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Postoperative bleeding after laparoscopic Roux en Y gastric bypass: predictors and consequences

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Abstract

Background Laparoscopic Roux-en-Y gastric bypass (LRYGB) is a common, safe and effective bariatric procedure. Bleeding is a significant source of postoperative morbidity. We aimed to determine the incidence, outcomes, and predictors of postoperative bleeding after LRYGB.

Methods LRYGB patients included in the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) 2015 dataset were identified. Preoperative and intraoperative factors were tested for associations with bleeding using univariable and multivariable logistic regression analysis. Outcomes of length of stay, in-hospital mortality, 30-day mortality, discharge disposition, and 30-day complications among patients with and without clinically significant postoperative bleeding were compared using multivariable regression.

Results In the 43,280 LRYGB patients included in this analysis, postoperative bleeding occurred in 652 (1.51%) patients. Of these, 165 (25.3%) underwent a re-operation and 97 (14.9%) underwent an unplanned endoscopy for 'bleeding'. Postoperative bleeding was associated with a longer median postoperative length of stay (4 vs. 2 days), higher in-hospital mortality (1.23 vs. 0.04%), higher 30-day mortality (1.38 vs. 0.15%), discharge to an extended-care facility (3.88 vs. 0.6%), and higher rates of major complications (all $P < 0.05$). Independent predictors of postoperative bleeding included; a history of renal insufficiency (OR 2.55, 95% CI 1.43–4.52), preoperative therapeutic anticoagulation (OR 2.44, 95% CI 1.69–3.53), and revisional surgery (OR 1.45, 95% CI 1.06–1.97). Intraoperative associated factors included conversions (OR 3.37, 95% CI 1.42–7.97), and drain placement (OR 1.40, 95% CI 1.18–1.67). Robotic approaches resulted in independently lower postoperative bleeding rates (OR 0.50, 95% CI 0.32–0.77).

Conclusions Postoperative bleeding occurs in 1.5% of patients undergoing a LRYGB and is associated with significantly increased morbidity and mortality. We have identified patient and operative factors that are independently associated with postoperative bleeding.

Keywords Bariatric surgery · Complications · Weight loss surgery · Outcomes

Laparoscopic Roux-en-Y Gastric Bypass (LRYGB) is a commonly performed weight-loss operation in the United States, with approximately 40,000 cases occurring annually [1, 2]. While often considered the "gold standard" bariatric operation and associated with significant, durable weight loss, it still has appreciable complications. Major complications occur in up to 12.4% of cases and mortality in up to 0.4% [3, 4]. Important early complications include leaks, obstruction, and hemorrhage [3–6].

Postoperative hemorrhage occurs in roughly 3% of patients and is associated with increases in re-operations, hospital length of stay, and mortality [7, 8]. It is theorized that surgical technique, patient illness severity, and specific preoperative comorbidities play a role in predisposing patients to postoperative hemorrhage. To our knowledge, there has been no comprehensive analysis of these predictors of postoperative bleeding after LRYGB. Since the incidence of postoperative bleeding complications is relatively low,

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only large multicenter analyses could adequately explore these associations. We aimed to determine the incidence, outcomes and predictors of postoperative bleeding after LRYGB using a large national dataset.

Methods

Data set

We analyzed data from the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) 2015 Participant Use File (PUF) [9]. The MBSAQIP representing a collaboration between the American College of Surgeons and the American Society for Metabolic and Bariatric Surgery, is the largest bariatric specific clinical dataset in the United States. It contains information on all metabolic and bariatric procedures and interventions performed by participating centers. Over 200 variables are collected which include preoperative, intraoperative, and postoperative factors. Outcomes are measured over a 30-day postoperative period. The dataset contains information from over 160,000 patients from > 740 participating centers across the United States.

The MBSAQIP participant user file contains no identifying information on patients, hospitals or health care workers. It is Health Insurance Portability and Accountability Act (HIPAA) compliant and exempt from IRB review. All variables herein are as defined by the publicly available 2015 MBSAQIP PUF Variables and Definition Manual [9].

