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Robotic sleeve gastrectomy has higher complication rates compared to laparoscopic: 8-year analysis of robotic versus laparoscopic primary bariatric surgery

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Abstract

Background: Robotic-assisted bariatric surgery is growing rapidly. The optimal approach to minimize complications remains unclear.

Objective: Assess robot utilization and compare 30-day outcomes for laparoscopic and robotic primary sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) using the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) database.

Setting: United States.

Methods: A retrospective analysis of the MBSAQIP database identified primary SG and RYGB cases from 2015 to 2022. Revisions/conversions, cases converted to another approach, and combined cases other than esophagogastroduodenoscopy were excluded. Outcomes were compared with logistic regression following 1:1 propensity-score matching to adjust for differences in patient demographics/comorbidities and operative variables.

Results: A total of 823,902 cases (591,118 SG; 232,784 RYGB) were included. From 2015 to 2022, the percentage of SG and RYGB performed robotically increased from 6.7% and 6.9% to 29.5% and 31.8%, respectively. Compared to laparoscopic, robotic SG had significantly higher overall morbidity (odds ratio 1.14 [1.07-1.21], $P < .001$), leak (1.24 [1.05-1.46], $P = .03$), and bleeding rates (1.34 [1.13-1.58], $P < .001$). Robotic RYGB had significantly lower overall morbidity (.75 [.70-.81], $P < .001$) and bleeding (.80 [.68-.94], $P < .01$) with similar leak rates (.87 [.71-1.07], $P = .18$). Combined robotic SG and RYGB outcomes were similar to laparoscopic for 2020-2022 cases, except for higher rates of organ/space infection, readmission, and septic shock in the robotic group.

Conclusion: Robotic SG has higher complication rates compared to laparoscopic, while robotic RYGB is protective against bleeding complications. Short-term outcomes for robotic surgery have become more similar to laparoscopic, but remain inferior. Further studies are warranted to elucidate the factors driving these findings. (Surg Obes Relat Dis 2024;■:1–10.) © 2024 American Society for Metabolic and Bariatric Surgery. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Keywords: Robotic bariatric surgery; Sleeve gastrectomy; Gastric bypass; Laparoscopic; MBSAQIP

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Metabolic and bariatric surgery (MBS) is the most effective evidence-based treatment for obesity [1,2]. Multiple studies with long-term follow-up have demonstrated that MBS provides superior sustained weight loss outcomes and reductions in obesity-related comorbidities compared to nonoperative management [2–4]. MBS is steadily gaining popularity as a result, with sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) being the most common procedures. With the advancement of laparoscopic and robotic techniques, minimally invasive surgery has become the preferred approach for MBS.

Robotic platforms are rapidly changing the practice of surgery across disciplines, including MBS [5,6]. Robotic surgery offers the benefits of improved ergonomics, dexterity, and visualization, which may be advantageous in cases with complex anatomy [7]. A recent study analyzing over 1 million cases from the 2015-2020 Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) Participant Use Data File (PUF) datasets found that robotic RYGB cases increased from 6.8% to 16.7%, while robotic SG increased from 6.0% to 17.2% [6]. Despite the technical advantages of robotic surgery, the ideal approach to optimize patient outcomes is unclear. There is a growing body of literature comparing the outcomes of laparoscopic and robotic MBS with varying results [7–12]. Many of these studies focus on comparing outcomes in revisional MBS [7,13,14].

The role of robotics in primary MBS is not as well characterized. A study of 2015-2016 MBSAQIP data found that primary robotic RYGB was associated with lower morbidity and mortality, while primary robotic SG had higher rates of many postoperative complications and reintervention [11]. Since this study, the MBSAQIP has been updated through 2022 with the addition of new variables. To our knowledge, there have been no studies comparing the outcomes of laparoscopic and robotic primary SG and RYGB with these new data. The goal of this study was to perform the largest retrospective study of the MBSAQIP database comparing perioperative outcomes between laparoscopic and robotic-assisted primary SG and RYGB cases. We also sought to assess operative time and outcomes in minimally invasive MBS over the 8-year period of available data to examine surgeon performance in the context of increasing robot utilization.

Methods

Case selection and study design

A retrospective analysis of the 2015-2022 MBSAQIP PUF was performed identifying primary SG and RYGB cases performed laparoscopically (L) and robotically (R). The case selection algorithm for this study is shown in Supplementary Fig. 1. Primary MBS cases were first selected by excluding revisions and conversions. To minimize the potential for confounding from additional procedures, MBS cases involving concurrent procedures other than esophagogastroduodenoscopy were excluded. All surgical approaches other than laparoscopic and robotic were then excluded. Cases converted to another surgical approach were also removed to reduce confounding from cases converted to open and more accurately assess longitudinal trends in operative time. SG and RYGB cases were then selected by current procedural terminology (CPT) codes 43,775, 43,644, and 43,645. CPT codes are a numeric coding system used by physicians and other health care professionals to identify specific medical procedures and services. Standard laparoscopic and robotic-assisted cases were then separated. Finally, cases with incomplete 30-day follow-up were excluded.

