9.2 software (NC) and P values of less than 0.05 were considered statistically significant.

Results

Using the current procedural terminology codes for LGBP, LSG, and LAGB; a total of 20,308 patients were identified in the ACS-NSQIP database from 2009 to 2011. There were 11,617 patients in the LGBP group, 3,069 patients in the LSG group, and 5,622 patients in the LAGB group.

The average age (mean ± SD) and BMI in the LGBP group were 43.8 ± 11.5 years and 46.6 ± 7.8 kg/m^2, respectively, when compared to the LSG group (43.7 ± 11.2 years; 46.7 ± 8.4 kg/m^2) and the LAGB group (44 ± 12.1 years; 44.2 ± 6.5 kg/m^2). The demographic data are listed in Table 1.

Postoperative complications

The incidence of postoperative complications is listed in Tables 2 and 3.

30-day postoperative complications were significantly higher in the LGBP group when compared to either the LSG or LAGB groups. These complications included re-intubation, pneumonia, PE, failure to wean, renal insufficiency, urinary tract infection, bleeding, DVT, and sepsis.

Wound complications

The incidence of superficial and organ space infections (anastomotic or staple line leaks) was significantly greater in the LGBP group when compared to either the LSG or LAGB. There was no difference in the incidence of deep site infections (infections of the fascial and muscle layers) and wound dehiscence in the three groups (Table 4).

Other postoperative variables

The operative times, re-operation rate, and length of stay were significantly higher in the LGBP group when compared to either the LSG or LAGB groups (Table 2).

Mortality and morbidity

The preoperative co-morbid factors such as ASA class, diabetes, smoking, dyspnea, COPD, PCI, HTN, steroid use,

Table 2 Postoperative complications

Variable	LGBP ($N = 11{,}617$)	LSG ($N = 3{,}069$)	LAGB ($N = 5{,}622$)	P value
Morbidity, *n* (%)	589 (5.1 %)	98 (1.4 %)	114 (3.7 %)	**<0.0001**
Mortality, *n* (%)	19 (0.2 %)	3 (0.1 %)	3 (0.1 %)	0.1401
Reoperation, *n* (%)	255 (2.2 %)	48 (1.6 %)	55 (1.0 %)	**<0.0001**
Op time, mean mins (sd)	126.5 (50.6)	93.3 (45.9)	64.2 (31.5)	**<0.0001**
LOS, median days (IQR)	2.0 (1.0)	2.0 (1.0)	1.0 (1.0)	**<0.0001**

Bold values are statistically significant ($P < 0.05$)

LOS length of stay

Table 3 Specific postoperative complications

Variable	LGBP ($N = 11{,}617$)	LSG ($N = 3{,}069$)	LAGB ($N = 5{,}622$)	P value
Pneumonia	50 (0.43 %)	10 (0.33 %)	9 (0.16 %)	**0.0166**
Re-intubation	46 (0.40 %)	10 (0.33 %)	4 (0.07 %)	**0.0011**
Pulmonary embolism	28 (0.24 %)	5 (0.16 %)	2 (0.04 %)	**0.0095**
Failure to wean	27 (0.23 %)	7 (0.23 %)	2 (0.04 %)	**0.0121**
Acute renal failure	12 (0.10 %)	4 (0.13 %)	1 (0.02 %)	0.0703
Renal insufficiency	10 (0.09 %)	9 (0.29 %)	2 (0.04 %)	**0.0011**
Urinary tract infection	82(0.71 %)	19 (0.62 %)	19 (0.34 %)	**0.0124**
Cardiac arrest	9 (0.08 %)	2 (0.07 %)	2 (0.04 %)	0.6324
Myocardial infarction	11 (0.09 %)	2 (0.07 %)	1 (0.02 %)	0.1822
Bleeding	153(1.32 %)	15 (0.49 %)	6 (0.11 %)	**<0.0001**
Deep vein thrombosis	19 (0.16 %)	14 (0.46 %)	5 (0.09 %)	**0.0005**
Periph nerve injury	3 (0.03 %)	0 (0.0 %)	0 (0.0 %)	0.7282
Coma	1 (0.01 %)	0 (0.0 %)	0 (0.0 %)	1.0
Stroke/CVA	4 (0.03 %)	1 (0.03 %)	0 (0.0 %)	0.4379