Patient selection and variables

We selected all patients that underwent a LRYGB (CPT code 43644). Patients at extremes of ages (< 10 or > 80 years), or who underwent mini gastric bypasses, gastric plications and natural orifice operations were excluded. We utilized demographic, preoperative, intraoperative and outcome information. Demographics included age, gender, ethnicity, and biometrics including the preoperative weight and body mass index (BMI). Preoperative variables included history of comorbid conditions, medication history, American Society of Anesthesiologists (ASA) score, information on prior relevant surgeries, and preoperative hematocrit and albumin levels. Intraoperative variables included operating times, approach, assistant level of training, conversions, and concurrent procedures (liver biopsy, hiatal hernia repair, laparoscopic cholecystectomy, and band removal). Outcomes included postoperative length of stay, in-hospital mortality, 30-day mortality, 30-day complications, discharge disposition, 30-day readmissions, and any unplanned procedure or intervention.

Postoperative bleeding (POB) was defined as any hemorrhagic event that required a blood transfusion within 72 h of operation or required a procedural intervention for "bleeding." For the purposes of analysis, age was stratified by decile. BMI was categorized as < 35, 35–40, 40–50, 50–70, and > 70 kg/m^2. Preoperative hematocrit was categorized as < 21, 21–30, 30–36, 36–45, and > 45%. Preoperative albumin was dichotomized by values above or below 3 g/dl.

Analysis

Categorical variables were reported as frequency and proportions. Means with standard deviations (SD) were calculated for continuous variables. Skewed continuous variables such as length of stay were summarized by medians and interquartile ranges. The frequency of patients requiring blood transfusions within 72 h and those requiring an operative, endoscopic or other intervention for 'bleeding' were summed to arrive at the frequency and proportion of those that suffered a postoperative bleeding. All preoperative and intraoperative variables were tested for associations with postoperative bleeding using the Chi-square test. Factors significant on univariate analysis and those that were clinically relevant were selected for the multivariable model. The variables 'previous foregut/bariatric surgery' was collinear with 'revisional surgery' and thus the previous foregut surgery variable was not used in the model. Multivariable logistic regression analysis was used to identify independent factors associated with postoperative bleeding events.

Outcomes of LOS, in-hospital mortality, 30-day mortality, discharge disposition, and 30-day complications were compared for patients that suffered a postoperative bleed (POB) versus those that did not using the chi-square test. Multivariate models were constructed to test for the independent association of POB with outcomes of 30-day mortality, postoperative length of stay, and any complication. Clinically relevant factors and those significant upon univariate analysis with the outcome were included in the final models. Multivariable logistic regression was used for the binary outcomes of mortality and complications while generalized linear modeling with log link was used for the length of postoperative stay outcome variable. All models were tested for fit using the Hosmer–Lemeshow goodness of fit [10]. Significance was determined at a two-sided *P*-value of 0.05 or less. All analyses were performed using STATA Version 13 (STATACorp, College Station, TX).

Results

A total of 43,280 patients undergoing a LRYGB were included in the analysis. The mean age was 45.4 years (SD ± 12 years). Eighty percent of patients were female and 77% reported being of White ethnicity. The mean BMI was 46.0 kg/m^2 (SD ± 8.4 kg/m^2). A total of 652 (1.51%) patients suffered a POB. Of these 165 (25.3%) underwent a re-operation and 97 (14.9%) underwent an unplanned endoscopic procedure. Patients received a mean 2.6 units of packed red blood cells (range of 1–13 units). Upon bivariate analysis between patients that did and did not suffer a POB, several significant differences were found. These are summarized in Table 1. Patients undergoing revisional surgery had a POB rate of 2.4%.

