Risk for Hospital Readmission following Bariatric Surgery

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Abstract

Background and Objectives: Complications resulting in hospital readmission are important concerns for those considering bariatric surgery, yet present understanding of the risk for these events is limited to a small number of patient factors. We sought to identify demographic characteristics, concomitant morbidities, and perioperative factors associated with hospital readmission following bariatric surgery.

Methods: We report on a prospective observational study of 24,662 patients undergoing primary RYGB and 26,002 patients undergoing primary AGB at 249 and 317 Bariatric Surgery Centers of Excellence (BSCOE), respectively, in the United States from January 2007 to August 2009. Data were collected using standardized assessments of demographic factors and comorbidities, as well as longitudinal records of hospital readmissions, complications, and mortality.

Results: The readmission rate was 5.8% for RYGB and 1.2% for AGB patients 30 days after discharge. The greatest predictors for readmission following RYGB were prolonged length of stay (adjusted odds ratio [OR], 2.3; 95% confidence interval [CI], 2.0–2.7), open surgery (OR, 1.8; CI, 1.4–2.2), and pseudotumor cerebri (OR, 1.6; CI, 1.1–2.4). Prolonged length of stay (OR, 2.3; CI, 1.6–3.3), history of deep venous thrombosis or pulmonary embolism (OR, 2.1; CI, 1.3–3.3), asthma (OR, 1.5; CI, 1.1–2.1), and obstructive sleep apnea (OR, 1.5; CI, 1.1–1.9) were associated with the greatest increases in readmission risk for AGB. The 30-day mortality rate was 0.14% for RYGB and 0.02% for AGB.

Conclusion: Readmission rates are low and mortality is very rare following bariatric surgery, but risk for both is significantly higher after RYGB. Predictors of readmission were disparate for the two procedures. Results do not support excluding patients with certain comorbidities since any reductions in overall readmission rates would be very small on the absolute risk scale. Future research should evaluate the efficacy of post-surgical managed care plans for patients at higher risk for readmission and adverse events.

Introduction

The astonishing rise in obesity prevalence and the marked decline in perioperative mortality over the previous two decades have both contributed to the growing popularity of bariatric surgery. In the period from 1998 to 2003, the number of bariatric procedures performed increased 10-fold [1], and in 2009 alone, 220,000 bariatric surgeries were performed in the United States and Canada [2]. Despite the clinical benefits, the potential for serious and costly major adverse events deters many patients and payers from utilizing its advantages.

Bariatric surgery is safe with a 0.15% to 0.5% 30-day mortality rate [3–6], however an appreciable proportion of patients suffer at least one major adverse event within the first 30 days following either Roux-en-Y gastric bypass (RYGB) or adjustable gastric banding (AGB) that results in hospital readmission. A hospital readmission increases the average 180-day cost of a bariatric operation from approximately $27,000 to $65,000 [7]. In response to the high costs of hospital readmission, in 2008 the National Quality Forum indicated that hospital readmission rates would be a central factor in evaluating hospital performance with penalties being levied against hospitals with high readmission rates.

Identifying patient and surgical factors that increase perioperative risk of readmission would improve both the tenability of bariatric surgery for patients and the cost-effectiveness for payers. Comprehensive assessment of patient risks a priori would provide physicians with a framework for either tailoring the selection of intervention or identifying patients most in need of enhanced education or monitoring post-operatively, which could, in turn, reduce the frequency of readmission following bariatric surgery. We have utilized the Bariatric Outcomes Longitudinal Database (BOLD), the largest prospective database of bariatric patient outcomes worldwide, to identify predictors of serious postoperative complications requiring hospital readmission within 30 days of discharge.

Methods

Design Overview

We obtained patient data from BOLD collected between January 1, 2007 and August 31, 2009 at 450 Bariatric Surgery Centers of Excellence (BSCOE) in the United States and Canada [2]. Patients were included if they underwent primary RYGB or AGB surgery from January 2007 to August 2009 and had at least one postoperative hospital visit within 30 days of discharge. The primary outcome was hospital readmission within 30 days of discharge. Predictors of readmission were identified using multivariable logistic regression analysis. Variables were included in the model based on clinical relevance and statistical significance. The model was internally validated using cross-validation techniques.
were performed on the readmission and mortality rates under a wide variety of assumptions, but had little effect on the rates due to the relative rarity of the outcome.

Outcomes and Follow-up

Predictors of interest were demographic, health, and surgical variables. Clinical definitions of comorbid conditions are presented in Table 1. Prolonged length of stay was defined as a hospital stay $\geq 4$ days for laparoscopic RYGB, $\geq 6$ days for open RYGB and $\geq 2$ days for AGB. Our outcome was all-cause hospital readmission within 30 days of discharge requiring hospitalization for $>23$ hours. We considered patients to be at risk for readmission on the day of discharge. No serious intraoperative complications requiring additional hospitalization were classified as readmissions. Patients were considered at risk for mortality on the day of surgery. Patients who were readmitted and died in the hospital within 30 days of surgery were classified as both readmissions and mortalities; patients who died outside a hospital were classified as mortalities but not readmissions.

Statistical Analysis

The demographic characteristics and medical histories of patients undergoing the two surgeries were compared with t-tests for continuous variables and chi-square tests for categorical variables, and Fisher’s exact tests for rare counts. Risk factors for readmission were evaluated using a series of generalized linear mixed-effects models. Demographic, health, and surgical covariates were estimated as fixed effects and a random effect was estimated for BSCOE to account for variation between and correlation within BSCOE in their readmission rates. Those covariates significantly associated with readmission in univariate analysis at a significance level of 0.10 or greater were entered into a multivariate model with an iterative backward selection procedure that continued until all variables were significant at the 0.10 level.