Following case selection, operative time and robotic utilization as a percentage of total minimally invasive primary MBS over the 8-year period were analyzed. Propensity score matching (PSM) was then performed for SG and RYGB between laparoscopic and robotic procedures. Laparoscopic and robotic SG and RYGB outcomes were compared for cases from 2015 to 2022. To evaluate for potential changes in robotic outcomes relative to laparoscopic over time, we performed two subgroup analyses. The first subgroup analysis combined SG and RYGB cases to compare outcomes for all laparoscopic and robotic primary MBS from 2015 to 2019. The second analysis compared laparoscopic and robotic primary MBS from 2020 to 2022. We elected to compare these groups of cases due changes in the reporting of postoperative bleeding and anastomotic leak in the main PUF beginning in 2020 and to attempt to account for evolutions in robotic platforms.

Primary outcomes were overall postoperative morbidity, anastomotic leak, and bleeding. Secondary outcomes were 30-day readmission, reoperation, reintervention, and mortality. Overall morbidity was defined as the occurrence of a postoperative complication reported in the MBSAQIP. Definitions for aggregate leak and aggregate bleeding were adapted from the aggregate complication methodology previously described by Berger et al. [15] (Supplementary Table 1).

The MBSAQIP is a database created by the American College of Surgeons (ACS) and American Society of Metabolic and Bariatric Surgery. All nationally accredited MBS centers in the United States report outcomes to the MBSAQIP. All outcomes recorded in the dataset are 30-day outcomes. The MBSAQIP is a deidentified database, and this study was therefore exempt from institutional review board approval. The ACS, MBSAQIP, and the centers participating in the MBSAQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

Statistical analysis

Categorical variables were reported as a frequency and percentage, and continuous variables as mean ± standard deviation (SD). PSM was used to estimate the effect of robotic surgery on primary MBS outcomes. Propensity scores were estimated using logistic regression based on patient demographics, comorbidities, and operative variables available in the MBSAQIP PUF (Supplementary Table 1). One-to-one greedy nearest neighbor matching was used, and all robotic cases were matched to a laparoscopic case. The PSM process was evaluated by the standardized differences between groups. A value of <.1 was considered as negligible imbalance.

Multivariate logistic regression was used to compare categorical outcomes between the propensity score-matched samples using patient demographics, comorbidities, and operative variables as independent variables in the regression. An odds ratio (OR) and 95% confidence interval (CI) were reported for each outcome with laparoscopic cases used as the reference group. Independent two sample *t*-test was used to compare continuous variables. A *P* value of < .05 was considered statistically significant. Statistical analysis was performed in R (Version 4.4.1).

Results

Robot utilization

The total number of primary R-SG cases increased by 624.2% from 2015 (3729) to 2022 (27,006). In contrast, the total number of primary L-SG cases increased by 24.0% from 2015 (51,946) to 2022 (64,393). The total number of primary R-RYGB cases also increased substantially by 506.8% from 2015 (1874) to 2022 (11,360). The number of primary L-RYGB cases decreased by 3.5% from 2015 (25,259) to 2022 (24,371). Taken together, the percentage of all primary SG and RYGB performed R increased from 6.7% and 6.9% to 29.5% and 31.8%, respectively over the 8-year period (Fig. 1).

Operative time

A longitudinal analysis of operative time for primary laparoscopic and robotic MBS was performed to examine surgeon performance over time. From 2015 to 2022, mean operative time for R-SG decreased significantly by 18.5 minutes (97.4 ± 40.8 vs 78.9 ± 33.4 minutes, *P* <.001). Mean operative time for L-SG over this period also significantly decreased by 11.3 minutes (70.5 ± 34.0 vs 59.2 ± 32.1 minutes, *P* < .001). Mean operative time for R-RYGB saw a significant reduction by 11.7 minutes (146.7 ± 59.9 vs 135.0 ± 51.3 minutes, *P* <.001); however, there was no difference in mean operative time for L-RYGB (111.4 ± 49.2 vs 111.4 ± 53.4 minutes, *P* >.99). Despite the reductions in mean operative time for R-SG and R-RYGB, L-SG and L-RYGB mean operative times were significantly shorter during each year over the 8-year period (Table 1).

Robotic versus laparoscopic SG and RYGB outcomes (2015-2022)

From 2015 to 2022, there were a total of 1,577,175 cases in the MBSAQIP. After case selection, 823,902 cases were included. The most common concurrent procedures excluded were hiatal hernia repair, bilateral transversus abdominis plane (TAP) block, and liver biopsy. There

