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ORIGINAL CONTRIBUTIONS

Characterizing Timing of Postoperative Complications Following Elective Roux-en-Y gastric Bypass and Sleeve Gastrectomy

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Abstract

Purpose With the growing prevalence of bariatric procedures performed worldwide, it is important to understand the timing of postoperative complications following bariatric surgery and the differences which may exist between procedures.

Methods This retrospective study was conducted using the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) data registry from 2017 to 2018. All patients with primary elective Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) procedures were included. The primary outcome was to characterize the timing of postoperative complications for RYGB and SG.

Results A total of 316,314 patients were identified with 237,066 (74.9%) in the SG cohort and 79,248 (25.1%) in the RYGB cohort. Early complications included myocardial infarction (4.7 ± 6.4 days), cardiac arrest (6.4 ± 8.5 days), pneumonia (6.9 ± 6.9 days), progressive renal insufficiency (8.1 ± 8.1 days), and acute renal failure (8.2 ± 7.6 days). Late complications included *Clostridioides difficile* infection (11.3 ± 7.8 days), organ space infections (11.7 ± 7.9 days), deep incisional infections (12.4 ± 6.6 days), superficial incisional infections (13.2 ± 6.9 days), and urinary tract infections (14.0 ± 8.4 days). SG patients were more likely to be diagnosed later than RYGB patients with regard to superficial incisional infections (14.0 ± 7.4 days vs 12.5 ± 6.3 days; $p = 0.002$), organ space infections (12.6 ± 7.8 days vs 10.8 ± 7.9 days; $p = 0.001$), acute renal failure (9.3 ± 8.1 days vs 6.8 ± 6.8 days; $p = 0.03$), and pulmonary embolism (13.7 ± 7.5 days vs 11.3 ± 8.0 days; $p = 0.003$). No significant difference in timing was observed for any other complication by procedures.

Conclusion We demonstrate that significant differences in timing exist between complications and that these differences also vary by surgical procedure.

Graphical abstract

Keywords Roux-en-Y gastric bypass · Sleeve gastrectomy · Postoperative complications · Timing

Key Points

• First study characterizing the timing of postoperative complications following RYGB and SG.

• Order of early complications (< 10 days): cardiac, pulmonary, renal, neurological.

• Late complications (> 10 days) are predominantly infectious in nature.

• Many complications occur later in the SG cohort as compared to the RYGB cohort.

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Introduction

Obesity is an evolving pandemic of particular consequence to North America where the prevalence of obesity has more than doubled in the last 20 years [1–3]. Approximately a quarter of Canadian and one-third of US citizens are currently diagnosed with obesity [1, 4, 5]. Failure of medical management to sustain long-term weight loss has led to the rising popularity of bariatric surgery [6, 7]. From 2006 to 2016, there has been a 400% increase in the number of bariatric surgeries performed in Canada [8] with similar trends observed in the USA [9]. To date, bariatric surgery is the only therapy which provides sustainable weight loss and improvement in obesity-related metabolic comorbidities [10, 11].

While bariatric surgery is generally safe and well tolerated, complications are associated with significant morbidity and mortality while also posing a large burden on healthcare resources [12–14]. An important aspect of postoperative clinical care is an understanding of the timing of complications in order to establish an early diagnosis and ensure prompt management [15, 16]. However, despite the rising number of bariatric cases performed worldwide [17–20], the progression and timing of postoperative complications following bariatric surgery remain poorly understood. Characterizing the timing of these complications and the differences that may exist between procedures may aid healthcare providers to improve postoperative care while also decreasing the healthcare burden of these complications [16].

Our study aims to address this gap in knowledge by characterizing the timing of postoperative complications following elective, primary Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) using the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) database. Our secondary outcome is to evaluate if differences in the timing of postoperative complications between these procedures exist.

Methods

Data Source

Clinical data for patients undergoing elective bariatric surgery was extracted using the MBSAQIP data registry from 2017 to 2018. Bariatric procedures performed in over 800 accredited centers in Canada and the USA are entered into the MBSAQIP database, making this the largest clinical bariatric database in North America. In order to maintain accreditation, standards of practice and data integrity must be met by each center. Standardized pre-, intra-, and postoperative variables are collected by trained clinical reviewers. A recent addition to these variables in 2017 and 2018 was the timing of postoperative complications, thus restricting our study period to these dates.