We used expanded mixed-effects logistic models with interactions to examine mediation of risk factors by surgical approach. Readmission risk was higher among open surgeries, however the risk factors for open and laparoscopic RYGB approaches were not significantly different in the expanded models, so we controlled for the higher rate of readmission among open procedures with an additional fixed effect and did not stratify models by surgical approach. All $P$ values are two-sided and are unadjusted for multiple comparisons. Statistical analyses were conducted in SAS version 9.2 (SAS Institute Inc., Cary, North Carolina) and graphs were generated in R version 2.14.0 (R Development Core Team, 2011).

Results

Patients

Figure 1 details the patient selection process. Among BSCOE eligible for analysis, 24,662 RYGB patients from 249 BSCOE and 26,002 AGB patients from 317 BSCOE were followed-up at 30 days. Bariatric surgery patients had a mean age of 45.9±11.9 years and were predominantly female (78.9%) and Caucasian (80.1%). Patients undergoing RYGB had higher BMI and higher prevalence of comorbidities than patients who underwent AGB (Table 2). The laparoscopic approach was employed for 90.7% of RYGB and 99.7% of AGB operations. Prior to discharge, 1,728 (7.7%) laparoscopic RYGB patients, 159 (7.0%) open RYGB patients, and 1,183 AGB patients (4.6%) had a prolonged length of stay.
Readmission and mortality

In the first 30 days after discharge, 1437 (5.8%) RYGB patients and 322 (1.2%) AGB patients were readmitted (Figure 2; $P<0.001$ for difference). Patients undergoing RYGB procedures with the laparoscopic approach had fewer readmissions than patients who underwent RYGB with an open approach (5.6% v. 7.9%, $P<0.001$). The most commonly reported complications at readmission were nausea/vomiting and dehydration for both procedures, though more than one reason could be recorded for a readmission (Table 3). For RYGB, other common complications at readmission were gastrointestinal bleeding, stricture, and obstruction; pneumonia, device-related infection, and obstruction were common complications reported at AGB readmissions.

Within the 30 days of the primary operation, 35 (0.14%) RYGB patients and 6 (0.02%) AGB patients died ($P<0.001$ for difference). For RYGB patients, causes of mortality were sepsis (n = 11), cardiac failure (n = 6), myocardial infarction (n = 4) respiratory failure (n = 4), stroke (n = 2), pulmonary embolus (n = 1), or could not be determined (n=6). For AGB patients, causes of death were myocardial infarction (n = 3) or indeterminate (n = 3).

Predictors of readmission

Table 4 presents univariate and multivariate risk factor analyses for readmission. After adjusting for other significant covariates, prolonged length of stay more than doubled the odds of readmission for a RYGB patient and the open surgical approach nearly doubled odds of readmission. Patients with current symptoms of clinical depression or psychosocial impairment, peripheral vascular disease, pseudotumor cerebri, or those with a previous history of gallstones or cholecystectomy were more likely to be readmitted than those without those symptoms. The number of medications used preoperatively was also associated with higher

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**Table 1. Clinical definitions of pre-existing conditions.**

| Condition                  | Clinical Definition                                                                 |
|----------------------------|-------------------------------------------------------------------------------------|
| Abdominal/serosa           | Any history of symptomatic or asymptomatic abdominal/serosa                          |
| Abdominal/pain             | Any current symptoms, including intertriginous irritation, interfering with ambulation, recurrent cellulitis, or ulceration |
| Alcohol use                | Any current alcohol use                                                              |
| Angina                     | Any chest pain symptoms or angina regardless of exertion                               |
| Asthma                     | Any symptoms of asthma regardless of medication usage                                 |
| Back pain                  | Has degenerative changes or positive objective findings, symptoms require narcotic treatment |
| Bipolar disorder           | Confirmed diagnosis of bipolar disorder                                               |
| Cholelithiasis             | Has had gallstones with severe symptoms or has had a cholecystectomy                  |
| Congestive heart failure   | Any history or symptoms of congestive heart failure (Class I, II, III, and IV)        |
| Depression                 | At least moderate depression with significant impairment, undergoing medical or therapeutic treatment |
| DVT/PE                     | Any history of resolved or recurrent deep venous thrombosis or pulmonary embolism    |
| Fibromyalgia               | Any degree of fibromyalgia                                                           |
| Gastroesophageal reflux disease | Symptoms require the use of medical treatment (at least H2 blockers or low-dose proton pump inhibitor) |
| Gout/hyperuricemia         | Has at least symptomatic or asymptomatic hyperuricemia                                |
| Hypertension               | Requires medical treatment with multiple medications                                  |
| Ischemic heart disease     | Has at least abnormal electrocardiogram, regardless of active ischemia; may include history of myocardial infarction |
| Lipids                     | Heightened cholesterol requiring at least single medication                            |
| Liver disease              | Any history of liver disease, including hepatomegaly or non-normal liver function test |
| Lower extremity edema      | Has symptoms requiring treatment, diuretics, elevation, or hose                        |
| Musculoskeletal disease    | Has pain with household ambulation, requires surgical intervention, or past joint replacement |
| Obesity hypovoletertension syndrome | Any symptoms including hypoxemia or hypercarbia on room air                        |
| Obstructive sleep apnea    | Sleep apnea requiring oral appliance, significant hypoxia, or oxygen-dependent        |
| Panic disorder             | Confirmed diagnosis of panic disorder                                                 |
| Peripheral vascular disease| Any symptoms of peripheral vascular disease                                            |
| Personality disorder       | Confirmed diagnosis of personality disorder                                           |
| Psychosocial impairment    | Any indicated psychosocial impairment, regardless of ability to perform primary tasks |
| Pseudotumor cerebri       | Any symptoms of pseudotumor cerebri (at least headaches with dizziness, nausea, or pain behind the eyes) with or without visual symptoms |
| Psychosis                  | Confirmed diagnosis of psychosis                                                     |
| Pulmonary hypertension     | Any symptoms associated with pulmonary hypertension (shortness of breath, dizziness, fainting) |
| Substance abuse            | Any recent substance abuse                                                            |
| Stress urinary incontinence| Frequent stress urinary incontinence, regardless of severity                          |
| Tobacco use                | Any recent tobacco use                                                                |
| Type-2 diabetes            | Diabetes requiring insulin                                                            |

