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ORIGINAL CONTRIBUTIONS

Bariatric Surgery Outcomes in Patients on Preoperative Therapeutic Anticoagulation: an Analysis of the 2015 to 2017 MBSAQIP

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Abstract

Background Obesity has been found to be an independent predictor of adverse cardiac and pulmonary embolic events. As the popularity of bariatric surgery grows, surgeons are encountering more patients taking therapeutic anticoagulation medications preoperatively. This study aims to assess the safety of bariatric surgery on these patients.

Methods Data was extracted from 2015 to 2017 using the MBSAQIP database. Included patients were those who underwent a primary LSG or LRYGB. A multivariable regression analysis was performed looking at 30-day outcomes for pre-operatively anticoagulated patients. A secondary propensity-matched analysis was performed comparing outcomes among patients undergoing LSG vs LRYGB.

Results A total of 430,396 patients were analyzed, 11,013 (2.56%) of which were taking anticoagulation medications pre-operatively. Absolute 30-day complication rates (8.73% vs 3.36%, $p < 0.001$), bleed rates (3.78% vs 0.88%, $p < 0.001$), leak rates (0.55% vs 0.41%, $p = 0.021$), cardiac event rates (0.43% vs 0.06%, $p < 0.001$), and venous thromboembolism rates (0.68% vs 0.25%, $p < 0.001$) were significantly higher among pre-operatively anticoagulated patients. On multivariable analysis, pre-operative anticoagulation was found to be an independent predictor of postoperative bleeding (OR 2.76, CI 2.43–3.14, $p < 0.001$) and mortality (OR 2.08, CI 1.49–2.90, $p < 0.001$). The LRYGB was associated with a significantly higher complication rate compared to the LSG (13.27% vs 7.40%, $p < 0.001$) in the propensity-matched cohorts.

Conclusions Patients undergoing bariatric surgery on anticoagulation medications pre-operatively are at a significantly higher risk of adverse outcomes post-operatively. Patients who require long-term anticoagulation should undergo careful consideration before proceeding with bariatric surgery.

Keywords Bariatric surgery · Obesity · Bariatrics · MBSAQIP · Anticoagulation

Background

Severe obesity has been linked to an increased risk of venous thromboembolism (VTE), myocardial ischemia, and atrial fibrillation [1, 2]. Given that these conditions often require anticoagulation therapy, bariatric surgeons frequently encounter patients who are chronically anticoagulated prior to bariatric surgery. These patients require careful consideration, both with regard to their hemorrhagic risk post-operatively and their potential

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Table 1 Patient characteristics

	No preoperative anticoagulation $n = 419,923$	Preoperative therapeutic anticoagulation $n = 11,013$	*p*value
Age, years			
Mean ± sd	44.3 ± 11.9	54.3 ± 11.3	< 0.001
18–29	49,870 (11.9)	250 (2.3)	
30–39	108,779 (25.9)	1070 (9.7)	
40–49	122,411 (29.2)	2325(21.1)	
50–59	92,455 (22.0)	3425 (31.1)	
≥ 60	45,712(10.9)	3941 (35.8)	
% female	79.9	58.9	< 0.001
Race/ethnicity			
White	306,430 (73.0)	8733 (79.3)	
Black	74,100 (17.6)	1634 (14.8)	< 0.001
Other	39,393 (9.4)	646 (5.9)	
BMI, kg/m^2			
Mean ± sd	45.3 ± 7.9	47.3 ± 9.0	< 0.001
< 35	13,996 (3.3)	298 (2.7)	
35–39	93,742 (22.3)	1943 (17.6)	
40–50	128,886 (30.7)	2899 (26.3)	
50–59	85,936 (20.5)	2365 (21.5)	
60–69	73,485 (17.5)	2443 (22.2)	
≥ 70	20,998 (5.0)	983 (8.9)	
Functional status			
Independent	415,923 (99.0)	10,548 (95.8)	
Partially dependent	2418 (0.6)	328 (3.0)	< 0.001
Fully dependent	1582 (0.4)	137 (1.2)	
ASA class			
1–2	97,685 (23.4)	731 (6.7)	
3	306,416 (73.3)	8760 (80.2)	< 0.001
4–5	13,917 (3.3)	1426 (13.1)	
Smoking status			
No	383,784 (91.4)	10,161 (92.3)	0.001
Yes	36,139 (8.6)	852 (7.7)	
Diabetes			
No	311,025 (74.1)	6080 (55.2)	
Non-insulin dependent	74,132 (17.7)	2543 (23.1)	< 0.001
Insulin dependent	34,766 (8.3)	2390 (21.7)	
Hypertension			
No	220,204 (52.4)	2230 (20.3)	< 0.001
Yes	199,719 (47.6)	8783 (79.7)	
GERD			
No	291,759 (69.5)	6497 (59.0)	< 0.001
Yes	128,164 (30.5)	4516 (41.0)	
COPD			
No	413,394 (98.5)	10,257 (93.1)	< 0.001
Yes	6529 (1.5)	756 (6.9)	
Hyperlipidemia			
No	322,505 (76.8)	5032 (45.7)	< 0.001
Yes	97,418 (23.2)	5981 (54.3)	
Chronic steroid use			
No	413,197 (98.4)	10,525 (95.6)	< 0.001
Yes	6726 (1.6)	488 (4.4)	
Renal insufficiency			
No	417,535 (99.4)	10,638 (96.6)	< 0.001
Yes	2388 (0.6)	375 (3.4)	
Dialysis dependent			
No	418,792 (99.7)	10,855 (98.6)	< 0.001
Yes	1131 (0.3)	158 (1.4)	
History of VTE			
No	413,857 (98.6)	7281 (66.1)	< 0.001
Yes	6066 (1.4)	3732 (33.9)	
Venous stasis			
No	416,240 (99.1)	10,375 (94.2)	< 0.001
Yes	3683 (0.9)	638 (5.8)	
Oxygen-dependent			
No	417,313 (99.4)	10,589 (96.2)	< 0.001