Study Design, Population, and Variable Definitions

All patients who underwent RYGB and SG in 2017 and 2018 were included in this retrospective cohort study. Exclusion criteria included prior bariatric surgery, revision surgery, conversion surgery, and emergency surgery. To evaluate for the differences in timing of complications between RYGB and SG cohorts, the complications were organized into early and late complications. Early complications were defined if the mean date to diagnosis was less than or equal to 10 days, while late complications were defined by a mean date to diagnosis of more than 10 days. Ten days was chosen as this corresponded with the natural bimodal distribution of our data. Complications were also organized by the distribution of timing and included intervals of 0–3 days, 4–6 days, 7–10 days, 11–14 days, and more than 14 days. The primary outcome was to characterize the timing of postoperative complications for RYGB and SG. Our secondary outcomes were to evaluate differences in postoperative complications between the two procedures and to evaluate if differences exist in the timing of these complications.

Patient clinical characteristics included age, sex, body mass index (BMI), functional status, American Society of Anesthesiologists (ASA) physical status classification, operative length, smoking status, and steroid use. ASA was further grouped into three categories: no or mild disturbance, severe disturbance, and life-threatening disturbance or moribund. Metabolic comorbidities included diabetes, hypertension, hyperlipidemia, and gastroesophageal reflux disease. Diabetes was grouped into three categories: no diabetes or diabetes controlled by diet alone, non-insulin dependent diabetes, and insulin-dependent diabetes. Renal comorbidities included renal insufficiency and dialysis dependency. Pulmonary comorbidities included chronic obstructive pulmonary disease (COPD), oxygen dependency, and sleep apnea. Hematologic abnormalities included prior venous thromboembolism, venous stasis, and therapeutic anticoagulation. Cardiac comorbidities included prior myocardial infarction (MI), prior cardiac surgery, and prior percutaneous coronary intervention (PCI).

Postoperative complications included 30-day reoperation, intervention, readmission, and mortality rates. More specific complications were grouped into categories: cardiac (myocardial infarction, cardiac arrest requiring cardiopulmonary resuscitation (CPR)), respiratory (pneumonia, ventilatory support), neurological (cerebral vascular accident, coma for more than 24 h, peripheral nerve injury), renal (acute renal failure, progressive renal failure), infectious (superficial surgical site infection (SSI), deep SSI, organ space SSI, wound disruption, anastomotic leak, sepsis, septic shock, urinary tract infection (UTI), *Clostridioides difficile* infection), and hematologic (bleed, need for transfusion within 72 h of surgery, pulmonary embolus).

Statistical Analysis

Continuous variables were expressed as means ± standard deviations (SD) while categorical variables were presented as absolute values and percentages. Wilcoxon signed-rank tests were used to evaluate differences between continuous outcomes. Chi-squared tests were used to evaluate categorical outcomes. Statistical significance was defined *a priori* as two-tailed with a p value < 0.05. Statistical analysis was conducted using Stata MP (v 15.1, StataCorp, College Station, Texas, USA).

Results

Patient Demographics

A total of 316,314 patients who underwent elective, primary RYGB ($n = 79{,}248$; 25.1%) and SG ($n = 237{,}066$; 74.9%) in 2017 and 2018 were identified in the MBSAQIP database. The overall population was predominantly female (80.3%) and had a mean age of 44.4 ± 12.0 years with a mean BMI of 45.2 ± 7.7 kg/m^2 (Table 1). Regarding metabolic comorbidities, the rates of medication/insulin-dependent diabetes (25.9%), hypertension (47.2%), hyperlipidemia (23.0%), and sleep apnea (38.3%) were consistent with prior MBSAQIP studies.