Abbreviations: DVT, deep venous thrombosis; PE, pulmonary embolism.

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readmission rates, and an African-American patient had 34% higher odds of readmission compared to a Caucasian individual holding other factors constant.

For AGB, prolonged length of stay also doubled a patient’s odds of readmission. Male patients had nearly 50% greater odds of readmission than female patients, and disabled and retired employment statuses were more likely to have been readmitted than employed individuals after controlling for other significant demographic and health factors. Patients undergoing AGB with symptomatic asthma, gastroesophageal reflux disease (GERD), obstructive sleep apnea (OSA), or a history of deep venous thrombosis or pulmonary embolism (DVT/PE) had significantly higher odds of being readmitted within 30 days compared to patients without those medical complications.

Discussion

The overall reduction in mortality and the resolution of chronic diseases such as type 2 diabetes are substantial following bariatric surgery [9–15]. However, the potential for serious complications is a barrier for patients and payers to utilizing the long-term advantages offered by bariatric surgery. The penalizing of hospitals for early readmissions is already underway, and several states are imposing mandates that call for further reductions in readmissions. Primary care providers and surgeons alike will see substantial decreases in reimbursements for readmitted patients, and it is therefore imperative that systems be in place to prevent the occurrence of readmissions. In this study, we have identified factors predictive of severe events requiring hospital readmission within 30 days of RYGB or AGB in the largest prospective bariatric cohort to date and have established that short-term risk for readmission is low for both procedures and risk profiles are largely unique to each procedure.

We observed a RYGB readmission rate nearly five times higher than AGB. Previously reported hospital readmission rates for bariatric surgery vary widely in the literature [6,7,16–20]. Possible explanations for these disparities may be due to differences in the patient populations, the definition of a hospital readmission, the
## Table 2. Characteristics of Study Participants by Surgery.

| Variable                        | Roux-en-Y Gastric Bypass (n = 24,662) | Adjustable Gastric Banding (n = 26,002) | P value<sup>a</sup> |
|---------------------------------|--------------------------------------|----------------------------------------|---------------------|
| **Demographics**                |                                      |                                        |                     |
| Age                             | 45.7 (11.6)                          | 46.1 (12.1)                            | <0.001              |
| Female sex                      | 19,259 (78.1)                        | 20,736 (79.8)                         | <0.001              |
| Black race                      | 2265 (9.2)                           | 2890 (11.1)                           | <0.001              |
| Caucasian race                  | 19,973 (81.0)                        | 20,590 (79.2)                         | <0.001              |
| Disabled                        | 2140 (8.7)                           | 1192 (4.6)                            | <0.001              |
| Private insurance               | 20,878 (84.7)                        | 21,478 (82.6)                         | <0.001              |
| Medicare/Medicaid               | 2919 (11.8)                          | 2148 (8.6)                            | <0.001              |
| **Medical history**             |                                      |                                        |                     |
| BMI<sup>b</sup>                 | 47.2 (8.3)                           | 44.2 (6.7)                            | <0.001              |
| Number of medications           | 3.8 (4.0)                            | 2.8 (3.5)                             | <0.001              |
| **Comorbidities**               |                                      |                                        |                     |
| Abdominal hernia                | 1379 (5.6)                           | 1032 (4.0)                            | <0.001              |
| Abdominal/skin pannus           | 2097 (8.5)                           | 1081 (4.2)                            | <0.001              |
| Alcohol use                     | 7469 (30.3)                          | 7194 (27.7)                           | <0.001              |
| Angina                          | 914 (3.7)                            | 576 (2.2)                             | <0.001              |
| Asthma                          | 3312 (13.4)                          | 2707 (10.4)                           | <0.001              |
| Back pain                       | 2629 (10.7)                          | 1926 (7.4)                            | <0.001              |
| Bipolar disorder                | 490 (2.0)                            | 350 (1.4)                             | <0.001              |
| Cholelithiasis                  | 4614 (18.7)                          | 3843 (14.8)                           | <0.001              |
| Congestive heart failure        | 703 (2.9)                            | 435 (1.7)                             | <0.001              |
| Depression                      | 3589 (14.6)                          | 3065 (11.8)                           | <0.001              |
| DVT/PE                          | 937 (3.8)                            | 850 (3.3)                             | 0.001               |
| Fibromyalgia                    | 908 (3.7)                            | 694 (2.7)                             | <0.001              |
| GERD                            | 6473 (26.3)                          | 5629 (21.7)                           | <0.001              |
| Gout/hyperuricemia              | 1006 (4.1)                           | 644 (2.5)                             | <0.001              |
| Hypertension                    | 5850 (23.7)                          | 5051 (19.4)                           | <0.001              |
| Ischemic heart disease          | 1299 (5.3)                           | 1152 (4.4)                            | <0.001              |
| Lipids                          | 6750 (27.4)                          | 6015 (23.1)                           | <0.001              |
| Liver disease                   | 2160 (8.8)                           | 1102 (4.2)                            | <0.001              |
| Lower extremity edema           | 3138 (12.7)                          | 2342 (9.0)                            | <0.001              |
| Musculoskeletal disease         | 2637 (10.7)                          | 2137 (8.2)                            | <0.001              |
| Obesity hypoventilation syndrome| 578 (2.3)                            | 506 (2.0)                             | 0.002               |
| Obstructive sleep apnea         | 7424 (30.1)                          | 5811 (22.4)                           | <0.001              |
| Panic disorder                  | 2073 (8.4)                           | 1520 (5.9)                            | <0.001              |
| Peripheral vascular disease     | 327 (1.3)                            | 227 (0.9)                             | <0.001              |
| Personality disorder            | 189 (0.8)                            | 59 (0.2)                              | <0.001              |
| Psychosocial impairment         | 4321 (17.5)                          | 3040 (11.7)                           | <0.001              |
| Pseudotumor cerebi              | 446 (1.8)                            | 278 (1.1)                             | <0.001              |
| Psychosis                       | 23 (0.1)                             | 15 (0.1)                              | 0.15                |
| Pulmonary hypertension          | 1430 (5.6)                           | 1051 (4.0)                            | <0.001              |
| Substance abuse                 | 105 (0.4)                            | 71 (0.3)                              | 0.004               |
| Stress urinary incontinence     | 2859 (11.6)                          | 2692 (10.4)                           | <0.001              |
| Tobacco use                     | 1805 (7.3)                           | 1748 (6.7)                            | 0.009               |
| Type-2 diabetes requiring insulin| 3029 (12.3)                         | 2030 (7.8)                            | <0.001              |