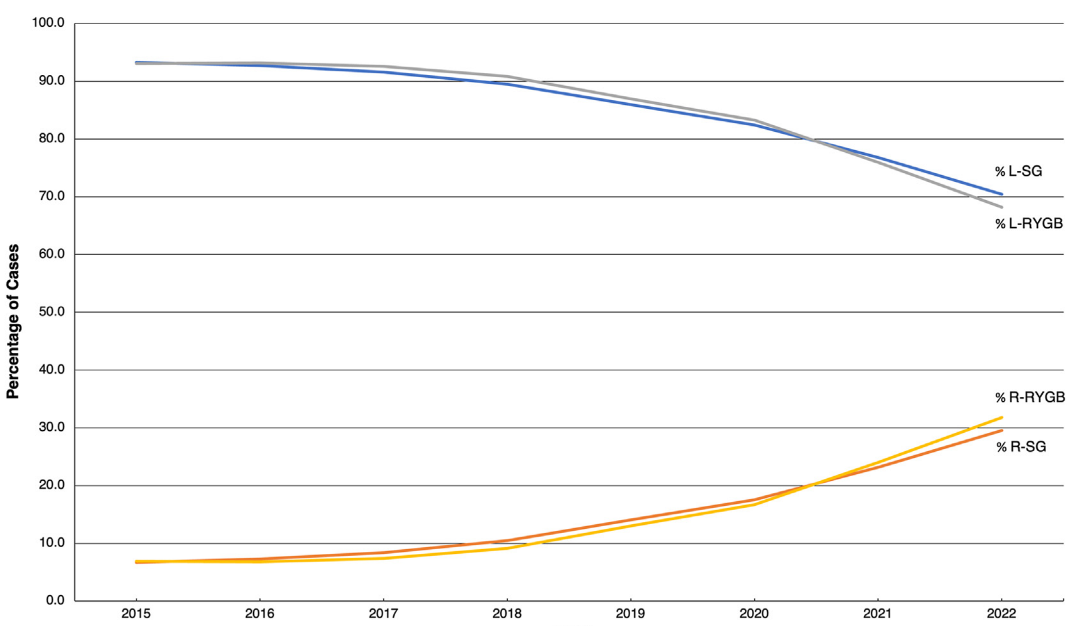

Fig. 1. Percentage of primary sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) cases performed laparoscopically (L-) and robotically (R-) from 2015 to 2022.

Table 1
Operative times for laparoscopic and robotic primary sleeve gastrectomy and Roux-en-Y gastric bypass from 2015 to 2022

Year	Operative time, mean ± SD (min)		Difference (R – L)	Operative time, mean ± SD (min)		Difference (R – L)	*P* value
	L-SG	R-SG		L-RYGB	R-RYGB		
2015	70.5 ± 34.0	97.4 ± 40.8	26.9	111.4 ± 49.2	146.7 ± 59.9	35.3	< .001
2016	68.2 ± 34.5	94.1 ± 41.2	25.9	113.4 ± 49.7	149.3 ± 59.5	35.8	< .001
2017	65.6 ± 32.4	91.7 ± 42.8	26.0	113.4 ± 49.3	156.7 ± 63.0	43.3	< .001
2018	64.7 ± 31.1	91.7 ± 38.7	27.0	115.0 ± 49.3	152.2 ± 57.9	37.2	< .001
2019	63.8 ± 31.3	85.5 ± 37.6	21.7	113.9 ± 48.6	148.9 ± 58.1	35.0	< .001
2020	63.4 ± 32.9	84.6 ± 37.4	21.2	115.5 ± 52.6	147.2 ± 56.5	31.7	< .001
2021	61.0 ± 32.2	80.9 ± 34.7	19.9	112.7 ± 52.0	140.0 ± 53.1	27.3	< .001
2022	59.2 ± 32.1	78.9 ± 33.4	19.7	111.4 ± 53.4	135.0 ± 51.3	23.6	< .001

L-SG = laparoscopic sleeve gastrectomy; R-SG = robotic sleeve gastrectomy; L-RYGB = laparoscopic Roux-en-Y gastric bypass; R-RYGB = robotic Roux-en-Y gastric bypass; SD = standard deviation.

Statistically significant *P* values in bold.

were 499,251 laparoscopic SG (L-SG, 60.6%), 91,867 robotic SG (R-SG, 11.2%), 197,302 laparoscopic RYGB (L-RYGB, 23.9%), and 35,482 robotic RYGB (R-RYGB, 4.3%). All R-SG and R-RYGB cases were matched 1:1 to laparoscopic cases. Standardized differences for all variables in the matched data were less than .05, indicating good balance between the laparoscopic and robotic groups (Supplementary Table 2 and Table 3).

Table 2
Thirty-day postoperative outcomes for laparoscopic and robotic primary sleeve gastrectomy from 2015 to 2022 after propensity score matching

