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Robotic versus laparoscopic sleeve gastrectomy: a MBSAQIP analysis

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Abstract
Background Laparoscopic sleeve gastrectomy has become the procedure of choice for the treatment of morbid obesity. Robotic sleeve gastrectomy is an alternative surgical option, but its utilization has been low. The aim of this study was to evaluate the contemporary outcomes of robotic sleeve gastrectomy (RSG) versus laparoscopic sleeve gastrectomy (LSG) using a national database from accredited bariatric centers.
Study design Using the 2015 Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) database, clinical data for patients who underwent RSG or LSG were examined. Emergent and revisional cases were excluded. A multivariate logistic regression model was utilized to compare the outcomes between RSG and LSG. **Results** A total of 75,079 patients underwent sleeve gastrectomy with 70,298 (93.6%) LSG and 4781 (6.4%) RSG. Preoperative sleep apnea and hypoalbumenia were significantly higher in the RSG group ($P < 0.01$). Mean length of stay was similar between RSG and LSG (1.8 ± 2.0 vs. 1.7 ± 2.0 days, $P = 0.17$). Operative time was longer in the RSG group (102 ± 43 vs. 74 ± 36 min, $P < 0.01$). There was no significant difference in 30-day mortality between the RSG versus LSG group (0.02% vs. 0.01%, AOR 0.85; 95% CI 0.11–6.46, $P = 0.88$). However, RSG was associated with higher serious morbidity (1.1% vs. 0.8%, AOR 1.40; 95% CI 1.05–1.86, $P < 0.01$), higher leak rate (1.5% vs. 0.5%, AOR 3.14; 95% CI 2.65–4.42, $P < 0.01$), and higher surgical site infection rate (0.7% vs. 0.4%, AOR 1.55; 95% CI 1.08–2.23, $P = 0.01$).
Conclusions Robotic sleeve gastrectomy has longer operative time and is associated with higher postoperative morbidity including leak and surgical site infections. Laparoscopy should continue to be the surgical approach of choice for sleeve gastrectomy.

Keywords Robotic sleeve gastrectomy · Laparoscopic sleeve gastrectomy · Short-term outcomes · MBSAQIP · Bariatric Surgery

Abbreviations

LSG	Laparoscopic sleeve gastrectomy
RSG	Robotic sleeve gastrectomy
MBSAQIP	Metabolic and bariatric surgery accreditation and quality improvement program
BMI	Body mass index
AOR	Adjusted odds ratio
CI	Confidence interval
COPD	Chronic obstructive pulmonary disease
GERD	Gastroesophageal reflux disease
DVT	Deep vein thrombosis
PE	Pulmonary embolism

OSA Obstructive sleep apnea

The prevalence of obesity continues to increase worldwide and has nearly tripled since 1975. According to the World Health Organization, more than 1.9 billion adults were overweight in 2016 and over 600 million with obesity [1]. Bariatric surgery is the most effective long-term treatment for severe obesity [2]. Laparoscopic sleeve gastrectomy (LSG) has become increasingly popular over the past decade due to its safety profile and excellent longterm efficacy, and is now the most common bariatric operation being performed in the U.S [3–5]. In recent years, robotic surgery has been utilized for many intraabdominal operations including bariatric surgery. Robotic surgery offers several theoretical advantages including enhanced three-dimensional imaging, greater dexterity, and precision in tissue manipulation [6]. The robotic approach was initially used for gastric bypass and biliopancreatic diversion [7], but there has been a recent increase in utilization of robotic sleeve gastrectomy (RSG). Several studies have compared the outcomes of LSG versus RSG, but most of these studies are under-powered to detect small differences in outcome [8–12]. The aim of this study was to employ a robust national database from accredited centers to evaluate the utilization and outcome of patients who underwent RSG compared to LSG.