Table 1 (continued)

	No preoperative anticoagulation $n = 419,923$	Preoperative therapeutic anticoagulation $n = 11,013$	*p*value
Yes	2610 (0.6)	424 (3.8)	
Sleep apnea			
No	262,885 (62.6)	4135 (37.6)	< 0.001
Yes	157,038 (37.4)	6878 (62.4)	
History of MI			
No	415,560 (99.0)	9855 (89.5)	< 0.001
Yes	4363 (1.0)	1158 (10.6)	
Previous major cardiac surgery			
No	416,358 (99.2)	9857 (89.5)	< 0.001
Yes	3565 (0.8)	1156 (10.5)	
Previous PCI			
No	413,152 (98.4)	9100 (82.6)	< 0.001
Yes	6771 (1.6)	1913 (17.4)	

ASA American Society of Anesthesiologists, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *VTE* venous thromboembolism, *GERD* gastroesophageal reflux disease, *MI* myocardial infarction, *PCI* percutaneous coronary intervention

thrombotic risk after altering their anticoagulation regime perioperatively.

Limited evidence exists regarding the safety of bariatric surgery in this patient population. Single institution reviews published in 2008 and 2018 demonstrated an increased risk of bleeding complications [3, 4] and hospital readmission within 30 days [4]. However, due to their low patient numbers, an adequate assessment of thrombotic, cardiovascular, and other secondary complications was incomplete. With these studies being limited to single institutions with low patient numbers, there remains a question as to the safety of bariatric surgery in this group of patients.

As of 2015, the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) began collecting data on pre-operative anticoagulation status. The MBSAQIP database collects data from 832 bariatric surgery centers and captures approximately 95% of all bariatric procedures performed in the USA and Canada [5]. This data includes pertinent risk-adjusted variables, based on standardized definitions for preoperative, intraoperative, and postoperative variables specific to metabolic and bariatric surgery. Given the tremendous number of patients and outcomes recorded in this database, there now appears to be an opportunity to properly quantify the risk of bariatric surgery in the preoperatively anticoagulated patient. Our study aims to quantify the 30-day post-operative outcomes of these patients compared to non-anticoagulated patients and to compare outcomes following laparoscopic sleeve gastrectomy (LSG) versus laparoscopic Roux-en-Y gastric bypass (LRYGB).

Methods

Data Source

The MBSAQIP data registry contains data collected by trained metabolic and bariatric surgical reviewers at each site. This prospective data is based on standardized definitions for variables that are specific for metabolic and bariatric surgery [6]. Data was extracted from the 2015, 2016, and 2017 datasets.

Study Population

Included patients were those over the age of 18 who underwent LRYGB or LSG from 2015 to 2017. Given their higher baseline risk of complications, patients who had previous bariatric surgery or were undergoing emergency surgery were excluded. Preoperative anticoagulation was defined as per the MBSAQIP Official Manual as a patient taking any anticoagulation medication within 30 days of surgery, or at the time the patient is being considered for surgery. This included coumarin derivates, platelet inhibitors (excluding Aspirin), and novel/direct oral anticoagulants [6]. This excluded any anticoagulation medication that was first started on the day of surgery or was prescribed prophylactically for surgery.