Outcome, n (%)	L-SG (N = 91,867)	R-SG (N = 91,867)	*P* value	OR (95% CI)
Overall morbidity	1941 (2.11)	2212 (2.41)	**<.001**	**1.14 (1.07-1.21)**
Aggregate leak	246 (.27)	298 (.32)	**.03**	**1.24 (1.05-1.46)**
Reoperation for leak	92 (.10)	110 (.12)	.22	1.18 (.90-1.57)
Intervention for leak	98 (.11)	103 (.11)	.74	1.05 (.79-1.38)
Readmission for leak	140 (.15)	146 (.16)	.74	1.04 (.82-1.31)
Organ/space SSI	125 (.14)	240 (.26)	**<.001**	**1.91 (1.54-2.38)**
Aggregate bleeding	234 (.25)	315 (.34)	**<.001**	**1.34 (1.13-1.58)**
Reoperation for bleeding	151 (.16)	157 (.17)	.79	1.03 (.82-1.29)
Intervention for bleeding	29 (.03)	19 (.02)	.14	.65 (.36-1.15)
Readmission for bleeding	71 (.08)	96 (.10)	.06	1.34 (.99-1.82)
Blood transfusion	428 (.47)	550 (.60)	**<.001**	**1.28 (1.13-1.45)**
Readmission	2378 (2.59)	2370 (2.58)	.87	1.00 (.94-1.06)
Reoperation	630 (.69)	661 (.72)	.45	1.04 (.94-1.16)
Reintervention	560 (.61)	564 (.61)	.87	1.01 (.90-1.14)
Mortality	35 (.04)	52 (.06)	.08	1.47 (.95-2.26)
Superficial incisional SSI	217 (.24)	265 (.29)	**.03**	**1.22 (1.02-1.46)**
Deep incisional SSI	23 (.03)	26 (.03)	.68	1.12 (.64-1.97)
Wound disruption	39 (.04)	47 (.05)	.39	1.20 (.79-1.84)
Sepsis	60 (.07)	95 (.10)	**<.01**	**1.56 (1.13-2.15)**
Septic shock	20 (.02)	37 (.04)	**.03**	**1.84 (1.06-3.17)**
Urinary tract infection	285 (.31)	259 (.28)	.25	.91 (.77-1.07)
Ventilator >48 hr	27 (.03)	44 (.05)	.06	1.60 (.99-2.59)
Unplanned intubation	56 (.06)	84 (.09)	**.02**	**1.49 (1.06-2.09)**
Pneumonia	105 (.11)	107 (.12)	.89	1.02 (.78-1.33)
Venous thrombosis requiring therapy	180 (.20)	217 (.24)	.07	1.20 (.99-1.46)
Pulmonary embolism	88 (.10)	97 (.11)	.55	1.09 (.82-1.46)
Stroke	11 (.01)	19 (.02)	.14	1.75 (.83-3.69)
Unplanned admission to ICU	389 (.42)	386 (.42)	.83	.98 (.85-1.13)
Acute renal failure requiring dialysis	32 (.03)	43 (.05)	.19	1.36 (.86-2.16)
Progressive renal insufficiency	53 (.06)	45 (.05)	.40	.84 (.57-1.25)
Cardiac arrest requiring CPR	20 (.02)	31 (.03)	.14	1.53 (.87-2.68)
Myocardial infarction	22 (.02)	17 (.02)	.38	.75 (.40-1.43)

L-SG = laparoscopic sleeve gastrectomy; R-SG = robotic sleeve gastrectomy; OR = odds ratio; CI = confidence interval; SSI = surgical site infection; GI = gastrointestinal; ICU = intensive care unit; CPR = cardiopulmonary resuscitation.

Statistically significant *P* values in bold.

Table 3
Thirty-day postoperative outcomes for laparoscopic and robotic primary Roux-en-Y gastric bypass from 2015 to 2022 after propensity score matching

Outcome, n (%)	L-RYGB (N = 35,482)	R-RYGB (N = 35,482)	*P* value	OR (95% CI)
Overall morbidity	1590 (4.48)	1217 (3.43)	**<.001**	**.75 (.70-.81)**
Aggregate leak	198 (.56)	172 (.48)	.18	.87 (.71-1.07)
Reoperation for leak	67 (.19)	77 (.22)	.41	1.15 (.83-1.60)
Intervention for leak	26 (.07)	31 (.09)	.51	1.19 (.71-2.01)
Readmission for leak	49 (.14)	58 (.16)	.38	1.19 (.81-1.74)
Organ/space SSI	132 (.37)	145 (.41)	.45	1.09 (.86-1.39)
Aggregate bleeding	328 (.92)	264 (.74)	**<.01**	**.80 (.68-.94)**
Reoperation for bleeding	111 (.31)	50 (.14)	**<.001**	**.45 (.32-.63)**
Intervention for bleeding	86 (.24)	64 (.18)	.07	.74 (.53-1.02)
Readmission for bleeding	167 (.47)	130 (.37)	**.03**	**.77 (.61-.97)**
Blood transfusion	371 (1.05)	247 (.70)	**<.001**	**.66 (.56-.78)**
Readmission	1872 (5.28)	1937 (5.46)	.31	1.03 (.97-1.10)
Reoperation	671 (1.89)	673 (1.90)	.97	1.00 (.90-1.12)
Reintervention	644 (1.82)	579 (1.63)	.06	.90 (.80-1.00)
Mortality	32 (.09)	45 (.13)	.20	1.35 (.85-2.13)
Superficial incisional SSI	287 (.81)	113 (.32)	**<.001**	**.39 (.31-.49)**
Deep incisional SSI	40 (.11)	14 (.04)	**<.001**	**.35 (.19-.64)**
Wound disruption	23 (.06)	30 (.08)	.35	1.30 (.75-2.24)
Sepsis	56 (.16)	50 (.14)	.57	.89 (.61-1.31)
Septic shock	35 (.10)	41 (.12)	.49	1.17 (.75-1.84)
Urinary tract infection	186 (.52)	165 (.47)	.26	.89 (.72-1.09)
Ventilator >48 hr	33 (.09)	44 (.12)	.23	1.32 (.84-2.09)
Unplanned intubation	48 (.14)	59 (.17)	.29	1.23 (.84-1.80)
Pneumonia	109 (.31)	114 (.32)	.75	1.04 (.80-1.36)
Venous thrombosis requiring therapy	57 (.16)	48 (.14)	.40	0858 (.58-1.24)
Pulmonary embolism	49 (.14)	58 (.16)	.39	1.18 (.81-1.73)
Stroke	2 (.01)	3 (.01)	.65	1.51 (.25-9.21)
Unplanned admission to ICU	292 (.82)	276 (.78)	.43	.94 (.79-1.10)
Acute renal failure	27 (.08)	25 (.07)	.77	.92 (.53-1.59)
Progressive renal insufficiency	30 (.08)	34 (.10)	.67	1.11 (.68-1.82)
Cardiac arrest requiring CPR	11 (.03)	19 (.05)	.15	1.74 (.83-3.66)
Myocardial infarction	10 (.03)	10 (.03)	.99	1.00 (.41-2.45)