Methods

Data source

We performed a retrospective cohort study using the 2015 Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) database. The MBSAQIP database was created in 2012 by the American College of Surgeons (ACS) and the American Society for Metabolic and Bariatric Surgery (ASMBS). The MBSAQIP database participant user data files have become available for analysis since 2015, and include Health Insurance Portability and Accountability Act (HIPAA)-compliant patient-level data on more than 150,000 metabolic and bariatric cases performed between January 1 and December 31, 2015, at 742 centers across the US and Canada [13]. The MBSAQIP is a rigorous dataset that captures 100% of all bariatric cases at each participating institution, has clear definitions of data parameters, and has the data collected by a certified clinical reviewer.

Study design and population

Clinical data on patients who underwent sleeve gastrectomy were analyzed based on the Current Procedural Terminology (CPT) code 43775. The surgical approach variable was used to differentiate laparoscopic and robotic cases. Emergent, revisional, and converted cases were excluded.

Patients were categorized into two groups, those who underwent LSG and those who underwent RSG. Preoperative characteristics, comorbidities, and 30-day outcomes were analyzed for RSG versus LSG. The MBSAQIP does not have a specific variable for leak rate. Therefore, postoperative leak was defined as a composite variable that includes surgical drain present at > 30 days, organ space surgical site infection, leak-related 30-day readmission, leak-related 30-day reoperation, and leak-related 30-day intervention. Serious morbidity was defined as organ space surgical site infection, wound dehiscence, ventilator dependence more than 48 h, progressive renal insufficiency, acute renal insufficiency, cerebrovascular accidents (CVA)/Stroke, cardiac arrest, myocardial infarction, bleeding requiring transfusion, pulmonary embolism, sepsis, and septic shock.

Statistical analysis

Statistical analyses were performed using SPSS software, Version 23 (SPSS Inc., Chicago, IL). Patient characteristics were reported as proportions for categorical variables and means ± standard deviations (SD) for continuous variables. A multivariate logistic regression model was used to analyze the 30-day outcomes. Variables used in the multivariate analyses included demographic data (age, gender, race, and body mass index [BMI]) and preoperative comorbidities. For each variable, the adjusted odds ratio (AOR) with a 95% confidence interval (CI) was calculated. Statistical significance was set at $P < 0.05$.

Results

Data on 75,079 patients who underwent LSG or RSG were analyzed, including 4781 (6.4%) RSG and 70,298 (93.6%) LSG procedures. Most patients were female (78.7%) and White (79%).

Table 1 summarizes the characteristics and comorbidities of patients who underwent RSG versus LSG. With respect to patient demographics, there were no significant differences between groups in age, ethnicity, or BMI. The percentage of male patients was lower in RSG compared to LSG (20.1% vs. 21.4%, $P < 0.01$). With regard to preoperative comorbidity, preoperative sleep apnea (36.7% vs. 35.8%, $P < 0.01$), and hypoalbuminemia (8.3% vs. 6.9%, $P < 0.01$) were significantly higher in the RSG group, whereas preoperative oxygen dependency (0.7% vs. 0.3%, $P < 0.01$) and chronic steroid use (1.7% vs. 1.2%, $P < 0.01$) were significantly higher in the LSG group.

Table 1 Patient characteristics, comorbidities, and interventions after robotic sleeve gastrectomy versus laparoscopic sleeve gastrectomy