After multivariable logistic regression (Table 2) independent factors associated with postoperative bleeding included: history of deep vein thrombosis (OR 1.62, 95% CI 1.02–2.59), history of renal failure (OR 2.55, 95% CI 1.43–4.52), preoperative therapeutic anticoagulation (OR 2.44, 95% CI 1.69–3.53), conversion to an open procedure (OR 3.37, 95% CI 1.42–7.97), drain placement (OR 1.40, 95% CI 1.18–1.67), and revisional surgery (OR 1.45, 95% CI 1.06–1.97). If an attending non-bariatric surgeon was assisting in the procedure, the likelihood of POB was 40% lower than a resident assistant (OR 0.60, 95% CI 0.38–0.97). A robotic approach was also associated with a 50% lower likelihood of having a postoperative bleed (OR 0.50, 95% CI 0.32–0.77). BMI, age, sex, prolonged operations, concurrent procedures, and lower serum albumin levels < 3.0 g/dl were not independently associated with POB. The model was also adjusted for preoperative hematocrit levels and this factor was significant in the final model. Since our definition of POB is based on interventions performed for bleeding (transfusions and procedures), the association of hematocrit with bleeding most likely represents a threshold effect. Patients with lower hematocrit levels are more likely to reach a transfusion and intervention threshold after bleeding than patients with a higher preoperative hematocrit level.

Patients that suffered a POB were more likely to have adverse outcomes. Postoperative bleeding was associated with a longer median postoperative length of stay (4 vs. 2 days), higher in-hospital mortality (1.23 vs. 0.04%), higher 30-day mortality (1.38 vs. 0.15%), discharge to an extended-care facility (3.88 vs. 0.62%), and higher rates of major complications including acute renal failure (2.45 vs. 0.12%), cardiac arrest (1.38 vs. 0.06%), myocardial infraction (1.07 vs. 0.04%), pneumonia (1.84 vs. 0.41%), and pulmonary embolism (1.53 vs. 0.15%) (all $P < 0.05$) (Table 3). Upon multivariable analysis, significant independent associations were found between patients that suffered a postoperative bleed and postoperative complications (OR 5.4, 95% CI 4.26–6.86), length of stay (OR 2.3, 95% CI 2.24–2.42), and 30-day mortality (6.2, 95% CI 2.78–13.84). Subset analyses excluding patients with revisional surgery yielded similar results. The overall rate of POB was 1.42% with similarly adverse outcomes.

Discussion

At MBSAQIP participating centers, postoperative bleeding occurred in 1.5% of patients undergoing LRYGB and was associated with significantly increased morbidity and mortality. Postoperative bleeding was associated with a longer length of stay, higher in-hospital mortality, higher 30-day mortality, discharge to an extended-care facility, and higher rates of major complications. Furthermore, we found several independent factors associated with postoperative bleeding, including history of renal insufficiency, preoperative therapeutic anticoagulation, revisional surgery, conversion operations, and certain intraoperative factors. The 1.5% incidence of postoperative bleed is consistent with previous studies. Fesco et al. found a bleeding rate of 2.16% in their retrospective study of all bariatric operations at their institution [11]. Rondelli et al. found a bleeding rate of 1.0% within 30 days of undergoing LRYGB [12], similarly Heneghan et al. found a rate of 0.94% within 30 days of undergoing either laparoscopic or open RYGB [13].

Prior reports have demonstrated postoperative complications to have adverse sequelae for both the patient and the hospital. Fesco et al. found patients who developed postoperative bleeding stayed almost three times longer than the patients who had an uncomplicated postoperative course [11]. Dick et al. found a similar increase in mean length of stay in patients who developed postoperative bleeding, increased from a mean of 3 days to 4.8 [14]. Heneghan et al. also found that discharge was delayed more than 4 days in 87% of patients who experienced an early postoperative bleed and a mean length of hospital stay 11.43 days [13]. Similar to our findings, they found significant morbidity as a consequence of bleeding in 35% of patients, including respiratory complications, sepsis or infected hematomas, and systemic inflammatory response syndrome-induced multiple organ failure [13]. In a large study examining the etiologies and risk factors for readmission following bariatric surgery, Garg et al. found that readmission was highly associated with any in-hospital complication [15]. Specifically, 40.4% of patients with readmissions had experienced a complication at the initial hospital stay and 6.6% of all readmissions were due to hemorrhage. Moreover, patients with bleeding in the early postoperative period were almost three times more likely to be readmitted (1.3 vs. 3%, $P < 0.001$). Our results also demonstrate POB to be associated with a myriad of adverse outcomes. These are summarized in Table 3. Unlike prior smaller studies, we were able to assess several specific complications due to the large number of patients available in the dataset.