Patient Variables

Basic demographic data included age, sex, race, and body mass index (BMI). Patient comorbidities, as defined by the MBSAQIP Operations Manual [6], included the following: hypertension, gastroesophageal reflux disease, type 2 diabetes, hyperlipidemia, renal insufficiency, dialysis dependency, chronic obstructive pulmonary disease, obstructive sleep apnea, oxygen dependency, chronic steroid use, venous stasis,

Table 2 Perioperative factors and 30-day complications

	No preoperative anticoagulation $n = 419,923$	Preoperative therapeutic anticoagulation $n = 11,013$	p value
Procedure			
Roux-en-Y gastric bypass	113,998 (27.1)	3161 (28.7)	< 0.001
Sleeve gastrectomy	305,925 (72.9)	7852 (71.3)	
Operative time, min			
Mean ± sd	85.1 ± 46.5	94.0 ± 51.3	< 0.001
0–59.9	137,777 (32.8)	2804 (25.5)	
61–119.9	205,095 (48.8)	5638 (51.2)	< 0.001
120–179.9	59,445 (14.2)	1901 (17.3)	
> 180	17,606 (4.2)	670 (6.1)	
Length of stay, days			
Mean ± sd	1.7 ± 1.5	2.2 ± 2.3	< 0.001
Anastomotic leak	1726 (0.41)	61 (0.55)	0.021
Bleed	3548 (0.84)	398 (3.61)	< 0.001
Reoperation	4954 (1.18)	244 (2.22)	< 0.001
Reintervention	5283 (1.26)	341 (3.10)	< 0.001
Readmission	15,551 (3.70)	904 (8.21)	<0.001
Venous thromboembolism	1055 (0.25)	75 (0.68)	< 0.001
Unplanned intubation	538 (0.13)	69 (0.63)	< 0001
Acute renal failure	473 (0.11)	105 (0.95)	< 0001
Cardiac event (cardiac arrest, MI, or CPR)	238 (0.06)	47 (0.43)	< 0.001
Coma for > 24 h	8 (0.00)	3 (0.03)	< 0.001
Cerebral vascular accidents	35 (0.01)	14 (0.13)	< 0.001
Major complications	14,107 (3.36)	961 (8.73)	< 0.001
Death	335 (0.08)	61 (0.55)	< 0.001

CPR cardio-pulmonary resuscitation, *MI* myocardial ischemia

and smoking. Patient history included previous myocardial infarction (MI), previous VTE, previous major cardiac surgery, and previous percutaneous coronary interventions. Functional status variables included preoperative functional status and American Society of Anesthesiologists (ASA) Physical Status classification.

Outcome Variables

The primary outcome of interest was 30-day overall major complication between patients who were anticoagulated preoperatively and those who were not. Our secondary outcome of interest was the 30-day overall major complication rate between anticoagulated patients who underwent LSG vs LRYGB. Major complication was defined as a composite endpoint in the database as any patient who had any of the following:

- Anastomotic leak
- Postoperative bleed
- Venous thromboembolism
- Reintervention
- Reoperation
- Unplanned intubation
- Acute renal failure
- Sepsis
- Pneumonia
- Deep surgical site infection or wound disruption
- Cardiac event (cardiac arrest, MI, or cardiopulmonary resuscitation)
- Coma for greater than 24 h
- Cerebral vascular accident (CVA)

Statistical Analysis

Statistical analysis was performed using Stata 15 [7]. Descriptive categorical data were expressed as percentages and continuous data were expressed as weighted mean ± standard deviation (SD). Baseline differences between groups were evaluated by univariate analyses using Chi-square analysis. Univariate analysis was used to compare differences between patients who were anticoagulated preoperatively and those who were not in the entire cohort.

A propensity-matched analysis was performed between preoperatively anticoagulated patients undergoing LSG vs LRYGB [8]. Propensity scores were calculated for anticoagulated patients between LSG and LRYGB as a function of age, sex, BMI, race, gastroesophageal reflux disease, hypertension, hyperlipidemia, diabetes, chronic obstructive pulmonary disease, sleep apnea, smoking, oxygen dependency, American Society of Anesthesiologist physical classification, functional status, chronic steroid use, renal insufficiency, dialysis, venous stasis, history of MI, previous percutaneous coronary intervention, and history venous thromboembolism. One-to-one propensity-matched cohorts were then determined using nearest neighbor matching within a specified caliper distance set at 0.2 standard deviations. This eliminated approximately 99% of bias due to measured confounders [9].