Patients' characteristics, comorbidities, and other factors	LSG (*N* = 70,298)	RSG (*N* = 4781)	*P* value
Demographics			
Age Mean ± SD (year)	44 ± 12	44.5 ± 12	0.21
Male (%)	15,036 (21.4%)	959 (20.1%)	< 0.01
BMI (kg/m^2) (Mean ± SD)	46 ± 8	46 ± 8	0.9
Comorbidities			
Hypertension	34,222 (48.7%)	2325 (48.6%)	0.94
Hyperlipidemia	16,412 (23.3%)	1136 (23.8%)	0.51
Smoking	6508 (9.3%)	436 (9.1%)	0.74
Gastroesophageal reflux disease	20,230 (28.8%)	1413 (29.6%)	0.25
COPD	1230 (1.7%)	80 (1.7%)	0.69
Diabetes mellitus	16,183 (23%)	1082 (22.6)	0.53
Dialysis	217 (0.3%)	14 (0.3%)	0.84
Chronic steroid use	1194 (1.7%)	58 (1.2%)	0.01
Renal insufficiency	460 (0.7%)	38 (0.8%)	0.24
History of deep vein thrombosis	1130 (1.6%)	78 (1.6%)	0.89
History of pulmonary embolism	797 (1.1%)	50 (1%)	0.57
Venous stasis	714 (1%)	56 (1.2%)	0.30
Obstructive sleep apnea	25,160 (35.8%)obs	1753 (36.7%)	0.04
Oxygen dependent	464 (0.7%)	16 (0.3%)	< 0.01
Hypoalbuminemia[a]	4819 (6.9%)	396 (8.3%)	< 0.01
Other factors			
Mean operative duration (Minutes ± SD)	74 ± 36	102 ± 43	< 0.01
Mean length of stay (Days ± SD)	1.7 ± 2.0	1.8 ± 2.0	0.17

NA not applicable, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *LSG* laparoscopic sleeve gastrectomy, *RSG* robotic sleeve gastrectomy

[a] Serum albumin level lower than 3.5 g/dL

Compared to the LSG group, the RSG group had longer mean operative time (102 ± 43 vs. 74 ± 36 min, P < 0.01). The mean length of hospital stay was similar between the two groups (1.8 ± 2.0 vs. 1.7 ± 2.0 days, P = 0.17).

Table 2 summarizes the results of the multivariate logistic regression model comparing the outcome of RSG versus LSG. No significant difference was observed in 30-day mortality between RSG versus LSG (0.02% vs. 0.01%, AOR 0.85; 95% CI 0.11–6.46; P = 0.88). There was a significantly higher rate of serious morbidity associated with RSG compared to LSG (1.1% vs. 0.8%, AOR 1.40; 95% CI 1.05–1.86; P < 0.01). The postoperative leak rate was significantly higher at 1.5% in RSG group compared to 0.5% in the LSG group (AOR 3.42; 95% CI 2.65–4.42; P < 0.01). In addition, the rate of venous thromboembolism (VTE; AOR 1.63, P = 0.04), surgical site infections (SSI; AOR

1.55, P = 0.01), 30-day reoperation (AOR 1.34, P = 0.04), and 30-day readmissions (AOR 1.27, P < 0.01) were also significantly higher in the RSG cohort compared to the LSG cohort.

Table 2 Risk-adjusted analysis of postoperative outcomes after robotic sleeve gastrectomy versus laparoscopic sleeve gastrectomy

Complications	LSG (*N* = 70,298)	RSG (*N* = 4781)	AOR	95% CI	*P* value
30-day mortality	17 (0.02%)	1 (0.01%)	0.85	0.11–6.46	0.88
Serious morbidity	550 (0.8%)	52 (1.1%)	1.40	1.05–1.86	< 0.01
Postoperative leak	318 (0.5%)	74 (1.5%)	3.42	2.65–4.42	< 0.01
Acute renal failure	40 (0.1%)	0 (0%)	–	–	–*
Renal insufficiency	54 (0.1%)	4 (0.1%)	1.12	0.40–3.11	0.82
Urinary tract infection	222 (0.3%)	10 (0.2%)	0.66	0.35–1.25	0.20
Unplanned intubation	70 (0.1%)	6 (0.1%)	1.26	0.54–2.90	0.58
Ventilator dependency	25 (0.0%)	5 (0.1%)	2.87	0.92–6.21	0.07
Pneumonia	90 (0.1%)	3 (0.1%)	0.48	0.15–1.54	0.22
Any respiratory complications	158 (0.2%)	13 (0.3%)	1.21	0.68–2.13	0.51
Pulmonary embolism	64 (0.1%)	8 (0.2%)	1.84	0.88–3.85	0.10
Deep vein thrombosis	118 (0.2%)	12 (0.3%)	1.50	0.82–2.72	0.18
Venous thromboembolism	172 (0.2%)	19 (0.4%)	1.63	1.01–2.62	0.04
Superficial SSI	172 (0.2%)	13 (0.3%)	1.09	0.62–1.92	0.75
Deep SSI	15 (0.02%)	0 (0%)	–	–	–*
Organ space SSI	111 (0.2%)	19 (0.4%)	2.51	1.54–4.10	< 0.01
Dehiscence	14 (0.01%)	1 (0.02%)	1.03	0.13–7.89	0.97
Any SSI	310 (0.4%)	33 (0.7%)	1.55	1.08–2.23	0.01
Sepsis	60 (0.1%)	5 (0.1%)	1.23	0.49–3.08	0.64
Bleeding disorders requiring transfusion	376 (0.5%)	22 (0.5%)	0.86	0.56–1.32	0.50
Reoperation	582 (0.8%)	53 (1.1%)	1.34	1.01–1.78	0.04
Readmission	2,302 (3.3%)	198 (4.1%)	1.27	1.09–1.47	< 0.01