Not surprisingly, postoperative complications consume significant health care resources leading to increased cost

Table 1 Bivariate analysis of preoperative and operative factors amongst patient that suffered a postoperative bleeding episode and those that did not from the MBSAQIP (n=43,280)

Variable	Categories	No POB (n=42,628) n (%)	POB (n=652) n (%)	Total n (%)	P-value
Demographics					
Age (years)	<30	4209 (9.9)	51 (7.8)	4260 (9.8)	0.018
	30–39	9941 (23.3)	140 (21.5)	10,081 (23.3)	
	40–49	12,433 (29.2)	184 (28.2)	12,617 (29.2)	
	50–59	10,331 (24.4)	163 (25.0)	10,494 (24.3)	
	≥60	5714 (13.4)	114 (17.5)	5828 (13.5)	
Sex	Male	8483 (19.9)	156 (23.9)	8639 (20.0)	0.011
	Female	34,145 (80.1)	496 (76.1)	34,641 (80.0)	
Ethnicity	American Indian	192 (0.5)	2 (0.3)	194 (0.5)	0.358
	Asian	170 (0.4)	3 (0.5)	173 (0.4)	
	Black or AA	6174 (14.5)	107 (16.4)	6281 (14.5)	
	Native Hawaiian	165 (0.4)	4 (0.6)	169 (0.4)	
	White	32,690 (76.7)	498 (76.4)	33,188 (76.7)	
	Missing	3237 (7.6)	38 (5.8)	3275 (7.6)	
BMI category	<35	1598 (3.8)	40 (6.1)	1638 (3.8)	0.010
	35–40	8318 (19.5)	141 (21.6)	8459 (19.5)	
	40–50	21,289 (49.9)	297 (45.6)	21,586 (49.9)	
	50–70	10, 595 (24.9)	161 (24.7)	10,756 (24.9)	
	>70	605 (1.4)	10 (1.5)	615 (1.4)	
Preoperative comorbid conditions					
GERD	Yes	16,221 (38.1)	277 (42.5)	16,498 (38.1)	0.021
	No	26,407 (61.9)	375 (57.5)	26,782 (61.9)	
Limited ambulation	Yes	975 (2.3)	22 (3.4)	997 (2.3)	0.066
	No	41,653 (97.7)	630 (96.6)	42,283 (97.7)	
Prior myocardial infarction	Yes	648 (1.5)	21 (3.2)	669 (1.6)	0.000
	No	41,980 (98.5)	631 (96.8)	42,611 (98.5)	
Prior cardiac surgery	Yes	470 (1.1)	21 (3.2)	491 (1.1)	0.000
	No	42,158 (98.9)	631 (96.8)	42,789 (98.8)	
Prior PCI/PTCA	Yes	1009 (2.4)	28 (4.3)	1037 (2.4)	0.001
	No	41,619 (97.6)	624 (95.7)	42,243 (97.6)	
Hypertension	Yes	22,623 (53.1)	398 (61.0)	23,021 (53.2)	0.000
	No	20,005 (46.9)	254 (39.0)	20,259 (46.8)	
Therapeutic anticoagulation	Yes	961 (2.3)	50 (7.7)	1011 (2.3)	0.000
	No	41,667 (97.8)	602 (92.3)	42,269 (97.7)	
Hyperlipidemia	Yes	12,446 (29.2)	228 (35.0)	12,674 (29.3)	0.001
	No	30,182 (70.8)	424 (65.0)	30,606 (70.7)	
Prior deep venous thrombosis	Yes	731 (1.7)	30 (4.6)	761 (1.8)	0.000
	No	41,897 (98.3)	622 (95.4)	42,519 (98.2)	
Venous stasis	Yes	519 (1.2)	15 (2.3)	534 (1.2)	0.013
	No	42,109 (98. 8)	637 (97.7)	42,746 (98.8)	
On dialysis	Yes	70 (0.2)	3 (0.5)	73 (0.2)	0.068
	No	42,558 (99.9)	649 (99.5)	43,207 (99.8)	
Renal insufficiency	Yes	264 (0.6)	17 (2.6)	281 (0.7)	0.000
	No	42,364 (99.4)	635 (97.4)	42,999 (99.4)	
Prior foregut surgery	Yes	3705 (8.7)	92 (14.1)	3797 (8.8)	0.000
	No	38,923 (91.3)	560 (85.9)	39,483 (91.2)	
Diabetes mellitus	Yes	28,134 (66.0)	396 (60.7)	28,530 (65.9)	0.005
	No	14,494 (34.0)	256 (39.3)	14,750 (34.1)	