Compared to the RYGB cohort, the SG cohort was younger (44.1 ± 12.0 years SG vs 45.2 ± 11.8 years RYGB; $p < 0.0001$), had lower pre-operative BMI (45.0 ± 7.7 kg/m^2 SG vs 45.9 ± 7.7 kg/m^2 RYGB; $p < 0.0001$), and had lower rates of metabolic comorbidities. For example, SG patients had decreased rates of medication/insulin-dependent diabetes (25.0% SG vs 33.9% RYGB; $p < 0.0001$), hypertension (45.7% SG vs 51.7% RYGB; $p < 0.0001$), hyperlipidemia (21.3% SG vs 28.2% RYGB; $p < 0.0001$), and sleep apnea (36.3% SG vs 44.3% RYGB; $p < 0.0001$). Sex, functional status, smoking status, and other pre-operative comorbidities were not clinically different between SG and RYGB cohorts.

Complication Rates by Bariatric Procedure

Overall, postoperative complication rates were lower in the SG cohort (Table 2). Those of clinical significance included superficial SSI (0.2% SG vs 0.8% RYGB; $p < 0.0001$), bleeds (0.7% SG vs 1.6% RYGB; $p < 0.0001$), and transfusion within 72 h (0.5% SG vs 1.1% RYGB; $p < 0.0001$). The SG cohort was also associated with lower reoperation (0.8% SG vs 2.1% RYGB; $p < 0.0001$), intervention (0.7% SG vs 2.0% RYGB; $p < 0.0001$), and readmission rates (2.8% SG vs 5.6% RYGB; $p < 0.0001$) than RYGB within 30 days. All other complication rates were not clinically different between cohorts.

Timing of Postoperative Complications Varies by Bariatric Procedure

Early complications (< 10 days) included need for transfusion within 72 h of surgery (1.4 ± 1.1 days), myocardial infarction (4.7 ± 6.4 days), cardiac arrest requiring CPR (6.4 ± 8.5 days), need for ventilatory support (6.6 ± 6.6 days), pneumonia (6.9 ± 6.9 days), progressive renal failure (8.1 ± 8.1 days), acute renal failure (8.2 ± 7.6 days), septic shock (8.3 ± 6.9 days), cerebral vascular accident (8.3 ± 7.5 days), and peripheral nerve injury (8.4 ± 7.4 days) (Table 3). Cardiac arrest requiring CPR, progressive and acute renal failure, and peripheral nerve injury have a predominantly bimodal distribution. Early complications primarily occurred within the first 3 days following surgery. More than half of MI ($n = 36$; 58.1%), and more than a third of other cardiac (cardiac arrest $n = 31$; 26.9%), pulmonary (ventilator requirement $n = 56$; 33.5%; pneumonia $n = 211$; 41.7%), and renal (progressive renal failure $n = 67$; 37.2%; acute renal failure $n = 73$; 43.7%) complications occurred within the first 3 days.

Late complications (> 10 days) included coma for more than 24 h (10.1 ± 10.3 days), sepsis (10.9 ± 7.6 days), *C. difficile* infection (11.3 ± 7.8 days), wound disruption (11.7 ± 7.6 days), organ space SSI (11.7 ± 7.9 days), deep SSI (12.4 ± 6.6 days), pulmonary embolus (12.7 ± 7.8 days), superficial SSI (13.2 ± 6.9 days), and urinary tract infections (14.0 ± 8.4 days). As compared to early complications, late complications had a more even distribution in the postoperative period (sepsis, organ space SSI, PE) or peaked during the 7–14-day time frame (*C. difficile* infection, wound disruption, deep SSI, superficial SSI, UTI).

SG patients were more likely to be diagnosed later than RYGB patient with regard to the following complications: acute renal failure (9.3 ± 8.1 days vs 6.8 ± 6.8 days, $p = 0.03$), superficial SSI (14.0 ± 7.4 days vs 12.5 ± 6.3 days, $p = 0.002$), organ space SSI (12.6 ± 7.8 days vs 10.8 ± 7.9 days, $p = 0.001$), sepsis (11.9 ± 7.7 days vs 9.8 ± 7.3 days, $p = 0.01$), septic shock (10.2 ± 7.7 days vs 6.8 ± 5.7 days, $p = 0.002$), and pulmonary embolus (13.7 ± 7.5 days vs 11.3 ± 8.0 days, $p = 0.003$) (Table 4). Only cardiac arrest requiring CPR (5.4 ± 8.3 days vs 7.0 ± 8.5 days, $p = 0.05$) and transfusion within 72 h (1.4 ± 1.0 days vs 1.5 ± 1.3 days, $p = 0.04$) occurred earlier in the SG cohort. The timing of the remaining complications was not statistically different between the two cohorts.