LSG laparoscopic sleeve gastrectomy, *RSG* robotic sleeve gastrectomy, *SSI* surgical site infection

*The number of events was zero in one of the groups and statistical analysis could not be performed

Discussion

Laparoscopy is the gold standard surgical approach for sleeve gastrectomy. Robotic sleeve gastrectomy is an alternative surgical approach being performed at selected centers. The present study compared the outcome of RSG versus LSG using a national database of accredited bariatric centers. Our study found a low utilization rate of RSG, with only 6.4% of all sleeve gastrectomy cases being performed using the robotic approach. Robotic sleeve gastrectomy was associated with a higher rate of serious complication, as well as higher rates of leaks and surgical site infections.

Table 3 summarizes findings of selected studies comparing RSG versus LSG. Most current published studies reported no significant differences in mortality, morbidity, or leak rates between RSG and LSG. However, the current study identified a higher leak rate and increased serious morbidity with RSG compared to LSG. One possible explanation for the increased complication rate in the RSG group might be related to the surgeon's learning curve of RSG. Currently, there is no established threshold case number to account for proficiency in robotic sleeve gastrectomy and the MBSAQIP database does not provide data on the surgeon's experience with RSG. Thus, we were unable to adjust for the learning curve in our analysis. However, other studies have shown minimal impact of the learning curve in RSG. In a single institutional study of 647 patients, Moon et al. reported no significant difference in leak rate during or after the learning curve [9]. Altieri et al. compared robotic versus laparoscopic approach among five different general surgical procedures, including sleeve gastrectomy, and concluded that patient-specific factors, not surgeon volume and experience, play a role in outcomes following robotic surgery. They concluded that robotic surgery can be performed safely in the setting of resident and fellowship training programs without a negative impact on outcome [14]. Other possible explanation for the higher leak rate might be related to the provider who performed the stapling portion during RSG versus LSG. Gastric stapling and construction of the sleeve is a critical step of the operation that is commonly performed by the surgeon during LSG. However, in RSG, this step is often relinquished to an alternate provider since the surgeon often sits at the console. Delegating this important step to an alternate provider may contribute to a higher complication rate associated with RSG. Recently, a robotic stapler was introduced that allows the surgeon to perform this critical aspect of the operation. Unfortunately, the database does not have specific information regarding the type of stapler used (laparoscopic or robotic) or the provider who performed the stapling portion of the procedure.

Table 3 Summary of the outcomes for selected robotic versus laparoscopic sleeve gastrectomy studies