Table 1 (continued)

Variable	Categories	No POB ($n=42{,}628$) *n* (%)	POB ($n=652$) *n* (%)	Total *n* (%)	*P*-value
Smoked within the past year	Yes	3600 (8.5)	59 (9.1)	3659 (8.5)	0.582
	No	39,028 (91.6)	593 (91.0)	39,621 (91.6)	
Pre-surgical functional status	Independent	42,212 (99.0)	640 (98.2)	42,852 (99.0)	0.034
	Partially dependent	328 (0.8)	8 (1.2)	336 (0. 8)	
	Totally dependent	88 (0.2)	4 (0.6)	92 (0.2)	
History of COPD	Yes	897 (2.1)	23 (3.5)	920 (2.1)	0.012
	No	41,731 (97.9)	629 (96.5)	42,360 (97.9)	
Oxygen dependence	Yes	380 (0.9)	7 (1.1)	387 (0.9)	0.624
	No	42,248 (99.1)	645 (98.9)	42,893 (99.1)	
History of pulmonary embolism	Yes	496 (1.2)	18 (2.7)	514 (1.2)	0.000
	No	42,132 (98.8)	634 (97.2)	42,766 (98.8)	
Obstructive sleep apnea requiring CPAP/BiPAP	Yes	17,676 (41.5)	287 (44.0)	17,963 (41.5)	0.189
	No	24,952 (58.5)	365 (56.0)	25,317 (58.5)	
Chronic steroid/immuno-suppressant use	Yes	591 (1.4)	11 (1.7)	602 (1.4)	0.515
	No	42,037 (98.6)	641 (98.3)	42,678 (98.6)	
Pre-op IVC filter	Yes	468 (1.1)	14 (2.2)	482 (1.1)	0.011
	No	42,160 (98.9)	638 (97.9)	42,798 (98.9)	
Intraoperative factors					
Robotic approach	Yes	2949 (6.9)	24 (3.7)	2973 (6.9)	0.001
	No	39,679 (93.1)	628 (96.3)	40,307 (93.1)	
Approach converted to open	Yes	85 (0.2)	6 (0.9)	91 (0.2)	0.000
	No	42,543 (99.8)	646 (99.0)	43,189 (99.8)	
Re-operation revision/conversion	Yes	3591 (8.4)	90 (13.8)	3681 (8.5)	0.000
	No	39,037 (91.6)	562 (86.2)	39,599 (91.5)	
Drain placed	Yes	14,096 (33.1)	270 (41.4)	14,366 (33.2)	0.000
	No	28,532 (66.9)	382 (58.6)	28,914 (66.8)	
ASA classification	I	114 (0.3)	0 (0.0)	114 (0.3)	0.121
	II	7596 (17.8)	105 (16.1)	7701(17.8)	
	III	32,912 (77.2)	505 (77.5)	33,417 (77.2)	
	IV	1944 (4.6)	42 (6.4)	1986 (4.6)	
	None assigned	62 (0.1)	0 (0.0)	62 (0.1)	
Pre-op hematocrit	<21	51 (0.1)	3 (0.5)	54 (0.1)	0.000
	21–30	118 (0.3)	13 (2.0)	131 (0.3)	
	30–36	2753 (6.5)	59 (9.1)	2812 (6.5)	
	36–45	30,576 (71.7)	426 (65.3)	31,002 (71.6)	
	>45	4591 (10.8)	82 (12.6)	4673 (10.8)	
	Unknown	4539 (10.7)	69 (10.6)	4608 (10.7)	
Pre-op albumin less than 3 mg/dl	Yes	218 (0.5)	9 (1.4)	227 (0.5)	0.002
	No	42,410 (99.5)	643 (98.6)	43,053 (99.5)	
Concurrent procedure	None	31,013 (72.6)	465 (71.3)	31,478 (72.7)	0.088
	Liver biopsy	4000 (9.4)	58 (8.9)	4058 (9.4)	
	Hiatal hernia repair	5279 (12.4)	78 (12.0)	5357 (12.4)	
	Cholecystectomy	886 (2.1)	16 (2.5)	902 (2.1)	
	Band removal	1450 (3.4)	35 (5.4)	1485 (3.4)	