Bold values are statistically significant ($P < 0.05$)

Table 4 Wound complications

Wound complication	LGBP ($N = 11{,}617$)	LSG ($N = 3{,}069$)	LAGB ($N = 5{,}622$)	P value
Superficial site infection	185 (1.59 %)	30 (0.98 %)	45 (0.80 %)	**<0.0001**
Deep site infection	17 (0.15 %)	1 (0.03 %)	3 (0.05 %)	0.0852
Organ space site infection	65 (0.56 %)	22 (0.72 %)	5 (0.09 %)	**<0.0001**
Wound dehiscence	9 (0.08 %)	1 (0.03 %)	4 (0.07 %)	0.8670

Bold values are statistically significant ($P < 0.05$)

Organ space infection-anastomotic or staple line leaks

Deep site infection-infections of the fascial and muscle layers

and bleeding disorders were evaluated between patients that developed any form of postoperative complication and those without in all the three groups (LGBP, LSG, and LAGB). A logistic regression model was then built using the co-morbid factors that were found to be statistically significant from the univariate analysis (Table 5).

Diabetes, HTN, SOB, and COPD were found to be important risk factors for developing postoperative complications following bariatric surgical procedures. The odds of postoperative complications increased by 1 % with each additional year of age (OR 1.01, 95 % CI 1.006–1.02), and by 2 % with every point increase in BMI (OR 1.02, 95 % CI 1.01–1.027). Postoperative complications were three times more likely after LGBP (OR 2.77, 95 % CI 2.23–3.45) and two times more likely after LSG (2.04, 95 % CI 1.55–2.69) when compared to patients undergoing LAGB. (Figs. 1, 2, 3).

Discussion

The incidence of morbid obesity has increased exponentially in the last decade and so has the number of patients undergoing bariatric procedures [17]. The decision of the appropriate bariatric procedure to offer is based on many factors such BMI, age, co-morbidities such as diabetes,

Table 5 Univariate analysis. ASA class, diabetes, dyspnea, COPD, and HTN were identified on univariate analysis as important risk factors for increased postoperative complications following bariatric surgery (LGBP, LSG, and LAGB)