Discussion

Herein, we present the first study characterizing the timing of postoperative complications following elective RYGB and SG. We importantly demonstrate that differences exist in the timing of these complications between elective RYGB and SG procedures and present a framework for characterizing complications as early and late. Early complications (< 10 days) tended to present in the following order: cardiac, pulmonary, renal, and neurological. Late complications (> 10 days) were predominantly infectious in nature with the exception of pulmonary emboli. Lastly, we show that there were differences in timing between the two procedures with many occurring later in the SG cohort, specifically

Table 1 Basic demographics of patients undergoing bariatric procedures; number of patients (%)

		RYGB, $n = 79{,}248$	SG, $n = 237{,}066$	p value
Age (years)				< 0.0001
	< 18	62 (0.1)	550 (0.2)	
	18–30	8477 (10.7)	30,012 (12.7)	
	30–40	19,483 (24.6)	63,098 (26.6)	
	40–50	23,225 (29.3)	68,341 (28.8)	
	50–60	18,539 (23.4)	49,581 (20.9)	
	> 60	9462 (11.9)	25,484 (10.8)	
Sex				< 0.0001
	Male	15,242 (19.2)	48,222 (20.3)	
	Female	64,006 (80.8)	188,844 (79.7)	
BMI (kg/m$^{2)}$				< 0.0001
	< 35	2232 (2.8)	8333 (3.5)	
	35–40	16,060 (20.4)	56,070 (23.8)	
	40–50	23,310 (29.6)	74,298 (31.5)	
	50–60	17,364 (22.0)	47,575 (20.2)	
	60–70	15,756 (20.0)	38,553 (16.4)	
	> 70	4063 (5.2)	10,996 (4.7)	
Functional status				< 0.0001
	Independent	78,401 (98.9)	234,723 (99.0)	
	Partially dependent	533 (0.7)	1303 (0.6)	
	Totally dependent	314 (0.4)	1040 (0.4)	
ASA category				< 0.0001
	ASA 1–2	13,024 (16.5)	55,360 (23.5)	
	ASA 3	62,677 (79.2)	172,950 (73.3)	
	ASA 4–5	3447 (4.4)	7495 (3.2)	
Smoking		6298 (7.8)	19,957 (8.4)	< 0.0001
Diabetes				< 0.0001
	Non-diabetic/diet controlled	51,596 (65.1)	182,679 (77.1)	
	Non-insulin dependent	16,969 (21.4)	39,099 (16.5)	
	Insulin-dependent	10,683 (13.5)	15,288 (6.5)	
Hypertension		40,963 (51.7)	108,291 (45.7)	< 0.0001
Hyperlipidemia		22,329 (28.2)	50,387 (21.3)	< 0.0001
GERD		30,899 (39.0)	63,547 (26.8)	< 0.0001
Chronic steroid use		1369 (1.7)	4394 (1.9)	0.02
Renal insufficiency		508 (0.7)	1445 (0.6)	0.3
Dialysis		158 (0.2)	902 (0.4)	< 0.0001
COPD		1431 (1.8)	3459 (1.5)	< 0.0001
Oxygen dependent		715 (0.9)	1452 (0.6)	< 0.0001
Sleep apnea		35,081 (44.3)	86,133 (36.3)	< 0.0001
Prior VTE		2136 (2.7)	5292 (2.2)	< 0.0001
Venous stasis		799 (1.0)	2138 (0.9)	0.007
Therapeutic anticoagulation		2401 (3.0)	6658 (2.8)	0.001
Prior MI		1112 (1.4)	2658 (1.1)	< 0.0001
Prior cardiac surgery		763 (1.0)	2421 (1.0)	0.2
Prior PCI		1670 (2.1)	3969 (1.7)	< 0.0001
Operative length (h)				< 0.0001
	< 1	5833 (7.4)	106,313 (44.8)	
	1–2	39,356 (49.7)	109,527 (46.2)	
	2–3	24,399 (30.8)	18,337 (7.7)	
	> 3	9660 (12.2)	2889 (1.2)	