Author (year)	Data source	*N*	Approach	Mean operative duration (minutes ± SD)	Mean length of stay (days ± SD)	Mortality (%)	Serious morbidity (%)	Leak (%)
Current study	MBSAQIP	4,781	RSG	102 ± 43*	1.8 ± 2.0	0.01	1.1*	1.5*
		70,298	LSG	74 ± 36	1.7 ± 2.0	0.02	0.8	0.5
Romero et al. [10] (2013)	Single institutional series of RSG versus systematic LSG review	134	RSG	106 ± 48	2.2 ± 0.6	0.0	2.9	0.0
		3,148	LSG	94 ± 39	3.3 ± 1.7	0.10	N/A	1.97
Altieri et al. [14] (2016)	New York statewide planning and research cooperative system administrative database (SPARCS)	118	RSG	N/A	2.4 ± 0.9	N/A	4.24	N/A
		7,690	LSG	N/A	2.3 ± 1.7	N/A	4.97	N/A
Moon et al. [9] (2016)	Single institutional series	268	RSG	N/A	1.7 ± 1.8*	N/A	N/A	1.9
		379	LSG	N/A	1.2 ± 0.5	N/A	N/A	3.2
Elli et al. [8] (2015)	Single institutional series	105	RSG	110 ± 48*	2.44 ± 0.75	0.0	0.0	0.0
		304	LSG	84 ± 24	3.1 ± 4.2	0.0	0.6	0.3
Villamere et al. [12] (2015)	University health system consortium (UHC)	957	RSG	N/A	2.4 ± 0.9	0.0	0.0	N/A
		18,694	LSG	N/A	2.1 ± 1.4*	0.01	0.01	N/A
Vilallonaga et al. [11] (2013)	Single institutional series	100	RSG	108 ± 18*	4.0 ± 3.0	0.0	N/A	3
		100	LSG	96 ± 18	3.0 ± 5.0	0.0	N/A	4

*P values ≤ 0.05, RSG versus LSG
N/A data not available

Operative time and cost are two of the most frequently considered factors in the comparison of the robotic and laparoscopic approaches to surgery. Regarding operative time, RSG was associated with a significantly longer mean operative time compared to LSG (102 vs. 74 min). Our finding is consistent with other published series [8, 10, 15, 16]. It is well known that one of the major disadvantages of robotic bariatric surgery is the high acquisition and operational costs of the robotic system [12, 17, 18]. The current study was not able to compare the costs of RSG versus LSG as cost data are not available in the MBSAQIP database. The studies by Moon et al. and Vilallonga et al. reported higher costs for RSG (range from $10,556 to $56,464) compared to LSG (range from $8795 to $49,498) [9, 11]. With respect to length of hospitalization, there is no consistent finding among the published series [8, 10, 19–21]. Romero and colleagues reported that patients who underwent LSG had significantly shorter length of hospital stay than patients who underwent RSG (2.2 vs. 3.3 days) [10]. In contrast, a recent published systematic review by Magouliotis et al. reported that the length of hospital stay after RSG was significantly shorter than after LSG (1.7–4 days for RSG group vs. 1.2–5.9 days for LSG group) [20]. The current study and the study of Elli et al. showed no difference in the length of hospital stay between RSG and LSG [8].

There are several limitations to this study. The MBSAQIP database only captures 30-day follow-up data and, therefore, underestimates the true rate of postoperative complications. As with any retrospective study, there could be inherent biases including selection bias and bias from inaccurately recorded or missing data. There is also variability in hospital setting and quality, as well as in surgeon's experience, that are not available for adjustment. Moreover, the lack of information regarding the provider who performed the stapling aspect of the operation, the type of stapler (robotic vs. conventional), and the utilization or lack of utilization of stapler line reinforcement make it difficult to understand the reasons for increased postoperative leak associated with RSG. Additionally, preoperative sleep apnea and hypoalbuminemia were significantly higher in the patients who underwent RSG, which may contribute to the increased risk for postoperative leak. Finally, we utilized the data that were collected from centers accredited by the MBSAQIP and, therefore, our results may not be representative of non-accredited centers. Despite these limitations, the current study provides a large sample size to examine the contemporary outcomes of RSG versus LSG.

Conclusions

The overall rate of RSG utilization is low at < 7% of sleeve gastrectomy cases. Robotic sleeve gastrectomy has longer operative time and a higher rate of postoperative morbidity, including leak and surgical site infections. In the present time, the laparoscopic approach should continue to be the gold standard surgical approach for sleeve gastrectomy. Acknowledgements This research did not receive any specific grant from any funding agencies in the public, commercial, or not-for-profit sectors.

Compliance with ethical standards

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