L-RYGB = laparoscopic Roux-en-Y gastric bypass; R-RYGB = robotic Roux-en-Y gastric bypass; OR = odds ratio; CI = confidence interval; SSI = surgical site infection; GI = gastrointestinal; ICU = intensive care unit; CPR = cardiopulmonary resuscitation.
Statistically significant *P* values in bold.

Compared to L-SG, R-SG had significantly higher overall morbidity (OR 1.14 [1.07-1.21], $P < .001$) and aggregate leak rates (OR 1.24 [1.05-1.46], $P = .03$), which appeared to be driven by a higher rate of organ/space surgical site infection (SSI) in the R-SG group (1.91 [1.54-2.38], $P < .001$). R-SG also had significantly higher rates of aggregate bleeding (1.34 [1.13-1.58], $P < .001$) and postoperative blood transfusion (1.28 [1.13-1.45], $P < .001$). Multiple infectious complications were significantly higher in the R-SG group, including superficial incisional SSI (1.22 [1.02-1.46], $P = .03$), sepsis (1.56 [1.13-2.15], $P < .01$), and septic shock (1.84 [1.06-3.17], $P = .03$). Unplanned intubation was also significantly higher for R-SG (1.49 [1.06-2.09], $P = .02$). There were otherwise no significant differences in all other postoperative complications, including readmission, reoperation, reintervention, and mortality (Table 2).

Compared to L-RYGB, R-RYGB had a significantly lower overall morbidity rate (.75 [.70-.81], $P < .001$) and lower rates of aggregate bleeding (.80 [.68-.94], $P < .01$), reoperation for bleeding (.45 [.32-.63], $P < .001$), readmission for bleeding (.77 [.61-.97], $P = .03$), and blood transfusion (.66 [.56-.78], $P < .001$). In terms of infectious complications, R-RYGB had lower rates of superficial incisional SSI (.39 [.31-.49], $P < .001$) and deep incisional SSI (.35 [.19-.64], $P < .001$). There were otherwise no significant differences in outcomes, including readmission, reoperation, reintervention, and mortality rates (Table 3).

Robotic versus laparoscopic outcomes (2015-2019)

Robotic cases from 2015-2019 (N = 45,522), including both SG and RYGB, were 1:1 matched to laparoscopic cases (N = 441,283) from the same period (Supplementary Table 4). Compared to laparoscopic cases, robotic cases from 2015-2019 had higher aggregate leaks (1.67 [1.38-2.02], $P < .001$), reoperations for leak (2.53 [1.74-3.69], $P < .001$), interventions for leak (1.97 [1.33-2.91], $P < .001$), readmissions for leak (1.77 [1.29-2.44], $P < .001$), and organ/space SSI (1.98 [1.49-2.62], $P < .001$). Robotic cases also had higher rates of readmission (1.16 [1.08-1.24], $P < .001$), wound disruption (2.34 [1.33-4.13], $P <$

.01), sepsis (1.65 [1.06-2.56], $P = .03$), and ventilator >48 hours (2.02 [1.16-3.52], $P < .01$). However, robotic cases had lower overall aggregate bleeding (.80 [.66-.97], $P = .02$), superficial SSI (.56 [.44-.72], $P < .001$), and deep SSI (.37 [.17-.80], $P = .01$). There was no difference in postoperative morbidity, reoperation, reintervention, or mortality (Table 4).

Robotic versus laparoscopic outcomes (2020-2022)

Robotic (N = 81,827) and laparoscopic (N = 255,270) SG and RYGB cases from 2020-2022 were 1:1 matched (Supplementary Table 5) with relatively few differences in outcomes compared to 2015-2019. Robotic cases had a higher rate of organ/space SSI (1.23 [1.01-1.48], $P = .04$), readmission (1.10 [1.03-1.16], $P < .01$), and septic shock (1.58 [1.01-2.48], $P = .045$). All other postoperative outcomes including overall morbidity, leak, and bleeding were similar between laparoscopic and robotic cases (Table 5).

Discussion

This study represents the largest retrospective comparison of laparoscopic and robotic primary SG and RYGB outcomes in the literature, and to our knowledge, the first study reporting these outcomes from the 2022 iteration of the MBSAQIP. The increasing utilization of robotic surgery highlights the importance of determining its role in MBS and the need to investigate the approach that optimizes patient outcomes. We found that R-SG was associated with generally worse outcomes compared to L-SG, while R-RYGB reduced the risk of multiple complications compared to L-RYGB. Outcomes for laparoscopic and robotic cases performed from 2020-2022 were more similar than outcomes from 2015-2019, though robotic outcomes remained inferior to laparoscopic.