Multivariable logistic regression analysis was performed to determine if preoperative therapeutic anticoagulation was independently associated with major complications, mortality, postoperative bleeding, and postoperative leak. Patient factors were

Table 3 Multivariable logistic regression for major complications

Risk factor	Odds ratio	95% confidence interval	*p* value
Age	1.00	1.00–1.00	0.078
LRYGB procedure	2.43	2.34–2.51	< 0.001
BMI	1.00	1.00–1.01	< 0.001
Female gender	1.03	0.99–1.08	0.112
Chronic steroid use	1.39	1.25–1.55	< 0.001
Dialysis dependent	1.55	1.25–1.93	< 0.001
History of venous stasis	1.07	0.93–1.22	0.35
Previous MI	1.27	1.13–1.44	< 0.001
History of PCI	1.10	0.99–1.23	0.064
ASA category			
ASA 3 (vs 1–2)	1.01	0.97–1.06	0.513
ASA 4–5 (vs 1–2)	1.22	1.12–1.33	< 0.001
GERD	1.25	1.21–1.30	< 0.001
Hypertension	1.09	1.05–1.14	< 0.001
Hyperlipidemia	1.02	0.98–1.07	0.326
History of VTE	1.61	1.48–1.75	< 0.001
Renal insufficiency	1.76	1.52–2.03	< 0.001
Preoperative therapeutic anticoagulation	1.75	1.62–1.90	< 0.001
Diabetes			
Type 1	1.02	0.97–1.06	0.429
Type 2	1.14	1.08–1.20	< 0.001
Smoker	1.16	1.09–1.22	< 0.001
COPD	1.34	1.21–1.48	< 0.001
Oxygen dependency	1.30	1.12–1.50	< 0.001
Sleep apnea	1.07	1.03–1.11	< 0.001

ASA American Society of Anesthesiologists, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *GERD* gastroesophageal reflux disease, *LRYGB* laparoscopic Roux-en-Y gastric bypass, *MI* myocardial infarction, *PCI* percutaneous coronary intervention, *VTE* venous thromboembolism

included in the model. A purposeful selection algorithm was used where any variable with a p value < 0.1 in univariate analysis was included in multivariable analysis. The threshold for significance was set at $p < 0.05$. The Brier score was used to assess calibration and discrimination of the model.

Results

Demographics

A total of 430,936 patients were included in this study, 11,013 (2.6%) of which received therapeutic anticoagulation preoperatively. The preoperative anticoagulation group was significantly older (mean age 54.3 ± 11.3 vs 44.3 ± 11.9 years, $p < 0.001$) and had a significantly higher percentage of males (41.1 vs 20.1%, $p < 0.001$) (Table1). Patients taking preoperative anticoagulation medications had a significantly higher incidence of diabetes, hypertension, GERD, COPD, hyperlipidemia, chronic steroid use, renal insufficiency, and dialysis dependency. These patients were also more likely to have history of VTE, venous stasis, oxygen dependency, sleep apnea, previous MI, major cardiac surgery, and percutaneous cardiac intervention (Table 1).

Operative Outcomes

Patients taking preoperative anticoagulation medications were more likely to undergo LRYGB than non-anticoagulated patients (28.7 vs 27.1%, $p < 0.001$). Operative time in the anticoagulated group was significantly longer (94.0 vs 85.1 min), as was the average length of stay in hospital (2.2 ± 2.3 vs 1.7 ± 1.5 days, $p < 0.001$) (Table 2). Preoperative therapeutic anticoagulation was associated with a significantly higher risk of all adverse outcomes measured in our analysis (Table 2). This included post-operative (within 30 days) anastomotic leak (0.55 vs 0.41%, $p =$

Table 4 Multivariable logistic regression for postoperative anastomotic leak

Risk factor	Odds ratio	95% confidence interval	*p* value
Age	1.00	1.00–1.00	0.115
History of LRYGB	1.52	1.38–1.68	< 0.001
BMI	1.01	1.00–1.01	0.020
Female gender	0.90	0.80–1.01	0.083
Chronic steroid use	1.38	1.02–1.87	0.037
Previous MI	1.06	0.71–1.59	0.760
ASA category			
ASA 3 (vs 1–2)	1.05	0.93–1.19	0.417
ASA 4–5 (vs 1–2)	1.10	0.85–1.43	0.451
GERD	1.08	0.98–1.20	0.128
History of PCI	0.98	0.70–1.37	0.915
Hypertension	1.05	0.94–1.18	0.348
Hyperlipidemia	1.01	0.89–1.14	0.931
History of VTE	1.19	0.89–1.59	0.235
Preoperative therapeutic anticoagulation	1.02	0.77–1.36	0.881
Diabetes			
Type 1	0.99	0.87–1.12	0.843
Type 2	1.16	0.99–1.37	0.072
Smoker	1.28	1.10–1.49	0.002
COPD	1.31	0.97–1.77	0.075
Oxygen dependency	1.04	0.66–1.66	0.853
Sleep apnea	1.05	0.95–1.17	0.317