Abbreviations: BSCOE, bariatric surgery center of excellence; DVT, deep venous thrombosis; GERD, gastroesophageal reflux disease; PE, pulmonary embolism.

<sup>a</sup>P values calculated using t-tests for continuous variables and Pearson's chi-squared tests or Fisher's exact tests for categorical variables.

<sup>b</sup>Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared.

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The proportion of patients within a sample undergoing open versus laparoscopic procedures, or surgeon experience.

The higher readmission and mortality rates for RYGB relative to AGB might suggest that AGB is preferable, however such risks must be weighed with the treatment outcomes. RYGB has been shown to result in greater weight loss and superior improvement in comorbid illness [11,21–23]. Our group recently reported on greater one-year improvements among patients with type 2 diabetes with respect to weight loss, hemoglobin A1C, medication scores, and rates of diabetes resolution for RYGB patients compared to matched AGB controls [11]. Short-term complications must be weighed against the long-term benefits and complications of each procedure.

The clearest predictors of readmission following RYGB were the use of the open surgical approach and prolonged length of stay. While open procedures are justified for certain complex cases...
Table 4. Univariate and Multivariate Models of Risk Factors for 30-Day All-Cause Hospital Readmission by Surgery.

| Variable                         | Roux-en-Y Gastric Bypass Univariate models | Roux-en-Y Gastric Bypass Multivariate model | Adjustable Gastric Banding Univariate models | Adjustable Gastric Banding Multivariate model |
|----------------------------------|------------------------------------------|-------------------------------------------|------------------------------------------|---------------------------------------------|
| Age (5 years)                    | OR (95% CI)                              | OR (95% CI)                               | OR (95% CI)                              | OR (95% CI)                                 |
| Male gender                      | 0.94 (0.83–1.08)                         | -                                         | 1.68 (1.32–2.14)                         | 1.45 (1.12–1.87)                            |
| Race (ref. Caucasian)            | Black/African American                   | 1.32 (1.10–1.58)                         | 0.63 (0.41–0.97)                         | -                                           |
|                                 | Hispanic/Latino                          | 1.01 (0.77–1.31)                         | 0.97 (0.55–1.70)                         | -                                           |
|                                 | Other                                    | 1.06 (0.74–1.51)                         | 0.83 (0.44–1.55)                         | -                                           |
| ASA classification* (ref. "1")  | 2/3 – mild systemic disease              | 1.45 (0.81–2.61)                         | 1.64 (0.77–3.47)                         | 1.41 (0.66–2.99)                            |
|                                 | 4/5 – severe disease                     | 2.23 (1.20–4.16)                         | 4.49 (1.88–10.7)                         | 2.44 (1.01–5.89)                            |
| BMI** (ref. 45–49.9)             | 30–34.9                                  | 1.07 (0.71–1.61)                         | -                                         | -                                           |
|                                 | 35–39.9                                  | 1.02 (0.86–1.22)                         | -                                         | -                                           |
|                                 | 40–44.9                                  | 0.98 (0.84–1.15)                         | -                                         | -                                           |
|                                 | 50–54.9                                  | 1.12 (0.94–1.35)                         | 1.48 (0.96–2.29)                         | -                                           |
|                                 | 55–59.9                                  | 1.15 (0.91–1.46)                         | -                                         | -                                           |
|                                 | 60+                                      | 1.35 (1.10–1.66)                         | -                                         | -                                           |
| Employment status (ref. Employed)| Disabled                                 | 1.55 (1.30–1.85)                         | 2.82 (1.95–4.09)                         | 1.79 (1.21–2.65)                            |
|                                 | Retired                                  | 1.18 (0.96–1.45)                         | 1.98 (1.43–2.73)                         | 1.43 (1.02–2.01)                            |
|                                 | Unemployed                               | 1.26 (1.03–1.53)                         | 1.15 (0.68–1.93)                         | 1.02 (0.60–1.72)                            |
| Payment method (ref. private insurance) | Self-payer                           | 0.67 (0.46–0.97)                         | -                                         | -                                           |
|                                 | Medicare/Medicaid                        | 1.46 (1.24–1.70)                         | 2.22 (1.63–3.03)                         | -                                           |
|                                 | Number of medications (5 med interval)   | 1.25 (1.17–1.34)                         | 1.50 (1.30–1.72)                         | -                                           |
|                                 | Open surgical method                     | 1.93 (1.56–2.39)                         | 2.48 (1.59–10.37)                        | -                                           |
|                                 | Prolonged length of stay                 | 2.47 (2.11–2.89)                         | 3.08 (2.19–4.33)                         | 2.32 (1.63–3.30)                            |
| Comorbidities                   | Alcohol use                              | 0.76 (0.66–0.87)                         | 0.83 (0.63–1.08)                         | -                                           |
|                                 | Angina                                   | 1.41 (1.09–1.83)                         | 2.35 (1.43–3.85)                         | 1.58 (0.95–2.63)                            |
|                                 | Asthma                                   | 1.26 (1.09–1.46)                         | 1.77 (1.32–2.37)                         | 1.52 (1.12–2.05)                            |
|                                 | Cholelithias                              | 1.29 (1.13–1.48)                         | 1.25 (0.93–1.68)                         | -                                           |
|                                 | Depression                               | 1.34 (1.15–1.56)                         | 1.18 (0.85–1.65)                         | -                                           |
|                                 | DVT/PE                                   | 1.49 (1.17–1.91)                         | 2.79 (1.78–4.37)                         | 2.09 (1.32–3.29)                            |
|                                 | GERD                                     | 1.22 (1.08–1.38)                         | 1.54 (1.20–1.97)                         | 1.30 (1.01–1.68)                            |
|                                 | Ischemic heart disease                   | 1.49 (1.21–1.83)                         | 1.86 (1.24–2.79)                         | -                                           |
|                                 | Lower extremity edema                    | 1.24 (1.06–1.45)                         | 1.98 (1.45–1.90)                         | 1.36 (0.99–1.89)                            |
|                                 | Obstructive sleep apnea                  | 1.10 (0.98–1.24)                         | 1.97 (1.56–2.49)                         | 1.45 (1.13–1.87)                            |
|                                 | Psychosocial impairment                  | 1.36 (1.17–1.57)                         | 0.97 (0.69–1.38)                         | -                                           |
|                                 | Pseudotumor cerebri                     | 1.75 (1.20–2.55)                         | 1.82 (0.79–4.22)                         | -                                           |
|                                 | Peripheral vascular disease              | 1.78 (1.23–2.57)                         | 1.28 (0.47–3.50)                         | -                                           |

Abbreviations: ASA, American Society of Anesthesiologists; CI, confidence interval; DVT, deep venous thrombosis; GERD, gastroesophageal reflux disease; OR, odds ratio; PE, pulmonary embolism. Ref denotes the reference group of a categorical variable. The variables for participation of surgical resident, COE volume, abdominal hernia, abdominal pannus, back pain, bipolar disorder, congestive heart failure, fibromyalgia, gout/hyperuricemia, hypertension, lipids, liver disease, musculoskeletal disease, obesity hypoventilation syndrome, panic disorder, personality disorder, psychosis, pulmonary hypertension, substance abuse, stress urinary incontinence, and type-2 diabetes were not significant at $P \leq 0.10$ in univariate analysis and/or not significant in either multivariate model for either surgery and are not shown. Dashes indicate that the variable was not included in the multivariate model because it was removed either for not meeting the significance threshold in the univariate model or for being removed in the backwards selection procedure.