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

Table 2 Complication rates by bariatric procedure; number of events (%)

	RYGB, *n* = 79,248	SG, n = 237,066	*p* value
Reoperation within 30 days	1692 (2.1)	1917 (0.8)	< 0.0001
Intervention within 30 days	1608 (2.0)	1683 (0.7)	< 0.0001
Readmission within 30 days	4456 (5.6)	6579 (2.8)	< 0.0001
Death within 30 days	108 (0.1)	158 (0.1)	< 0.0001
MI	28 (0.0)	48 (0.0)	0.02
Cardiac arrest requiring CPR	46 (0.1)	78 (0.0)	0.002
Pneumonia	238 (0.3)	282 (0.1)	< 0.0001
Ventilator	98 (0.1)	95 (0.0)	< 0.0001
CVA	9 (0.0)	34 (0.0)	0.5
Coma > 24 h	2 (0.0)	5 (0.0)	0.8
Peripheral nerve injury	11 (0.0)	9 (0.0)	0.002
Acute renal failure	84 (0.1)	102 (0.0)	< 0.0001
Progressive renal failure	77 (0.1)	100 (0.0)	< 0.0001
Superficial SSI	633 (0.8)	569 (0.2)	< 0.0001
Deep SSI	100 (0.1)	56 (0.0)	< 0.0001
Organ space SSI	293 (0.4)	322 (0.1)	< 0.0001
Wound disruption	60 (0.1)	100 (0.0)	< 0.0001
Anastomotic leak	374 (0.5)	610 (0.3)	< 0.0001
Sepsis	137 (0.2)	157 (0.1)	< 0.0001
Septic shock	95 (0.1)	77 (0.0)	< 0.0001
UTI	382 (0.5)	684 (0.3)	< 0.0001
C. diff	159 (0.2)	196 (0.1)	< 0.0001
Bleed	1289 (1.6)	1578 (0.7)	< 0.0001
Transfusion within 72 h	839 (1.1)	1212 (0.5)	< 0.0001
PE	136 (0.2)	200 (0.1)	< 0.0001

RYGB, Roux-en-Y gastric bypass; *SG*, sleeve gastrectomy; *MI*, myocardial infarction; *CPR*, cardiopulmonary resuscitation; *CVA*, cerebral vascular accident; *SSI*, surgical site infection; *UTI*, urinary tract infection; *C. diff*, *Clostridioides difficile*; *PE*, pulmonary embolus

superficial SSI, organ space SSI, acute renal failure, sepsis, septic shock, and PE.

As expected, there are differences in patient demographics between the cohorts. The SG cohort had a lower pre-operative BMI, lower ASA classification, and less pre-operative comorbidities. Given that studies show RYGB, as compared to SG, has improved results with regard to excess weight loss, and remission of comorbidities such as hypertension, dyslipidemia, GERD, and sleep apnea [7, 21–26], patients are selected carefully for the type of procedure they undergo and this affects the demographics. Perhaps secondarily to this difference in demographics, complication rates are lower for the SG cohort as compared to those for the RYGB cohort. The lower rate of complications in the SG cohort has been observed and addressed in more detail in other studies [22, 25, 26].

The timing of postoperative complications varies dramatically across surgical literature bringing to question the surgical dictum of "wind, water, wound, walk" which has aided medical students in differentiating surgical causes of postoperative fever for the past few decades. In an elegant study performed by Sonnenberg et al. [16], this dictum was assessed using the National Surgical Quality Improvement Program data registry and 11,137 adults undergoing general surgical procedures. Comparing median and mean dates of postoperative complications, the authors instead proposed a different progression of postoperative complications: pneumonia (wind), urinary tract infection (water), venous thromboembolism (walk), followed by surgical site infections (wound). Thompson et al. [15] conducted perhaps the most comprehensive analysis of temporal patterns of postoperative complications in a study of 1221 patients undergoing a diversity of intra-abdominal operations. The authors proposed a different method to characterize the temporality of postoperative complications: early postoperative (day 1), mid-postoperative (days 1–7), and late postoperative (days 8–30). Together these studies highlight the difficulty in attempting to characterize the sequence of complications using relatively small sample sizes, heterogenous populations, and immense variation in surgical procedures.