Table 1 (continued)

Variable	Categories	No POB ($n = 42{,}628$) *n* (%)	POB ($n = 652$) *n* (%)	Total *n* (%)	*P*-value
Assistant level	Resident	7338 (17.2)	117 (17.9)	7455 (17.2)	0.421
	Fellow	5068 (12.0)	78 (12.0)	5146 (11.9)	
	PA/NP/RNF	16,656 (39.1)	256 (39.3)	16,912 (39.1)	
	Attending	6058 (14.2)	101 (15.5)	6159 (14.2)	
	Attending non-bariatric	2267 (5.3)	23 (3.5)	2290 (5.3)	
	None	5241 (12.3)	77 (11.8)	5318 (12.3)	

POB postoperative bleed, *ASA* American society of anesthesiology, *PCI* percutaneous coronary intervention

Table 2 Multivariable predictors of postoperative bleed after laparoscopic Roux en Y gastric bypass (only significant variables are listed)

Variable	Categories	Odds ratio	95% CI	*P*-value
Preoperative hematocrit level	< 21 (reference)	1.00	–	–
	36–45	0.25	0.08–0.78	0.020
	> 45	0.29	0.09–0.97	0.044
History of DVT	Yes	1.62	1.02–2.59	0.043
	No			
History of renal insufficiency	Yes	2.55	1.43–4.52	0.001
	No	1.00	–	–
Therapeutic anticoagulation	Yes	2.44	1.69–3.53	< 0.001
	No	1.00	–	–
Robotic approach	Yes	0.50	0.32–0.77	0.002
	No	1.00	–	–
Revisional surgery	Yes	1.45	1.06–1.97	0.019
	No	1.00		
Converted to open	Yes	3.37	1.42–7.97	0.006
	No	1.00	–	–
Drain placed	Yes	1.40	1.18–1.67	< 0.001
	No	1.00	–	–
Assistant level of training	Resident	1.00	–	–
	Attending non-bariatric	0.60	0.38–0.97	0.038