Variable	LGBP ($N = 11{,}617$)			LSG ($N = 3{,}069$)			LAGB ($N = 5{,}622$)		
	No comp	Comp	*P*	No comp	Comp	*P*	No comp	Comp	*P*
Patients, *n* (%)	11,028 (94.9 %)	589 (5.1 %)	–	2,955 (96.3 %)	114 (3.7 %)	–	5,524 (98.3 %)	98 (1.7 %)	–
ASA class									
1	49 (0.5 %)	2 (0.3 %)	**0.01**	12 (0.4 %)	0 (0.0 %)	**0.04**	37 (0.7 %)	0 (0.0 %)	**<0.01**
2	3,927 (35.7 %)	170 (28.9 %)		1,016 (34.4 %)	32 (28.1 %)		2,304 (41.8 %)	21 (21.4 %)	
3	6,798 (61.8 %)	401 (68.1 %)		1,850 (62.7 %)	74 (64.9 %)		3,107 (56.3 %)	72 (73.5 %)	
4	231 (2.1 %)	16 (2.7 %)		73 (2.5 %)	8 (7.0 %)		71 (1.3 %)	5 (5.1 %0	
Diabetes, *n* (%)	**3,099 (28.1 %)**	**222 (37.7 %)**	**<0.01**	**709 (24.0 %)**	**36 (31.6 %)**	**0.06**	**1,167 (21.1 %)**	**35 (35.7 %)**	**<0.01**
Smoking, *n* (%)	1,262 (11.4 %)	79 (13.4 %)	0.15	299 (10.1 %)	10 (8.8 %)	0.64	618 (11.2 %)	11 (11.2 %)	1.0
Dyspnea, *n* (%)	**2,211 (20.1 %)**	**143 (24.3 %)**	**0.01**	**458 (15.5 %)**	**30 (26.3 %)**	**<0.01**	**835 (15.1 %)**	**23 (23.5 %)**	**0.02**
COPD, *n* (%)	**172 (1.6 %)**	**20 (3.4 %)**	**<0.01**	**34 (1.2 %)**	**3 (2.6 %)**	**0.16**	**71 (1.3 %)**	**4 (4.1 %)**	**0.02**
PCI, *n* (%)	164 (1.9 %)	13 (2.8 %)	0.15	47 (2.2 %)	4 (4.7 %)	0.14	98 (2.3 %)	4 (5.3 %)	0.09
PCS, *n* (%)	80 (0.9 %)	5 (1.1 %)	0.61	28 (1.3 %)	1 (1.2 %)	1.0	43 (1.0 %)	3 (4.0 %)	0.04
HTN, *n* (%)	**5,660 (51.3 %)**	**371 (63.0 %)**	**<0.01**	**1,498 (50.7 %)**	**71 (62.3 %)**	**0.02**	**2,672 (48.4 %)**	**66 (67.4 %)**	**0.01**
Steroids, *n* (%)	79 (0.7 %)	6 (1.0 %)	0.45	31 (1.1 %)	2 (1.8 %)	0.35	44 (0.8 %)	2 (2.0 %)	0.19
Bld dis, *n* (%)	92 (0.8 %)	12 (2.0 %)	<0.01	31 (1.1 %)	3 (2.6 %)	0.13	72 (1.3 %)	2 (2.0 %)	0.37

Bold values are statistically significant ($P < 0.05$)

PCI percutaneous coronary intervention, *PCS* percutaneous coronary stenting, *Bld dis* bleeding disorders

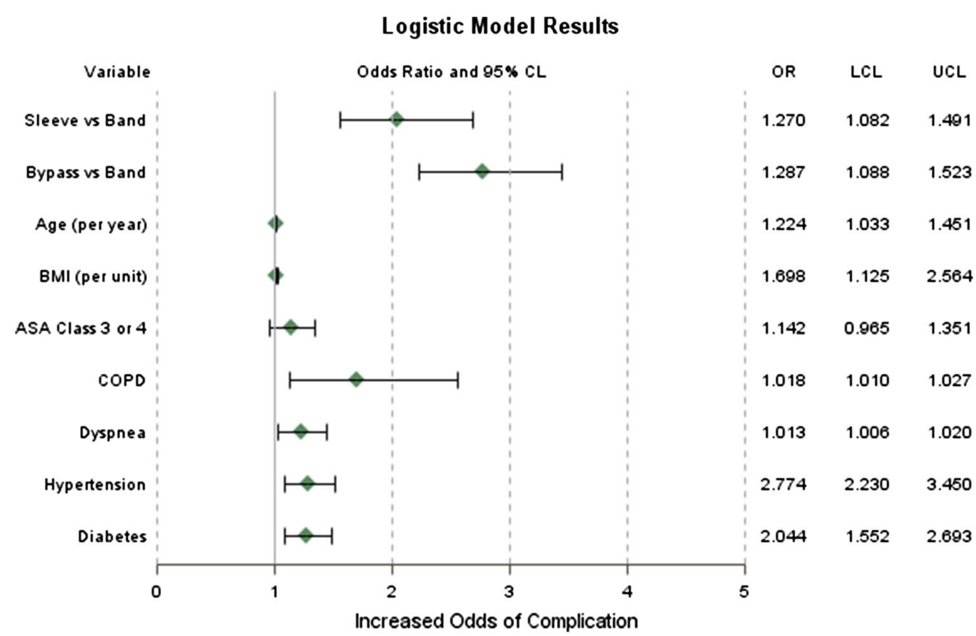

Fig. 1 Logistic regression results. The logistic regression model identified diabetes, hypertension, dyspnea, and COPD as important risk factors for postoperative complications following bariatric surgery. Postoperative complications were two to three times more likely after LSG or LGBP when compared to LAGB, respectively

hypertension, COPD, and other obesity related arthropathies [4]. The morbidity and mortality rates of the different bariatric procedures have been well studied and reported in the literature. To our knowledge, this report is the only study that has investigated the incremental risk accumulation related to increasing age and BMI during laparoscopic bariatric procedures.