This study attempts to overcome the challenges of heterogeneity limiting prior literature by studying only the two

Table 3 Early vs late postoperative complications following bariatric surgery and their distribution over 30 days; mean days (SD), number of events (%)

	Days to complication	0–3 days	4–6 days	7–10 days	11–14 days	> 14 days
Early						
Transfusion within 72 h	1.4 (1.1)	1645 (98.7)	17 (1.0)	1 (0.1)	2 (0.1)	2 (0.1)
MI	4.7 (6.4)	36 (58.1)	9 (14.5)	7 (11.3)	4 (6.5)	6 (9.7)
Cardiac arrest requiring CPR	6.4 (8.5)	31 (36.9)	14 (16.7)	8 (9.5)	9 (10.7)	22 (26.2)
Ventilator	6.6 (6.6)	56 (33.5)	44 (26.4)	27 (16.2)	14 (8.4)	26 (15.6)
Pneumonia	6.9 (6.9)	211 (41.7)	116 (22.9)	61 (12.1)	46 (9.1)	72 (14.2)
Progressive renal failure	8.1 (8.1)	67 (37.2)	28 (15.6)	28 (15.6)	11 (6.1)	46 (25.6)
Acute renal failure	8.2 (7.6)	73 (43.7)	21 (12.6)	9 (5.4)	24 (14.4)	40 (24.0)
Septic shock	8.3 (6.9)	53 (31.0)	39 (22.8)	31 (18.1)	15 (8.8)	33 (19.3)
CVA	8.3 (7.5)	12 (27.9)	12 (27.9)	6 (14.0)	4 (9.3)	9 (20.9)
Peripheral nerve injury	8.4 (7.4)	5 (27.8)	3 (16.7)	2 (11.1)	3 (16.7)	5 (27.8)
Late						
Coma > 24 h	10.1 (10.3)	0	3 (50.0)	1 (16.7)	0	2 (33.3)
Sepsis	10.9 (7.6)	52 (17.9)	54 (18.6)	50 (17.2)	43 (14.8)	92 (31.6)
C. diff	11.3 (7.8)	46 (13.1)	73 (20.7)	79 (22.4)	46 (13.1)	108 (30.7)
Wound disruption	11.7 (7.6)	24 (15.7)	12 (7.8)	29 (19.0)	33 (21.6)	55 (36.0)
Organ space SSI	11.7 (7.9)	101 (16.6)	101 (16.6)	102 (16.8)	90 (14.8)	215 (35.3)
Deep SSI	12.4 (6.6)	5 (3.2)	10 (10.3)	55 (35.5)	30 (19.4)	49 (31.6)
PE	12.7 (7.8)	44 (13.2)	44 (13.2)	53 (15.9)	59 (17.7)	133 (39.9)
Superficial SSI	13.2 (6.9)	33 (2.8)	143 (11.9)	344 (38.7)	253 (21.1)	426 (35.5)
UTI	14.0 (8.4)	99 (9.5)	134 (12.9)	159 (15.3)	143 (13.8)	504 (48.5)

MI, myocardial infarction; *CPR*, cardiopulmonary resuscitation; *CVA*, cerebral vascular accident; *SSI*, surgical site infection; *UTI*, urinary tract infection; *C. diff*, *Clostridioides difficile*; *PE*, pulmonary embolus. Bold label categorizes complications into early (< 10 days) and late (> 10 days)

most commonly performed bariatric procedures (RYGB and SG) using the largest North American bariatric data registry. We indeed found a significant overlap in timing of complications, with some complications primarily occurring early, some late, while others occurred in a bimodal distribution. This pattern made it difficult to identify a clear progression or temporality of postoperative complications. General trends, however, were observed in the early complication group suggesting a progression from technical (bleeding and transfusion) to cardiac, pulmonary, renal, and then to neurologic complications. Late complications occurring after 10 days were predominantly infectious (sepsis, *C. difficile*, SSIs, UTIs) in nature with the addition of pulmonary embolus.