of patient care. Vonlanthen et al. found that complications classified as grade IIIb (requiring surgical, endoscopic, or radiological intervention under general anesthesia) or higher led to a significant increase in costs compared to procedures without postoperative complications [16]. Specifically, the mean cost of RYGB in patients with any complication is increased by $9000 compared to patients without complications and by about $50,000 for more severe complications. Furthermore, the mean cost of a postoperative bleeding complication ranged from $7995 for grade I complications to $98,227 for grade IIIB and $149,582 for grade IV complications [16]. In our analysis, of the patients that bled, 25.3% underwent a re-operation and 14.9% underwent an unplanned endoscopy. Additionally, Ibrahim et al. in a study exploring the relationship of outcomes and cost after bariatric surgery found a strong correlation between hospitals identified as high-quality (having the lowest rates of serious complications), and lower Medicare payments [17]. They concluded that reducing complication rates following bariatric surgery may result in significant savings for payers and the health-care system overall.

We found several risk factors for postoperative bleeding. Some of these factors, such as therapeutic anticoagulation, are modifiable. Other risk factors, such as renal insufficiency, may not be modifiable but patients may be medically optimized pre-operatively to potentially reduce the risk of postoperative bleeding. Chronic anticoagulation is a well-known risk factor for postoperative bleeding with any elective surgical procedure. A recent study on bariatric surgery patients on chronic anticoagulation showed that 12% of patients who underwent LRYGB developed early postoperative bleeding [18]. Furthermore, 12% of patients undergoing LRYGB required readmission within 30 days

Table 3 Outcomes for patients that suffered a postoperative bleeding episode vs. those that did not from the MBSAQIP 2015 ($n=43{,}280$)

Outcome	No POB ($n=42{,}628$), n (%)	POB ($n=652$), n (%)	Total n (%)	P-value
Length of stay				
0–1 days	11,594 (27.0)	26 (4.0)	11,620 (26.9)	< 0.001
2 days	23,042 (54.1)	76 (11.7)	23,118 (53.5)	
3–7 days	7468 (17.6)	475 (73.1)	7943 (18.4)	
> 7 days	453 (1.1)	73 (11.2)	526 (1.2)	
Length of stay median (IQR)	2 (1–2)	4 (3–5)	2 (1–2)	< 0.001*
Discharged to facility	254 (0.6)	25 (3.8)	279 (0.6)	< 0.001
In-hospital mortality	15 (0.04)	8 (1.2)	23 (0.1)	< 0.001
30-day mortality	64 (0.2)	9 (1.4)	73 (0.2)	< 0.001
Unplanned readmission within 30 days	433 (1.0)	142 (21.8)	575 (1.3)	< 0.001
Acute renal failure requiring hemodialysis	53 (0.1)	16 (2.5)	69 (0.2)	< 0.001
Cardiac arrest requiring CPR	24 (0.1)	9 (1.4)	33 (0.08)	< 0.001
CVA	3 (0.01)	0 (0.0)	3 (0.01)	0.830
Post-op deep incisional SSI	74 (0.2)	3 (0.5)	77 (0.2)	0.085
Superficial incisional SSIs	392 (0.9)	15 (2.3)	407 (0.9)	0.001
Post-op organ space SSIs	171 (0.4)	15 (2.3)	186 (0.4)	< 0.001
Wound disruption	27 (0.1)	4 (0.6)	31 (0.1)	< 0.001
Post-op ventilator requirement > 48 h	65 (0.2)	19 (2.9)	84 (0.2)	< 0.001
Myocardial infarction	15 (0.04)	7 (1.1)	22 (0.1)	< 0.001
Pulmonary embolism	62 (0.2)	10 (1.5)	72 (0.2)	< 0.001
Progressive renal insufficiency (not requiring hemodialysis)	45 (0.1)	10 (1.5)	55 (0.1)	< 0.001
Sepsis	94 (0.2)	7 (1.1)	101 (0.2)	< 0.001
Post-op septic shock	55 (0.1)	9 (1.4)	64 (0.2)	< 0.001
Unplanned intubation	102 (0.2)	31 (4.8)	133 (0.3)	< 0.001
Post-op UTI	196 (0.5)	10 (1.5)	206 (0.5)	< 0.001
Venous thrombosis requiring treatment	72 (0.2)	8 (1.2)	80 (0.2)	< 0.001
Pneumonia	175 (0.4)	12 (1.8)	187 (0.4)	< 0.001
Any complication	1241 (2.9)	107 (16.4)	1348 (3.1)	< 0.001