Multiple studies have demonstrated an increasing proportion of MBS cases being performed R [6,16,17]. A recent study including 2020 MBSAQIP data reported an increase in robotic surgery use across MBS procedures, with

Table 4
Thirty-day postoperative outcomes for laparoscopic and robotic primary bariatric surgery cases from 2015 to 2019 after propensity score matching

Outcome, n (%)	Laparoscopic (N = 45,522)	Robotic (N = 45,522)	*P* value	OR (95% CI)
Overall morbidity	1307 (2.87)	1243 (2.73)	.18	.95 (.87-1.03)
Aggregate leak	170 (.37)	282 (.62)	**<.001**	**1.67 (1.38-2.02)**
Reoperation for leak	38 (.08)	96 (.21)	**<.001**	**2.53 (1.74-3.69)**
Intervention for leak	38 (.08)	75 (.16)	**<.001**	**1.97 (1.33-2.91)**
Readmission for leak	59 (.13)	105 (.23)	**<.001**	**1.77 (1.29-2.44)**
Organ/space SSI	73 (.16)	144 (.32)	**<.001**	**1.98 (1.49-2.62)**
Drain present at 30 d	71 (.16)	82 (.18)	.31	1.18 (.86-1.62)
Aggregate bleeding	233 (.51)	190 (.42)	**.02**	**.80 (.66-.97)**
Reoperation for bleeding	126 (.28)	87 (.19)	**<.01**	**.68 (.52-.90)**
Intervention for bleeding	55 (.12)	47 (.10)	.36	.83 (.56-1.23)
Readmission for bleeding	95 (.21)	94 (.21)	.78	.96 (.72-1.28)
Blood transfusion	289 (.63)	251 (.55)	.09	.86 (.72-1.02)
Readmission	1610 (3.5)	1854 (4.1)	**<.001**	**1.16 (1.08-1.24)**
Reoperation	510 (1.12)	561 (1.23)	.12	1.10 (.98-1.24)
Reintervention	539 (1.18)	599 (1.32)	.07	1.11 (.99-1.25)
Mortality	31 (.07)	30 (.07)	.90	.97 (.58-1.61)
Superficial incisional SSI	183 (.40)	104 (.23)	**<.001**	**.56 (.44-.72)**
Deep incisional SSI	24 (.05)	9 (.02)	**.01**	**.37 (.17-.80)**
Wound disruption	17 (.04)	40 (.09)	**<.01**	**2.34 (1.33-4.13)**
Sepsis	32 (.07)	53 (.12)	**.03**	**1.65 (1.06-2.56)**
Septic shock	22 (.05)	28 (.06)	.37	1.29 (.74-2.27)
Urinary tract infection	158 (.35)	122 (.27)	**.03**	**.77 (.60-.97)**
Ventilator >48 hr	19 (.04)	38 (.08)	**.01**	**2.02 (1.16-3.52)**
Unplanned intubation	47 (.10)	68 (.15)	.05	1.45 (1.00-2.10)
Pneumonia	85 (.19)	87 (.19)	.88	1.02 (.76-1.38)
Venous thrombosis requiring therapy	85 (.19)	78 (.17)	.57	.91 (.67-1.24)
Pulmonary embolism	51 (.11)	44 (.10)	.43	.85 (.57-1.27)
Stroke	4 (.01)	8 (.02)	.27	1.98 (.59-6.63)
Unplanned admission to ICU	283 (.62)	285 (.63)	.99	1.00 (.85-1.18)
Acute renal failure	33 (.07)	30 (.07)	.70	.91 (.55-1.49)
Progressive renal insufficiency	29 (.06)	23 (.05)	.39	.79 (.45-1.36)
Cardiac arrest requiring CPR	12 (.03)	18 (.04)	.28	1.50 (.72-3.12)
Myocardial infarction	10 (.02)	7 (.02)	.45	.69 (.26-1.82)

OR = odds ratio; CI = confidence interval; SSI = surgical site infection; GI = gastrointestinal; ICU = intensive care unit; CPR = cardiopulmonary resuscitation.

Statistically significant *P* values in bold.

Table 5
Thirty-day postoperative outcomes for laparoscopic and robotic primary bariatric surgery cases from 2020 to 2022 after propensity score matching