The overall temporality of these complications has several implications for healthcare providers. More than half of all cardiac (MI), pulmonary (pneumonias), and renal (acute and progressive renal failure) complications occurred within the first 6 days of surgery. Patients presenting to the emergency department within this timeframe should be treated with a high degree of clinical suspicion for these complications and should undergo a workup to rule them out with a chest X-ray, basic metabolic panel, serum troponin, and an EKG. These complications should remain on the differential even in an outpatient setting given the atypical presentation of angina in this population. As more than half of infectious wound and urinary complications occurred after 10 days, an emphasis to evaluate for these complications should be undertaken during this period. Given the low diagnostic yield of abdominal exams in patients with obesity, clinicians must retain a high degree of suspicion for postoperative complication based on clinical history and the anticipated timing of various complications. Notwithstanding, it is important to acknowledge that almost all complications can occur throughout the postoperative period. These identified complication trends do not replace clinical assessment, but instead may help to guide a differential for bariatric and non-bariatric clinicians alike.

Lastly, our findings suggest that the timing of postoperative complications appears to be dependent on the type of bariatric procedure performed. Of those that were statistically different (superficial and organ space SSI, sepsis, septic shock, acute renal failure, need for transfusion, and PE), the majority were diagnosed later in the SG cohort as compared to the RYGB cohort. The difference in timing of diagnosis for these complications was in the order of 1.5–3.4 days on average. While an interesting finding, it is not entirely clear as to why this difference in the timing of complications exists between procedures. One

Table 4 Time to complication in days by bariatric procedure; means days (SD)

	RYGB, *n* = 79,248	SG, *n* = 237,066	*p* value
Cardiac			
MI	3.7 (4.4)	5.3 (7.2)	0.5
Cardiac arrest requiring CPR	7.9 (8.5)	5.4 (8.3)	**0.05**
Pulmonary			
Pneumonia	6.6 (6.3)	7.3 (7.3)	0.9
Ventilator	6.6 (6.5)	6.6 (6.8)	0.6
Neurologic			
Coma > 24 h	6.0 (2.8)	11.8 (12.0)	0.7
CVA	7.2 (7.3)	8.6 (7.7)	0.6
Peripheral nerve injury	7.5 (6.9)	9.4 (8.2)	0.7
Renal			
Acute renal failure	6.8 (6.8)	9.3 (8.1)	**0.03**
Progressive renal failure	7.1 (7.5)	8.9 (8.5)	0.3
Infectious			
Superficial SSI	12.5 (6.3)	14.0 (7.4)	**0.001**
Deep SSI	12.6 (6.6)	12.1 (6.7)	0.7
Organ space SSI	10.8 (7.9)	12.6 (7.8)	**0.001**
Wound disruption	11.8 (7.5)	11.7 (7.7)	0.8
Sepsis	9.8 (7.3)	11.9 (7.7)	**0.01**
Septic shock	6.8 (5.7)	10.2 (7.7)	**0.002**
C. diff	11.4 (7.8)	11.2 (7.8)	0.8
UTI	14.1 (8.7)	14.0 (8.3)	1.0
Hematologic			
Transfusion within 72 h	1.5 (1.3)	1.4 (1.0)	**0.04**
PE	11.3 (8.0)	13.7 (7.5)	**0.003**