Length of stay variables are postoperative length of stay

UTI urinary tract infection

*Wilcoxon rank sum test

of surgery, approximately half of them admitted with postoperative bleeding [18]. Sharma et al. recommended careful surgical technique and tissue handling during surgery in patients on chronic anticoagulation, in addition to paying close attention to postoperative anticoagulation protocols to minimize bleeding [18].

While our study is not designed to assess it, other researchers have explored factors that could prevent postoperative bleeding after LRYGB. Silecchia et al. found that certain patient-related factors, such as liver disease, coagulopathy, hypertension, super-obesity, and revisional surgery, increase the risk of bleeding following LRGYB, while surgeon-related factors like no staple-line reinforcement and mechanical circular anastomosis also increased the bleeding risk [19]. The authors recommended the use of either a hand-sewn or linear cutting stapler technique for creation of anastomoses, and the use of staple-line buttress or application of glue to staple lines [19]. Dick et al. also recommend using staple line reinforcement devices to prevent early postoperative GI bleeding [14]. Several small studies have demonstrated a reduction in intraoperative and postoperative staple line bleeding with the use of buttressing [20, 21]. However, cost effectiveness studies of using this approach are still pending. Robotic-assisted RYGB is also associated with a lower incidence of postoperative bleed. The reasons for this finding are unclear and may be attributed to selection bias when choosing patients for robotic approaches, the use of staple line buttressing, and possibly more meticulous dissection and hemostasis with robot assisted surgery. This however warrants further study. Recent studies comparing robot-assisted gastric bypass operations to standard LRYGB have shown the robot to be more resource intensive and possibly associated with worse overall outcomes [22, 23].

Our analysis has several limitations which should be taken in to consideration. This is a retrospective analysis of prospectively collected data and thus we are only able to test variables that were present in the dataset. For example, the dosage and use or venous thromboembolism prophylaxis, or details on intraoperative technique, including management of staple lines, were unavailable for assessment. Cost data were also unavailable. Additionally, our definition of postoperative hemorrhage selects for major or clinically relevant bleeding events, patients with postoperative hemorrhage that did not result in any blood transfusion or intervention would not be identified by our methodology, so it is possible we are underestimating the true rate of postoperative bleeding events. Similarly, the risk factor analysis determines associations with clinically significant hemorrhage that required an intervention and discounts minor bleeding events. Also, we could not account for 'thresholds' for transfusion or intervention and these are likely to vary between providers. Since data on facility and surgeons are not available in the PUF, we are unable to account for clustering effects by facility or provider. It is also important to understand that we reveal and association of POB with adverse outcomes and this does not imply a causation. It is possible that high risk patients due to other factors are at a higher risk of morbidity and mortality and also happened to have higher POB rates. However, this is the largest study to date focusing on postoperative bleeding following LRYGB. With 43,280 patients and 652 POB events, we are able to use multivariable analysis to provide for meaningful conclusions.

In this large database study containing information from over 740 centers, the incidence of postoperative bleeding following LRYGB is substantial at 1.5%. It is associated with increased morbidity and mortality which would subsequently lead to higher health care costs. It is essential for providers to prevent early postoperative bleeding by recognizing high risk patients and optimizing them prior to surgery. The use of intraoperative hemostatic techniques to prevent postoperative hemorrhage may be beneficial but is still being studied. We identify several factors associated with bleeding events. Surgeons and policy makers can use these to inform further research or practice.

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Compliance with ethical standards

Disclosures Syed Nabeel Zafar, Jessica Felton, Kaylie Miller, Eric S. Wise, and Mark Kligman have no conflicts of interest or financial ties to disclose.

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