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| Variable                        | Included BSCOE | Excluded BSCOE | P value<sup>a</sup> |
|--------------------------------|----------------|----------------|---------------------|
| **BSCOE**                      |                |                | -                   |
| **Age**                        | 45.6 (11.6)    | 45.1 (11.5)    | <0.001              |
| **Female sex**                 | 20,162 (77.9)  | 17,051 (76.7)  | 0.04                |
| **Race**                       |                |                | <0.001              |
| Black                          | 2406 (9.3)     | 2373 (11.0)    |                     |
| Caucasian                      | 20,909 (80.8)  | 15,808 (73.0)  |                     |
| Hispanic/Latino                | 1789 (6.9)     | 1799 (8.3)     |                     |
| Other                          | 773 (3.0)      | 1684 (7.8)     |                     |
| **ASA Classification**         |                |                | <0.001              |
| 1 – normal, healthy            | 338 (1.3)      | 1337 (6.2)     |                     |
| 2/3 – mild systemic disease    | 24,072 (93.0)  | 19,276 (89.0)  |                     |
| 4/5 – severe/very severe disease | 1467 (5.7)   | 1051 (4.9)     |                     |
| **BMI**<sup>b</sup>           | 47.2 (8.3)     | 47.3 (8.3)     | 0.37                |
| **Employment status**          |                |                | <0.001              |
| Employed                       | 19,879 (76.8)  | 16,885 (77.9)  |                     |
| Disabled                       | 2273 (8.8)     | 1680 (7.8)     |                     |
| Retired                        | 1819 (7.0)     | 1425 (6.6)     |                     |
| Unemployed                     | 1906 (7.4)     | 1674 (7.7)     |                     |
| **Payment Information**        |                |                | 0.10                |
| Private insurance              | 21,876 (84.5)  | 18,467 (85.2)  |                     |
| Self-payer                     | 903 (3.5)      | 731 (3.4)      |                     |
| Medicare/Medicaid              | 3098 (12.0)    | 2466 (11.4)    |                     |
| **Number of medications**      | 3.8 (4.0)      | 3.2 (3.8)      | <0.001              |
| **Comorbidities**              |                |                |                     |
| Abdominal hernia               | 1456 (5.6)     | 939 (4.3)      | <0.001              |
| Abdominal/skin pannus          | 2180 (8.4)     | 1111 (5.1)     | <0.001              |
| Alcohol use                    | 7798 (30.1)    | 6167 (28.5)    | <0.001              |
| Angina                         | 976 (3.8)      | 488 (2.3)      | <0.001              |
| Asthma                         | 3477 (13.4)    | 2903 (13.4)    | 0.91                |
| Back pain                      | 2754 (10.6)    | 1982 (9.2)     | <0.001              |
| Bipolar disorder               | 521 (2.0)      | 446 (2.1)      | 0.74                |
| Cholelithiasis                 | 4836 (18.7)    | 3470 (16.0)    | <0.001              |
| Congestive heart failure       | 751 (2.9)      | 437 (2.0)      | <0.001              |
| Depression                     | 3782 (14.6)    | 2890 (13.3)    | <0.001              |
| DVT/PE                         | 971 (3.8)      | 612 (2.8)      | <0.001              |
| Fibromyalgia                   | 949 (3.7)      | 670 (3.1)      | <0.001              |
| GERD                           | 6781 (26.2)    | 5073 (23.4)    | <0.001              |
| Gout/hyperuricemia             | 1036 (4.0)     | 655 (3.0)      | <0.001              |
| Hypertension                   | 6115 (23.6)    | 4587 (21.2)    | <0.001              |
| Ischemic heart disease         | 1374 (5.3)     | 917 (4.2)      | <0.001              |
| Lipids                         | 7014 (27.1)    | 5562 (25.7)    | <0.001              |
| Liver disease                  | 2264 (8.8)     | 1091 (5.0)     | <0.001              |
| Lower extremity edema          | 3287 (12.7)    | 2370 (10.9)    | <0.001              |
| Musculoskeletal disease        | 2766 (10.7)    | 2319 (10.7)    | 0.96                |
| Obesity hypoventilation syndrome | 608 (2.4) | 525 (2.4) | 0.60                |
| Obstructive sleep apnea        | 7779 (30.1)    | 6474 (29.9)    | 0.67                |