Karkarla et al. [18] reported the effect of high BMI on morbidity and mortality in bariatric surgery. This study utilized the ACS-NSQIP data consisting of 29,323 patients who had undergone laparoscopic bariatric procedures from 2005 to 2008. They compared the 30-day perioperative morbidity and mortality in super-obese patients (BMI > 50) and morbidly obese patients. They found that the super-

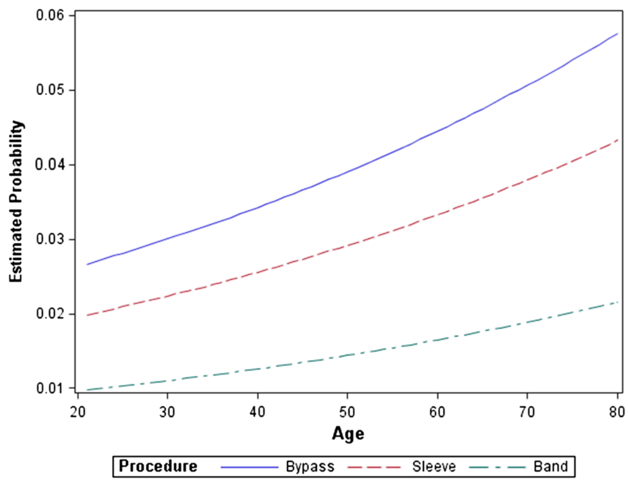

Fig. 2 Probability of postoperative complications with increasing age. The odds of postoperative complications increased by 1 % with each additional year of age (OR 1.01, 95 % CI 1.006–1.02)

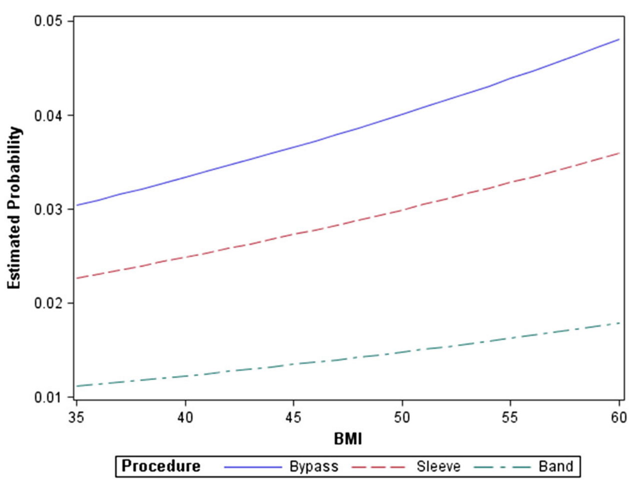

Fig. 3 Probability of postoperative complications with increasing BMI. The odds of postoperative complications increased by 2 % with every point increase in BMI (OR 1.02, 95 % CI 1.01–1.03)

obese group had significantly higher postoperative complications (3.9 vs. 2.9 %; $P = 0.004$) when compared to the rest of the morbidly obese group who underwent a laparoscopic gastric bypass as well as those who had a laparoscopic gastric banding procedure.

Nandipati et al. [13] reported that patients on dialysis, low preoperative serum albumin, and a history of bleeding disorders had a tendency to go back to the operating room increasing the overall morbidity in these patients.

Total morbidity as defined by our study was very low (3.84 %). The incidence of the specific complications including superficial wound infection (3.37 %), sepsis (0.96 %), pneumonia (0.92 %), re-intubation (0.8 %), failure to wean from ventilator (0.5 %), renal insufficiency (0.42 %), and MI (0.18 %) was also very low considering the co-morbidities of bariatric patients and are similar to previous reports in the literature [15, 19–22].