ASA American Society of Anesthesiologists, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *GERD* gastroesophageal reflux disease, *LRYGB* laparoscopic Roux-en-Y gastric bypass, *MI* myocardial infarction, *PCI* percutaneous coronary intervention, *VTE* venous thromboembolism

0.021), bleed (3.61 vs 0.84%, $p < 0.001$), venous thromboembolism (0.68% vs 0.25%, $p < 0.001$), major cardiac event (0.43 vs 0.06%, $p < 0.001$), and cerebrovascular accident (0.13 vs 0.01%, $p < 0.001$). Other outcomes measured included the incidence of postoperative renal failure, unplanned intubation, coma for greater than 24 h, 30-day reoperation rate, reintervention rate, and readmission rate. All of which were significantly higher in the anticoagulation group (Table 2) as were the 30-day mortality (0.55 vs 0.08%, $p < 0.001$) and major complication rate (8.73 vs 3.36%, $p < 0.001$).

Multivariable Logistic Regression

Multivariable logistic regression analysis was performed to determine if preoperative anticoagulation was independently associated with the incidence of major complications, mortality, postoperative bleeding, and postoperative leak. As seen in Table 3, preoperative therapeutic anticoagulation had the third highest odds for a major post-operative complication (OR 1.75, CI 1.62–1.90, $p < 0.001$). Although it was not associated with a higher anastomotic leak rate (OR 1.02, CI 0.77–1.36, $p = 0.881$) (Table 4), it was, not surprisingly, associated with the highest likelihood of developing a post-operative bleed (OR 2.76, CI 2.43–3.14, $p < 0.001$) (Table 5). Remarkably, therapeutic preoperative anticoagulation was also associated with the second highest odds for mortality (30 days) for patients undergoing bariatric surgery (OR 2.08, CI 1.49–2.90, $p < 0.001$). Only preoperative dialysis dependency was found to be associated with a higher likelihood of mortality (Table 6). The forecast model for all four multivariable regression models was found to be highly accurate as indicated by Brier scores of 0.0333 or less.

LRYGB vs LSG Among Anticoagulated Patients

A propensity-matched analysis was performed between anticoagulated patients undergoing LRYGB vs LSG. A total of 6272 patients were included in the analysis (3136 pairs). All measured confounding factors were controlled for except for chronic steroid use (Table 7). As seen in Table 8, among anticoagulated patients undergoing bariatric surgery, LRYGB was associated with significantly higher operative times, length of stay, rates of leak, bleed, reoperation, reintervention, readmission, and overall major complications

Table 5 Multivariable logistic regression for postoperative bleed

Risk factor	Odds ratio	95% confidence interval	*p* value
Age	1.01	1.00–1.01	< 0.001
History of LRYGB	2.51	2.36–2.68	< 0.001
BMI	0.99	0.98–0.99	< 0.001
Female gender	0.93	0.86–1.00	0.050
Chronic steroid use	1.49	1.24–1.80	< 0.001
Dialysis dependent	1.33	0.89–1.98	0.163
History of venous stasis	1.08	0.84–1.37	0.551
Previous MI	1.18	0.96–1.46	0.119
ASA category			
ASA 3 (vs 1–2)	1.01	0.92–1.10	0.835
ASA 4–5 (vs 1–2)	1.31	1.11–1.53	0.001
GERD	1.40	1.07–1.22	< 0.001
History of PCI	1.00	0.83–1.20	0.999
Hypertension	1.20	1.11–1.29	< 0.001
Hyperlipidemia	1.01	0.93–1.10	0.771
History of VTE	1.37	1.18–1.60	< 0.001
Renal insufficiency	1.75	1.36–2.24	< 0.001
Preoperative therapeutic anticoagulation	2.76	2.43–3.14	< 0.001
Diabetes			
Type 1	1.18	1.09–1.29	< 0.001
Type 2	1.20	1.09–1.33	< 0.001
COPD	1.18	0.98–1.43	0.079
Oxygen dependency	1.11	0.84–1.45	0.473
Sleep apnea	1.13	1.05–1.21	0.001

ASA American Society of Anesthesiologists, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *GERD* gastroesophageal reflux disease, *LRYGB* laparoscopic Roux-en-Y gastric bypass, *MI* myocardial infarction, *PCI* percutaneous coronary intervention, *VTE* venous thromboembolism

compared to LSG. There was no significant difference in the mortality rate, VTE rate, or major cardiac event rate.