| Panic disorder                 | 2175 (8.4)     | 1483 (6.9)     | <0.001              |
| Peripheral vascular disease    | 247 (1.3)      | 241 (1.1)      | 0.02                |

<sup>a</sup> P value for t-test or chi-square test.

<sup>b</sup> BMI values may be lower than expected due to the nature of the surgery.

For more information, please refer to Table 5 in the original document.
our results, when considered with previous research [25], suggest that laparoscopic techniques should be preferred to open surgery in the absence of contraindications for laparoscopy.

Patients with previous histories of bariatric surgery or other anatomical abnormalities may be best suited for open surgeries and would understandably be at higher risk for readmission. However, 7.6% of hospitals [19 of 249 BSCOE] conducted >80% of their RYGB procedures using the open approach and accounted for 46.6% of all open procedures in the database, suggesting that the open approach may be often dictated by surgeon preference in these hospitals rather than case difficulty.

The importance of serious comorbid disease on readmission risk for RYGB patients is expected, though the causal pathway of elevated risk for African-Americans is less clear. We suspect that the association with race may have been confounded by unmeasured variables such as surgical preparation, social support, economic status, or dietary intake. For AGB, readmission risk factors were quite different from those identified with RYGB with the exception of prolonged length of stay and severe ASA score: disability status, asthma, male gender, history of DVT/PE, and the presence of OSA or GERD.

Surprisingly, the profiles of risk factors for readmission were almost entirely distinct for the AGB and RYGB procedures. Prolonged length of stay following surgery was one of the only factors that significantly predicted readmissions in both surgical populations in multivariate analysis. That procedure-specific risk factors contrast so greatly between the two procedures is an important finding potentially overlooked by prior investigations. Previous studies have chosen to pool patients across procedures for analysis assuming that the underlying risk factors were the same [5, 26]. While several of our results are complementary, the choice to aggregate surgical patients may account for some important differences in results. Some previous studies examining readmission rates have identified high BMI as a risk factor for readmission [5, 17], while our own did not. Risk analyses that pooled patients from multiple procedures may have observed an artificial inflation of risk for high-BMI patients who tend to undergo RYGB, which has a significantly higher readmission rate than AGB. The relationship between BMI and readmission risk may also have been confounded by a less complete comorbidity profile in risk models, since many conditions are more prevalent among individuals of greater weight. The ability to examine the role of a very extensive list of comorbidities is a major strength of this analysis.

Many of the identified risk factors, while complex, multifactorial, and often not necessarily modifiable, provide an impetus to follow patients at higher risk for readmission more aggressively following discharge. Prolonged length of stay, for example, was identified as an important risk factor yet the reasons for the longer stay varied widely in BOLD; both preoperative and perioperative factors can interact to influence the duration of a patient’s stay. Despite this heterogeneity, prolonged length of stay could be utilized as a prompt for enhanced post-discharge monitoring in patients at higher risk for readmission. Intervention studies are needed to determine if and how enhanced monitoring, adjunctive treatments, or additional education might reduce readmission rates for high-risk patients. Certainly, enhanced monitoring is unlikely to prevent more serious readmissions such as those in patients who develop gastrointestinal leaks or obstructions. Further, it is unknown at this time how much effort would need to be applied to significantly lower the current readmission rates that are already acceptably low. However, it may be possible to impact the most prevalent reasons for readmission, nausea and vomiting, by establishing infusion centers for patients suffering from a slow return of bowel function and dehydration.