We evaluated the trend in postoperative complication rates using different BMI classes. There was a longitudinal increase in the probability of postoperative complications with increasing BMI. The odds of postoperative complications increased by 2 % with every point increase in BMI (OR 1.02, 95 % CI 1.01–1.03). An inflection point was not observed in our analysis thus we could not define a certain BMI beyond which there is an exponential increase in the probability of postoperative complications and mortality.

Dorman et al. [23] reported that elderly patients (>65 years) had similar postoperative outcomes following bariatric surgery when compared to their younger counterparts. This was an ACS-NSQIP study looking at 48,378 patients from 2005–2009 that underwent laparoscopic and open bariatric procedures including gastric bypass, gastric banding, vertical banded gastroplasty, and duodenal switch. The postoperative outcomes were then compared after dividing them into different age classes such as <65 year and >65 year old. Patients >65 years were not found to have experienced major complications for either open or laparoscopic cases. However, they were more likely to experience prolonged length of hospital stay. In contrast, our study found that the odds of postoperative complications increased by 1 % with each additional year of age (OR 1.01, 95 % CI 1.01–1.02).

The use of the univariate analysis identified the important risk factors such as ASA class, DM, dyspnea at rest, COPD, and HTN which we then used for our stepwise multiple logistic regression. The model then identified BMI, age, diabetes, hypertension, dyspnea, COPD, and the bariatric procedures (LGBP/LSG) as major risk factors for postoperative major morbidity. Bleeding disorder, male sex, ASA class, and congestive heart failure have all been reported as important risk factors for postoperative morbidity in bariatric surgery by other studies [19, 24–26]. These were not included in our logistic regression model as they were not found significant on the univariate analysis. These differences in the important risk factors detected in our study might be due to the relative small sample sizes of previous reports and also important factors not collected in the other databases. Our multiple regression analysis confirms that after correcting for all these important risk factors, the probability of postoperative morbidity increases by about 1–2 % as age or BMI increases.

Our study based on ACS-NSQIP database has many strengths not seen in most of the other studies. The huge database provides a large sample size enabling calculations of smaller confidence intervals. It is based on data from both academic and community hospitals with a large sample size and takes into account several peri-operative variables. This is different from the many registry based and Medicare analyses that are lacking the accuracy and details that the ACS-NSQIP data provide.

There are also limitations from using the ACS-NSQIP database. This database was built for all operations and not specifically bariatric procedures so it does not take into account all factors that are relevant to bariatric surgery. Important co-morbidities such as obstructive sleep apnea, history of DVT and complications such as bowel obstruction, gastrointestinal hemorrhage, and anastomotic stricture are not recorded in the database. Anastomotic leaks are indirectly recorded under organ space infections. This database provides only short term outcomes of the complications and mortality that occur within 30 days after the procedure. Long-term outcomes such as re-admission, reoperation, morbidity and mortality after 30 days were not captured by this database and so were not evaluated in this study. Conclusions are drawn from data submitted from hospitals participating in the ACS-NSQIP which might not be a statistically valid nationally representation.

Conclusion

Morbidity following bariatric surgery increases independently and predictably with increasing age and BMI. There is increased risk of morbidity for stapling procedures (LGBP&LSG) when compared to LAGB, but this must be considered in context of surgical efficacy when choosing a bariatric procedure. These data can aid in the evaluation and counseling of patients considering bariatric surgery. Further investigation may lead to the ability of surgeons to specifically counsel patients individually and specifically regarding personal risks and benefits of surgery.

ACS NSQIP data disclaimer

The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in it represent the source of the data used therein; they have not verified and are not responsible for the statistical validity of the data analysis or for the conclusions derived by the authors.

Acknowledgments This research was supported by the Foundation for Surgical Fellowships.

Disclosure Aliu Sanni, Sebastian Perez, Rachel Medbery, Juan P. Toro, Ankit D. Patel, Hernan D. Urrego, John F. Sweeney, Edward Lin and S. Scott Davis Jr. have no conflicts of interest to disclose.

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