Discussion

This study is the first to use the MBSAQIP database to assess the safety of bariatric surgery when performed on patients on preoperative therapeutic anticoagulation. The results of this study indicate that preoperatively anticoagulated patients who undergo bariatric surgery are at an increased risk of major complications postoperatively, including death. The rate of anastomotic leakage and bleeding are significantly higher in this patient population, as are the rates of postoperative VTE, CVA, and major cardiac events. When analyzed using multivariable analysis, preoperative anticoagulation remains strongly associated with postoperative bleed rate and mortality, but not leak rate.

One can speculate that the increased rate of thromboembolic events in this group is secondary to the change or pause in the patient's therapeutic anticoagulation regime during the perioperative period. Given the limited data available on the MBSAQIP database however, it is difficult to completely quantify the manner in which patients had their anticoagulation regime altered prior to and following surgery. A recent study by Rottenstreich et al. demonstrated that 10 days following surgery, there is biochemical evidence that patients undergoing LSG remain in a hypercoagulable state [8]. For patients at an increased risk of thromboembolism to begin with, who then have a stoppage in their anticoagulation regime, it is reasonable to suspect that the added hypercoagulable changes that occur postoperatively put them at a significantly higher risk of developing a thromboembolic event compared to the average patient.

Previous research has also found that the most predictive risk factor for development of VTE after bariatric surgery is a history of a previous VTE [10]. Over one third of the patients in the preoperative anticoagulation group had a history of a previous VTE, and it is not surprising that this group of patients is at an inherently higher risk of developing another venous thromboembolism. Due to genetic or acquired risk factors, patients with a history of VTE, particularly a primary unprovoked VTE, are often suffering from a relative state of hypercoagulability at baseline [11]. Although the MBSAQIP

Table 6 Multivariable logistic regression for postoperative mortality

Risk factor	Odds ratio	95% confidence interval	*p* value
Age	1.05	1.04–1.06	< 0.001
LRYGB procedure	2.00	1.63–2.45	< 0.001
BMI	1.05	1.05–1.06	< 0.001
Female gender	0.52	0.42–0.64	< 0.001
Chronic steroid use	1.15	0.64–2.07	0.644
Dialysis dependent	2.63	1.14–6.10	0.024
History of venous stasis	0.99	0.56–1.75	0.97
Previous MI	1.55	0.95–2.52	0.078
ASA category			
ASA 3 (vs 1–2)	1.42	0.98–2.05	0.065
ASA 4–5 (vs 1–2)	1.65	1.01–2.68	0.044
GERD	1.08	0.87–1.32	0.498
History of PCI	1.07	0.71–1.72	0.651
Hypertension	1.01	0.78–1.30	0.969
Hyperlipidemia	1.29	1.01–1.64	0.037
History of VTE	1.68	1.15–2.45	0.007
Renal insufficiency	1.26	0.67–2.37	0.464
Preoperative therapeutic anticoagulation	2.08	1.49–2.90	< 0.001
Diabetes			
Type 1	0.96	0.74–1.25	0.766
Type 2	1.18	0.88–1.57	0.256
COPD	1.93	1.29–2.88	0.001
Oxygen dependency	1.08	0.61–1.93	0.784
Sleep apnea	1.04	0.83–1.29	0.748

ASA American Society of Anesthesiologists, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *GERD* gastroesophageal reflux disease, *LRYGB* laparoscopic Roux-en-Y gastric bypass, *MI* myocardial infarction, *PCI* percutaneous coronary intervention, *VTE* venous thromboembolism

does not differentiate previous primary versus secondary VTE, the percentage of patients with an underlying hypercoagulable disorder will certainly be higher among the group of patients receiving preoperative therapeutic anticoagulation.

The bridging anticoagulation therapy and/or postoperative anticoagulants these patients receive can also partially explain why the bleed rate is higher in this patient group. The results by Mourelo et al. reflect this as they found that patients on chronic anticoagulation therapy, who were bridged preoperatively and started back on their therapeutic anticoagulation medications 24 h after surgery, were at an increased risk of bleeding complications during their initial inpatient stay [3]. Interestingly, however, a retrospective review by Bechtel et al. demonstrated that patients taking warfarin prior to LRYGB have an increased sensitivity to warfarin for up to 30 days postoperatively [12]. In this scenario, patients may present more than 10 days postoperatively with a bleed secondary to supratherapeutic INR levels. Adding to the confusion is that many newer anticoagulants are being encountered by surgeons who may not be as comfortable in managing these medications and may not appropriately hold, bridge, or restart these medications. As the MBSAQIP does not specify when a clinically identified bleed occurs within 30 days of surgery, it is difficult to differentiate immediate from delayed bleeds in this patient population.