It is important to recognize the magnitude of relative risk differences associated with the predictors of readmission in this analysis; primarily, comorbid conditions must be weighed with the absolute risk for each procedure. For example, a relative risk of 1.5 for a high-risk patient group compared to a group of typical patients would equate to an increase of the readmission rate from 5.8% to 8.7% for RYGB and from 1.2% to 1.8% for AGB, or absolute risk differences of 2.9% and 0.6%, respectively. Patients, payers, and practitioners alike may find these higher risks acceptable if outweighed by the benefits of surgery, which are often greatest among patients with more severe comorbidity profiles. For these reasons, we deem that the current results do not support patient selection, but rather highlight patient groups that could benefit from appropriate preventative or educational efforts, and possibly, closer post-discharge follow-up.

This study has several limitations. The exclusion of centers with low follow-up rates is the most important limitation, since it is

| Variable                | Included BSCOE (n = 25,877) | Excluded BSCOE (n = 21,664) | P valuea |
|-------------------------|----------------------------|----------------------------|----------|
| Personality disorder    | 196 (0.8)                  | 52 (0.2)                   | <0.001   |
| Psychosocial impairment| 4544 (11.6)                | 3138 (14.5)                | <0.001   |
| Pseudotumor cerebri    | 467 (1.8)                  | 635 (2.9)                  | <0.001   |
| Psychosis               | 23 (0.1)                   | 24 (0.1)                   | 0.47     |
| Pulmonary hypertension  | 1502 (5.8)                 | 727 (3.4)                  | <0.001   |
| Substance abuse         | 111 (0.4)                  | 96 (0.4)                   | 0.83     |
| Stress urinary incontinence | 2968 (11.5)            | 2683 (12.4)                | 0.002    |
| Tobacco use             | 1910 (7.4)                 | 1447 (6.7)                 | 0.003    |
| Type-2 diabetes         | 3172 (12.3)                | 2493 (11.5)                | 0.01     |

Abbreviations: BSCOE, bariatric surgery center of excellence; DVT, deep venous thrombosis; GERD, gastroesophageal reflux disease; PE, pulmonary embolism.

aP values calculated using a t-test for continuous variables and Pearson’s chi-squared test or Fisher’s exact test for categorical variables.

bBody mass index (BMI) was calculated as weight in kilograms divided by height in meters squared.
Table 6. Comparison of AGB Patients from Included and Excluded BSCOE.

| Variable                | Included BSCOE | Excluded BSCOE | P value* |
|-------------------------|----------------|----------------|----------|
|                         | n = 26,765     | n = 8814       |          |
| BSCOE                   | 317 (68.3)     | 147 (31.7)     | -        |
| Age                     | 46.1 (12.1)    | 46.5 (12.3)    | 0.01     |
| Female sex              | 21,319 (79.7)  | 6919 (78.5)    | 0.02     |
| Race                    |                |                | <0.001   |
| Black/African American  | 2979 (11.1)    | 942 (10.7)     |          |
| Caucasian               | 21,171 (79.1)  | 6183 (70.2)    |          |
| Hispanic/Latino         | 1089 (4.1)     | 674 (7.7)      |          |
| Other                   | 1526 (5.7)     | 1015 (11.5)    |          |
| ASA Classification      | 0.004          |                |          |
| 1 – normal, healthy     | 1388 (5.2)     | 381 (4.3)      |          |
| 2/3 – mild systemic disease | 24,635 (92.0) | 8200 (93.0) |          |
| 4/5 – severe/very severe disease | 742 (2.8) | 233 (2.6) |          |
| BMI                      | 44.2 (6.7)     | 44.2 (7.2)     | 0.62     |
| Employment Status       |                |                | <0.001   |
| Employed                | 21,937 (82.0)  | 7132 (80.9)    |          |
| Disabled                | 1240 (4.6)     | 527 (6.0)      |          |
| Retired                 | 2313 (8.6)     | 783 (8.9)      |          |
| Unemployed              | 1275 (4.8)     | 372 (4.2)      |          |
| Payment Information     |                |                | <0.001   |
| Private Insurance       | 22,085 (82.5)  | 7169 (81.3)    |          |
| Self-Payer              | 2447 (9.1)     | 652 (7.4)      |          |
| Medicare/Medicaid       | 2233 (8.3)     | 993 (11.3)     |          |
| Number of medications   | 2.8 (3.5)      | 3.1 (3.5)      | <0.001   |
| Comorbidities           |                |                |          |
| Abdominal hernia        | 1054 (3.9)     | 486 (5.5)      | <0.001   |
| Abdominal/Skin pannus   | 1107 (4.1)     | 381 (4.3)      | 0.44     |
| Alcohol use             | 7407 (27.7)    | 2750 (31.2)    | <0.001   |
| Angina                  | 596 (2.2)      | 158 (1.8)      | 0.01     |
| Asthma                  | 2788 (10.4)    | 893 (10.1)     | 0.45     |
| Back pain               | 1999 (7.5)     | 626 (7.1)      | 0.25     |
| Bipolar disorder        | 364 (1.4)      | 140 (1.6)      | 0.12     |
| Cholelithiasis          | 3938 (14.7)    | 1146 (13.0)    | <0.001   |
| Congestive heart failure| 445 (1.7)      | 140 (1.6)      | 0.66     |
| Depression              | 3144 (11.8)    | 767 (8.7)      | <0.001   |
| DVT/PE                  | 878 (3.3)      | 218 (2.5)      | <0.001   |
| Fibromyalgia            | 708 (2.7)      | 240 (2.7)      | 0.70     |
| GERD                    | 5783 (21.6)    | 1563 (17.7)    | <0.001   |
| Gout/hyperuricemia      | 661 (2.5)      | 414 (4.7)      | <0.001   |
| Hypertension            | 5197 (19.4)    | 1693 (19.2)    | 0.67     |
| Ischemic heart disease  | 1197 (4.5)     | 359 (4.1)      | 0.12     |
| Lipids                  | 6192 (23.1)    | 2278 (25.9)    | <0.001   |
| Liver disease           | 1151 (4.3)     | 438 (5.0)      | 0.008    |
| Lower extremity edema   | 2413 (9.0)     | 671 (7.6)      | <0.001   |
| Musculoskeletal disease | 2219 (8.3)     | 814 (9.1)      | 0.02     |
| Obesity hypoventilation syndrome | 517 (1.9) | 150 (1.7) | 0.17 |
| Obstructive sleep apnea | 5993 (22.4)    | 1931 (21.9)    | 0.34     |
| Panic disorder          | 1567 (5.9)     | 541 (6.1)      | 0.33     |
| Peripheral vascular disease | 234 (0.9) | 89 (1.0) | 0.24 |
possible that BSCOE excluded for low follow-up rates may have been the hospitals with the highest readmission rates, as well. Our sensitivity analyses comparing included and excluded centers did not indicate that there were substantive clinical differences between the patient populations (Tables 5 and 6), and if such a bias were present, it is highly unlikely that an underestimation of readmission rates would have a considerable impact on the strength or direction of the risk factors themselves. Long-term follow-up in BOLD was limited and precluded the examination of readmissions occurring beyond 30 days. RYGB patients continue to require readmission up to and beyond one year, and the need for band revisions generally do not occur within the first 30 days of