Outcome, n (%)	Laparoscopic (N = 81,827)	Robotic (N = 81,827)	*P* value	OR (95% CI)
Overall morbidity	2102 (2.57)	2186 (2.67)	.26	1.03 (.97-1.10)
Aggregate leak	159 (.19)	195 (.24)	.06	1.22 (.99-1.51)
Reoperation for leak	73 (.09)	91 (.11)	.17	1.24 (.91-1.68)
Intervention for leak	48 (.06)	59 (.07)	.30	1.22 (.83-1.79)
Readmission for leak	95 (.12)	99 (.12)	.78	1.04 (.79-1.38)
Organ/space SSI	196 (.24)	241 (.29)	**.04**	**1.23 (1.01-1.48)**
Anastomotic/staple line leak	115 (.14)	144 (.18)	.08	1.25 (.98-1.59)
Aggregate bleeding	406 (.50)	389 (.48)	.45	.95 (.82-1.09)
Reoperation for bleeding	135 (.16)	120 (.15)	.32	.88 (.69-1.13)
Intervention for bleeding	47 (.06)	36 (.04)	.21	.76 (.49-1.17)
Readmission for bleeding	122 (.15)	132 (.16)	.61	1.07 (.83-1.37)
GI tract bleeding	318 (.39)	305 (.37)	.50	.95 (.81-1.11)
Blood transfusion	503 (.61)	546 (.67)	.23	1.08 (.95-1.22)
Readmission	2235 (2.7)	2453 (3.0)	**<.01**	**1.10 (1.03-1.16)**
Reoperation	694 (.85)	773 (.94)	.05	1.10 (1.00-1.23)
Reintervention	540 (.66)	544 (.66)	.96	1.00 (.89-1.13)
Mortality	51 (.06)	64 (.08)	.29	1.22 (.84-1.77)
Superficial incisional SSI	304 (.37)	274 (.33)	.20	.90 (.76-1.06)
Deep incisional SSI	35 (.04)	31 (.04)	.57	.87 (.54-1.41)
Wound disruption	40 (.05)	37 (.05)	.73	.92 (.59-1.45)
Sepsis	70 (.09)	92 (.11)	.10	1.30 (.95-1.77)
Septic shock	31 (.04)	50 (.06)	**.045**	**1.58 (1.01-2.48)**
Urinary tract infection	324 (.40)	302 (.37)	.39	.93 (.80-1.09)
Ventilator >48 hr	38 (.05)	50 (.06)	.26	1.28 (.84-1.95)
Unplanned intubation	54 (.07)	75 (.09)	.08	1.37 (.97-1.95)
Pneumonia	128 (.16)	134 (.16)	.79	1.03 (.81-1.32)
Venous thrombosis requiring therapy	169 (.21)	187 (.23)	.36	1.10 (.90-1.36)
Pulmonary embolism	103 (.13)	111 (.14)	.60	1.07 (.82-1.40)
Stroke	11 (.01)	14 (.02)	.62	1.22 (.55-2.70)
Unplanned admission to ICU	340 (.42)	377 (.46)	.25	1.09 (.94-1.26)
Acute renal failure	33 (.04)	38 (.05)	.66	1.11 (.69-1.78)
Progressive renal insufficiency	49 (.06)	56 (.07)	.60	1.11 (.75-1.63)
Cardiac arrest requiring CPR	34 (.04)	32 (.04)	.76	.93 (.57-1.51)
Myocardial infarction	25 (.03)	20 (.02)	.45	.80 (.44-1.44)

OR = odds ratio; CI = confidence interval; SSI = surgical site infection; GI = gastrointestinal; ICU = intensive care unit; CPR = cardiopulmonary resuscitation.

Statistically significant *P* values in bold.

revisional MBS and R-SG showing the greatest increases [6]. Our study extends these prior investigations and demonstrates a continued increase in robotic MBS, with approximately 30% of primary SG and RYGB cases performed R in 2022. The adoption of robotic surgery in MBS remains controversial, in part due to concerns related to increased costs. A retrospective analysis of the National Inpatient Sample by Khorgami et al. showed that robotic-assisted MBS was a strong independent predictor of increased cost (OR 3.58, CI 3.22–3.97). A systematic review by Bailey et al. found that the expected costs for R-RYGB ($15,447) were higher than L-RYGB ($11,956) [18]. However, there is evidence that the cost of robotic MBS is decreasing, and single-institution studies have reported no cost difference between approaches [19–21]. The addition of standardized cost data to the MBSAQIP would be a helpful adjunct to track costs over time. Iterative robot utilization studies are also warranted to identify a potential laparoscopic-robotic inflexion point in the future.

For each year, we found that R-SG and R-RYGB operative times were significantly longer than laparoscopic, consistent with previous studies of the MBSAQIP [11,16,17]. Robotic operative times did significantly improve from 2015 to 2022 for SG and RYGB, reflecting the aggregate progression of surgeons across the robotic MBS learning curve. However, this dataset does not provide relevant surgeon and technique variables that may directly influence operative time. For example, surgeon experience and case volume in robotic MBS have been shown to have a significant effect on outcomes, but this data is not available in the MBSAQIP [22,23]. Nevertheless, longer operative times have been associated with increased MBS complications [24,25]. A matched analysis of SG and RYGB cases in the MBSAQIP found that longer operative time was associated with increased risk of postoperative complications, readmission, and reoperation [24]. Our data comparing L-RYGB and R-RYGB cases seem to contradict these prior studies, highlighting the need for more granular data in the MBSAQIP that may account for this discrepancy. Future MBSAQIP studies are warranted to assess if the difference in operative time between laparoscopic and robotic MBS continues to decline.