RYGB, Roux-en-Y gastric bypass; *SG*, sleeve gastrectomy; *MI*, myocardial infarction; *CPR*, cardiopulmonary resuscitation; *CVA*, cerebral vascular accident; *SSI*, surgical site infection; *UTI*, urinary tract infection; *C. diff*, *Clostridioides difficile*; *PE*, pulmonary embolus. Bolded: statistically significant

possible explanation is that the patient demographics differed between SG and RYGB cohorts, which may in part be due to how patients were selected for the type of metabolic procedure delivered. Patients undergoing RYGB, for example, had a higher degree of metabolic comorbidities (increased rates of insulin-dependent diabetes, sleep apnea, higher BMI)[20], all of which have been associated with an increased predisposition for developing postoperative complications due to higher degree of systemic inflammation [27], malnutrition, and sarcopenia [28], as well as immunologic dysfunction [29]. Additionally, there is an increased physiologic insult associated with the RYGB procedure-itself due to an increased operative length and prolonged anesthetic burden [22, 30, 31] that may also contribute to the earlier timing of complications when compared to the SG cohort. Another potential explanation is that the formation of anastomoses distally in the gastrointestinal tract in which the bowel is entered has been shown to predispose to increased burden of infectious complications [32, 33] as compared to procedures resecting proximal hollow viscous organs in which the bacterial load is typically much smaller [34]. Other potential reasons may be due to diagnostic bias, as the hospital stay for RYGB patients is typically longer and may allow for more prompt recognition of such complications. The expectedly higher complication rate for RYGB may further bias patients and clinicians towards an earlier clinical follow-up if postoperative concerns arise subsequently also leading to an early diagnosis.

With improved understanding of optimal patient recovery after surgery and the advent of enhanced recovery after surgery (ERAS), many patients are now going home within 2 to 3 days following bariatric surgery [35, 36]. A meta-analysis looking at the length of stay following bariatric surgery in ERAS and non-ERAS cohorts demonstrated a mean length of stay of 2.8 days for the ERAS group. There is also a trend towards outpatient bariatric surgery [37]. The majority of complications that can occur therefore fall outside the typical inpatient admission. It is important for clinicians to have an understanding of the types of complications and their timing following bariatric surgery. This knowledge will lead to an earlier diagnosis and management of postoperative complications, and to prompt referral to a center specializing in bariatric surgery when warranted.

Our study has several limitations. Given the retrospective study design which employed the MBSAQIP database, only complications occurring within the first 30 days could be characterized. However, as most complications occur within the first 30 days, we believe our design is appropriate to evaluate our hypothesis and achieve our study aims. As with any database, coding errors do occur, such as timing of transfusion within 72 h occurring after 72 h. Additionally, in the process of de-identifying data, databases such as this one eliminate the context of collected variables and limit their interpretation, such as differentiating between medical and surgical complications, sequential or linked complications, and complications in relation to pre-existing comorbidities. Our study to characterize the timing of complications has been designed with these limitations in mind, as it is not possible to elucidate the etiology and complex interactions between complications using this database. Because of the multi-center and multination nature of the registry used for this study, there may be significant differences in practices that affect the timing of diagnosis of postoperative complications. For example, the timing of follow-up appointments may vary and affect the timing of diagnosis. This would directly affect our data by skewing timing of postoperative complications to the timing of postoperative follow-up. Likewise, the use of medication to treat certain complications may also alter when the diagnosis of a complication is made. For example, the use of antibiotics prior to opening a wound would delay the diagnosis of a wound infection or other infectious complications. The data collected in this registry does not include the timing of some important complications such as anastomotic leaks and bleeding which affects the interpretation of the data, and others that are specific to bariatric procedures such as postoperative reflux, dysphagia, and nutritional deficiencies. Regardless, this study is the first step in understanding the timing of postoperative complications following bariatric surgery and we hope the results of this study prompt further research into the complex nature of their timing.

Despite these limitations, our study, to our knowledge, is the first to evaluate the timing of postoperative complications following bariatric surgery. We believe that an understanding of these findings will serve to improve postoperative bariatric care by helping facilitate a prompt diagnosis of postoperative complications and overcoming potential delays in their management.

Conclusion

This study provides the first characterization regarding the timing of postoperative complications following bariatric surgery. We demonstrate that significant differences in timing exist between complications and that these differences also vary by surgical procedure. Understanding the course of bariatric surgical complications will enable providers to optimize perioperative care by helping overcome delays in diagnosis and management.

Declarations

Ethics Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent to Participate Informed consent does not apply.

Conflict of Interest The authors declare no competing interests.

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