Table 6. Cont.

| Variable                  | Included BSCOE | Excluded BSCOE |
|---------------------------|----------------|----------------|
|                           | n = 26,765     | n = 8814       |
| Personality disorder      | 62 (0.2)       | 10 (0.1)       |
| Psychosocial impairment   | 3145 (11.8)    | 1034 (11.7)    |
| Pseudotumor cerebri       | 290 (1.1)      | 88 (1.0)       |
| Psychosis                 | 15 (0.1)       | 6 (0.1)        |
| Pulmonary hypertension    | 1084 (4.1)     | 167 (1.9)      |
| Substance abuse           | 73 (0.3)       | 35 (0.4)       |
| Stress urinary incontinence| 2748 (10.3)    | 833 (9.5)      |
| Tobacco use               | 1813 (6.8)     | 568 (6.4)      |
| Type-2 diabetes           | 2093 (7.8)     | 670 (7.6)      |

Abbreviations: BSCOE, bariatric surgery center of excellence; DVT, deep venous thrombosis; GERD, gastroesophageal reflux disease; PE, pulmonary embolism.

*P values calculated using a t-test for continuous variables and Pearson’s chi-squared test or Fisher’s exact test for categorical variables.

Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared.

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Figure 3. Loess plot of RYGB readmission rates on follow-up rates. Circles represent BSCOE hospitals with the size weighted by the number of patients who underwent the procedure in the hospital during the study period.

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surgery; however, the greatest proportion of readmissions occur within 30 days [17,18], so the current study likely captures the most important risk factors for readmission.

The present analysis was also unable to control for surgeon volume, an important factor in readmission [16,19,20]. However, surgeons reporting to BOLD must log over 50 cases annually in order to maintain BSCOE certification. Also, the distribution of readmission rates was not consistent with a uniform rate across centers (Figures 3 and 4). An appreciable number of BSCOE, for AGB in particular, reported readmission rates considerably lower than would be expected under a constant rate across centers of varying surgical volume. We suspect that unusually low BSCOE readmission rates reflect unmeasured variables such as surgical experience, and those with high rates of readmission could be indicative of either surgeon inexperience, case difficulty, or surgeon preference for open procedures. Data entered into BOLD is self-reported by BSCOE, so post-discharge events are potentially underreported in the database, though our selection of centers with high follow-up rates was undertaken to offset potential underreporting in the larger database.

Finally, the observational nature of the study precludes causal inference about risk factors. Given that examination of factors influencing relatively rare events like readmissions requires thousands of patients to be adequately powered to assess differences in risk, it is unlikely that randomized studies of these factors will ever be performed. Therefore, decisions on patient selection and risk calculations will inevitably be based on large prospective observational databases like BOLD. Nested case-control studies, in which more extensive collection of possible explanatory variables is performed, may shed light on the problem of unmeasured confounders in the BOLD dataset.

In conclusion, we have characterized patterns of risk for readmission associated with patient and intraoperative factors for the two most common bariatric procedures in the largest prospective cohort of bariatric surgery patients to date. While the overall readmission rates for both procedures are low, the present results may prove to be an important clinical tool in the development of patient education programs, algorithms for procedure selection, and follow-up plans. In an effort to maximize patient benefit and cost-effectiveness of bariatric surgery and to reduce penalties from payers, primary care providers and surgeons should understand patient-specific risks to optimize clinical care for patients when both selecting for and immediately following their bariatric operation.

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**Author Contributions**

Conceived and designed the experiments: RBD CJM DBL FJS BS HB JEC SI. Analyzed the data: RBD CJM JEC SI. Contributed reagents/materials/analysis tools: BS. Wrote the paper: RBD CJM JEC SI. Conducted statistical analyses: CJM JEC. Contributed to manuscript revisions: DBL FJS BS HB.
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