Our study demonstrated increased overall morbidity, leak, organ/space SSI, aggregate bleeding, and need for blood transfusion with R-SG compared to L-SG. R-SG was also associated with an increased risk of superficial incisional SSI, sepsis, and septic shock. We did not find higher rates of readmission or reoperation with R-SG, contrary to Alizadeh et al. who compared L-SG and R-SG outcomes with 2015 MBSAQIP data [12]. That study also found a significantly higher leak rate in their R-SG cohort using the same aggregate leak methodology. Tartarian et al. similarly found a higher leak rate in primary R-SG using 2015-2018 data [16]. Many of our findings are consistent with those of Acevedo et al., who performed a case-controlled study of primary MBS cases with 2015-2016 data and found that R-SG was associated with significantly higher rates of drain present at 30 days, sepsis, and organ/space SSI [11]. In contrast to this study, we found a higher risk of bleeding and need for blood transfusion in the R-SG cohort. The reasons for increased bleeding complications with R-SG are unclear with currently available data. It's possible that R-SG may serve as an index procedure for bariatric surgeons beginning robot training, and the higher leak and bleeding rates seen with R-SG may reflect surgeons working along their robotic learning curves. Further monitoring of R-SG outcomes specifically is necessary in this regard to assess the suitability of R-SG as an appropriate robotic training procedure.

We found that R-RYGB had lower overall morbidity, bleeding, reoperation/readmission for bleeding, and blood transfusions compared to L-RYGB. R-RYGB also had lower rates of superficial and deep incisional SSI. These results are consistent with prior studies of the MBSAQIP that found higher rates of bleeding, blood transfusion, and overall complications with L-RYGB [11,26]. We did not however find a lower leak rate with R-RYGB, contrary to the propensity score matched MBSAQIP analysis by Sebastian et al. [26] Reported reductions in leak and bleeding rates with R-RYGB may be related to a higher rate of handsewn anastomosis with the robotic platform compared to the stapled anastomosis commonly used with conventional laparoscopy. A study by Buchs et al. provided some evidence for this by demonstrating a leak rate of .3% for R handsewn anastomoses versus 3.6% with laparoscopic stapled anastomoses [27]. However, the MBSAQIP does not report data regarding anastomosis technique; therefore, we cannot determine the technique that was most commonly used for each approach and its influence on outcomes.

Our 2015-2019 subgroup analysis showed an advantage for laparoscopic surgery in reducing the risk of leak, while robotic surgery reduced the risk of postoperative bleeding. Overall morbidity in this analysis was similar, but there were several other differences in postoperative outcomes with some favoring laparoscopic and others robotic. Many of these differences were absent in the 2020-2022 subgroup analysis, apart from organ/space SSI, readmission, and septic shock favoring laparoscopy. This analysis also revealed small absolute improvements for robotics in overall morbidity, leak, readmission, reoperation, and reintervention compared to 2015-2019 robotic cases. Based on these data it appears that robotic outcomes have improved to become more similar to laparoscopic in recent years, though they remain inferior, consistent with recent studies [28]. Improvements in robotic outcomes are likely due to increased surgeon experience, and may also be influenced by evolutions in robotic technology over the study period.

In the context of rapidly increasing robot use, it should be recognized that the beginning of laparoscopic bariatric surgery was also met with early challenges and suboptimal results prior to its widespread adoption [29]. While the learning curve for robotic surgery may be shorter than laparoscopy, past and present investigations of robotic MBS outcomes are likely being performed during the aggregate learning curve of robotic MBS [30]. It's likely that additional experience with robotic MBS is needed before the benefit of this technology can be comprehensively evaluated on a large scale.

There are several limitations to this retrospective study of a large national database. There is a risk of selection bias given that patients were not randomized to laparoscopic or robotic surgery. Many important and potentially confounding variables are not available, such as years of surgeon experience with robotic MBS, hospital case volume, anastomosis techniques (handsewn, stapled, or combination), and whether cases were totally or partially robotic. Before 2019, a robotic stapler was not widely available, and all stapling was performed L by a bedside assistant as a result. It is unclear how surgeon practices have changed with the introduction of the robotic stapler and other evolutions in robotic technology and how these changes may have impacted patient outcomes. We did however attempt to examine this phenomenon in our subgroup analyses, and the improved outcomes for robotic surgery relative to laparoscopy may have been influenced by these technological changes. In addition, the change in reporting of postoperative bleeding and leak in the MBSAQIP limits our ability to compare these outcomes across years. Outcome measures beyond 30 days are also not available, limiting the ability to assess long-term results. In studies with very large sample sizes, it is important to carefully interpret statistical differences, as small differences in outcomes may be statistically significant, but not clinically significant. Prospective randomized trials on this topic are needed given these limitations.

Conclusion

Robot utilization in primary MBS is steadily increasing. While robotic operative times are decreasing, they remain significantly longer than laparoscopic. Robotic SG has higher complication rates compared to laparoscopic, while robotic RYGB is protective against bleeding complications, though rates remain low. Short-term outcomes for robotic primary bariatric surgery appear to be improving relative to laparoscopic, but remain inferior. Further investigation is needed regarding variability in robotic experience and operative technique to determine what factors are driving these differences.

Disclosures

Dr. Broderick is a consultant for Stryker Corporation. Dr. Sandler is a consultant for Boston Scientific. Dr. Horgan is a consultant for Stryker Corporation and Ethicon. Dr. Jacobsen is a consultant for Gore Medical and Viacyte. Drs. Spurzem, Kunkel, and Hollandsworth have no disclosures.

Supplementary data

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.soard.2024.11.014.

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