The second part of this study compared outcomes between the LSG and LRYGB among patients who were on anticoagulation therapy preoperatively. In our analysis, we found LRYGB to be associated with significantly higher morbidity than the LSG in this patient group, with higher operative times, rates of leak, bleed, reoperation, reintervention, readmission, and overall major complications. That being said, this increased risk is in keeping with previous research demonstrating that the risk of a postoperative bleed or leak within the general population is higher following LRYGB compared to the LSG [13]. Therefore, similar to the average patient population, for patients on preoperative anticoagulation, the LRYGB is associated with a higher leak and bleed rate compared to the LSG; however, this risk is significantly elevated for both procedures.

Inherent weaknesses in this study relate primarily to limitations in the available data from the MBSAQIP database. The MBSAQIP variable for "Therapeutic Anticoagulation" includes all anticoagulant medications (excluding Aspirin) [6].

Table 7 LRYGB vs LSG among preoperatively anticoagulated patients (propensity matched)

	LSG $n = 3136$	LRYGB $n = 3136$	p value
Age, years			
Mean ± sd	54.3 ± 11.1	54.6 ± 11.0	0.3943
18–29	57 (1.8)	70 (2.2)	
30–39	291 (9.3)	277 (8.8)	
40–49	709 (22.6)	651 (20.8)	0.401
50–59	967 (30.8)	1007 (32.1)	
≥ 60	1111 (35.4)	1130 (36.0)	
% female	60.5	60.7	0.918
Race/ethnicity			
White	2478 (79.0)	2512 (80.1)	
Black	497 (15.9)	407 (13.0)	< 0.001
Other	161 (5.1)	217 (6.9)	
BMI, kg/m^2			
Mean ± sd	47.9 ± 9.6	47.8 ± 8.9	0.7122
< 35	77 (2.5)	75 (2.4)	
35–39	551 (17.6)	504 (16.1)	
40–50	768 (24.5)	796 (25.4)	
50–59	678 (21.6)	691 (22.0)	
60–69	738 (23.5)	767 (24.5)	
≥ 70	324 (10.3)	303 (9.7)	
Functional status			
Independent	3008 (95.9)	3004 (95.8)	
Partially dependent	94 (3.0)	102 (3.25)	0.749
Fully dependent	34 (1.08)	30 (0.96)	
ASA class			
1–2	194 (6.19)	180 (5.7)	
3	2534 (80.8)	2553 (81.4)	0.731
4–5	408 (13.0)	403 (12.9)	
Smoking status			
No	2905 (92.63)	2908 (92.7)	0.884
Yes	231 (7.4)	228 (7.3)	
Diabetes			
No	1403 (44.7)	1433 (45.7)	
Non-insulin dependent	861 (27.5)	783 (25.0)	0.071
Insulin dependent	872 (27.8)	920 (29.3)	
Hypertension			
No	586 (18.7)	580 (18.5)	0.846
Yes	2550 (81.3)	2556 (81.5)	
GERD			
No	1702 (54.3)	1700 (54.2)	0.960
Yes	1434 (45.7)	1436 (45.8)	
COPD			
No	2918 (93.1)	2910 (92.8)	0.694
Yes	218 (6.9)	226 (7.2)	
Hyperlipidemia			
No	1331 (42.4)	1336 (42.6)	0.898
Yes	1805 (57.6)	1800 (57.4)	
Chronic steroid use			
No	2972 (94.8)	3017 (96.2)	0.006
Yes	164 (5.2)	119(4.4)	
Renal insufficiency			
No	3042 (97.0)	3046 (97.1)	0.765
Yes	94 (3.0)	90 (2.9)	
Dialysis dependent			
No	3121 (99.5)	3117 (99.4)	0.492
Yes	15 (0.5)	19 (0.6)	
History of VTE			
No	2028 (64.7)	2015 (64.2)	0.732
Yes	1108 (35.3)	1121 (35.8)	
Venous stasis			
No	2956 (94.3)	2958 (94.3)	0.913
Yes	180 (5.7)	178 (5.7)	
Oxygen-dependent			
No	2997 (95.6)	3011 (96.0)	0.379
Yes	2139 (4.4)	125 (4.0)	
Sleep apnea			
No	1035 (33.0)	1061 (33.8)	0.486
Yes	2101 (67.0)	2075 (66.2)	
History of MI			
No	2793 (89.1)	2800 (89.3)	0.776
Yes	343 (10.9)	336 (10.7)	
Previous major cardiac surgery			
No	2840 (90.6)	2845 (90.7)	0.828
Yes	296 (9.4)	291 (9.3)	
Previous PCI			
No	2571 (82.0)	2578 (82.2)	0.818
Yes	565 (18.0)	558 (17.8)	

ASA American Society of Anesthesiologists, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *VTE* venous thromboembolism, *GERD* gastroesophageal reflux disease, *MI* myocardial infarction, *PCI* percutaneous coronary intervention

It is therefore not possible to separate patients who were on coumarin derivatives versus those on platelet inhibitors or novel oral anticoagulants. Given the heterogeneity within these groups with regard to pre-existing risk factors, perioperative management, and presumed postoperative risk, it would have been ideal to look at each of these groups separately, which we were unable to do. We were also unable to specify how patient's anticoagulation regimes were managed perioperatively, such as the number of patients who completely stopped their anticoagulation medication vs those who were bridged preoperatively, nor how long after surgery patients were restarted on their therapeutic medications, or what their indication for chronic anticoagulation was. Additionally, outcome data were limited to 30 days

Table 8 Perioperative factors and 30-day complications (propensity-matched LRYGB vs LSG among anticoagulated patients)

	LSG $n = 3136$	LRYGB $n = 3136$	p value
Operative time, min			
Mean ± sd	80.6 ± 41.8	129.4 ± 58.5	< 0.001
0–59.9	1039 (33.1)	156 (5.0)	
61–119.9	1674 (53.4)	1453 (46.3)	< 0.001
120–179.9	354 (11.3)	1037 (33.1)	
> 180	69 (2.2)	490 (15.63)	
Length of stay, days			
Mean ± sd	2.1 ± 2.3	2.6 ± 2.8	< 0.001
Anastomotic leak	14 (0.5)	27 (0.9)	0.042
Bleed	90 (2.9)	180 (5.7)	< 0.001
Reoperation	64 (2.0)	106 (3.4)	0.001
Reintervention	76 (2.4)	159 (5.1)	< 0.001
Readmission	229 (7.3)	368 (11.7)	< 0.001
Venous thromboembolism	22 (0.7)	25 (0.8)	0.660
Unplanned intubation	19 (0.6)	26 (0.8)	0.295
Acute renal failure	30 (1.0)	44 (1.4)	0.102
Cardiac event (cardiac arrest, MI, or CPR)	14 (0.5)	20 (0.6)	0.302
Coma for > 24 h	1 (0.0)	2 (0.1)	0.564
Cerebral vascular accidents	7 (0.2)	2 (0.1)	0.095
Major complications	232 (7.4)	416 (13.3)	< 0.001
Death	17 (0.5)	24 (0.8)	0.273

CPR cardio-pulmonary resuscitation, *MI* myocardial ischemia

and complications that occur beyond this time period were not accounted for. Lastly, given the retrospective nature of our study, there may be unaccounted confounders we were unable to adjust for in our analysis that could ultimately affect our conclusions.

Despite these limitations, our study is the single largest study looking at the safety of bariatric surgery in the chronically anticoagulated patient population. Our findings indicate that patients within this population who undergo bariatric surgery are at an increased risk of major complications and death postoperatively. Further research is needed to determine the risk profile associated with specific patients within this population, such as those who stop their anticoagulants completely versus those who are bridged perioperatively. The risk profile also likely differs based on the patients underlying disease necessitating anticoagulation. But until these risks are delineated, great care must be taken when operating on these patients. Surgeons and patients should be aware of the potential dangers following surgery in this group of patients, and an informed decision should only be made after these risks have been discussed. Surgeons must also ensure that they understand how to optimally manage these medications perioperatively, as this can greatly influence patient outcomes postoperatively.

Conclusions

Patients taking therapeutic anticoagulation who have bariatric surgery are at a higher risk of 30-day major complications and death. Patients should be carefully informed of their increased risk prior to undergoing surgery, and surgeons must be aware of the current recommendations for perioperative management of anticoagulant medications to optimize patient care and outcomes.

Compliance with Ethical Standards

Conflicts of Interest Aryan Modasi has no conflict of interest.
Jerry Dang has no conflict of interest.
Sadaf Afraz has no conflict of interest.
Joshua Hefler has no conflict of interest.
Noah Switzer has no conflict of interest.
Daniel Birch has no conflict of interest.
Shahzeer Karmali has no conflict of interest.

Ethics Approval Statement This article does not contain any studies with human participants or animals performed by any of the authors. For this type of study formal consent is not required.

Informed Consent Statement Does not apply.

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