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ORIGINAL RESEARCH

Trends, Patient Outcomes, and Resource Utilization Associated with Surgical Staplers During Robotic Sleeve Gastrectomy

I-Wen Pan, Zasim Azhar Siddiqui

Medtronic PLC, Boston, MA, USA

Correspondence: I-Wen Pan, Medtronic PLC, 266 Summer St, 5th Floor, Boston, MA, 02110, USA, Email iwen.pan@gmail.com

Purpose: Robotic platforms are commonly used for sleeve gastrectomy, despite the high capital costs and little understanding of the roles of platform-specific consumables and standard surgical alternatives in clinical outcomes and healthcare resource utilization. This study evaluates the trend, the effectiveness (outcomes) and efficiency (resource utilization) of different types of surgical staplers used in robotic sleeve gastrectomy (RSG).

Patients and Methods: This was a retrospective observational cohort study analyzing data from the PINC AI™ Healthcare Data database. Patients were included if they underwent elective, inpatient, primary sleeve gastrectomy performed using the Intuitive Surgical robotic system (Sunnyvale, CA) with either a bedside stapler (BS, Signia™, Endo-GIA™, or Tri-staple™) or a robotic stapler (RS, Sureform™). The primary outcome measures included inpatient costs, complications, operating room time (ORT), length of stay (LOS), and intensive care unit visits. Outcomes were analyzed using bivariate analyses, multivariable generalized linear models (GLM), and propensity-score matching (PSM).

Results: Of 18,892 total RSG procedures that met eligibility criteria, robotic staplers were used in 15,152 procedures (80.2%) and bedside staplers were used in 3740 (19.8%). While RSG increased dramatically during the period, RS were shown to be associated with a greater risk of blood transfusion compared to bedside staplers both in a GLM [0.5% (BS) vs 0.7% (RS); Odds ratio (OR): 1.55; 95% confidence interval (CI): 1.02–2.36; p = 0.04] and after PSM [0.3% (BS) vs 0.9% (RS); OR: 3.02; 95% CI: 1.35–6.73; p = 0.007]. Bedside staplers were associated with total costs reduction [mean cost savings: \$3084; 95% CI: \$2860 - \$3309; p < 0.001] and shorter ORT (21 minutes; 95% CI: 18.6–23.5; p < 0.001) compared to robotic staplers. Difference in LOS was not clinically significant.

Conclusion: When used during RSG, bedside staplers are cost-saving, with equivalent or better clinical outcomes and reduced resource utilization compared to robotic staplers.

Plain Language Summary: Robotic sleeve gastrectomy (RSG) is a type of weight loss surgery that involves reducing the stomach size using surgical staples. Robotic systems are becoming increasingly popular for this surgery and physicians often use staplers that are integrated and sold with robotic surgery systems. However, surgeons can also use an alternative - the standard "bedside" stapler. In this study, we evaluate whether the type of stapler used affects patient outcomes or costs.

We analyzed data from over 18,000 individuals who underwent RSG between 2018 and 2022. Robotic staplers were used in 80.2% of these surgeries, while bedside staplers were used in 19.8% of surgeries. We found that patients who used robotic staplers had a higher chance of needing a blood transfusion, while using bedside staplers saved inpatient costs and shortened surgery time. These findings suggest that bedside staplers offer a safe and more cost-effective option for RSG.

Keywords: bariatric surgery, robotic surgery, healthcare costs and resource utilization

Introduction

Metabolic and bariatric surgery procedures currently represent one of the most effective and durable treatments for obesity.[1] The most common bariatric procedure is the sleeve gastrectomy (SG), which involves the use of surgical staples

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to resect a portion of the stomach, thereby reducing its volume.[2] Simpler than other bariatric procedures, SG has been widely adopted and as of 2022 represented nearly 60% of bariatric procedure volume.[1]

The use of robotic-assisted SG (RSG) has increased in popularity in recent years despite the high cost of capital equipment and branded consumables recommended by robotic-system manufacturers.[3] There is limited empirical evidence to support the cost-effectiveness of robotic procedures in robotic sleeve gastrectomy when performed using integrated robotic consumables compared to standard, laparoscopic consumable alternatives. One example is the choice of surgical staplers. A recent study shows that using bedside staplers in robotic bariatric procedures, including SG and Roux-en-Y gastric bypass, reduced total inpatient costs and shortened operating room time (ORT) compared to robotic staplers.[4] In addition, another study identified that the type of stapler used, including laparoscopic bedside staplers, unspecified bedside staplers, or robotic staplers, could be a cost driver of RSG.[5] Investigating whether the types of staplers affect costs and clinical outcomes when sleeve gastrectomy is performed robotically would make a worthwhile contribution to the literature. A deep understanding of the relative effectiveness and efficiency of various stapler types could help surgeons justify the sources of cost variation that contribute to the cost of robotic SG procedures and provide information to conserve costs without compromising patient outcomes.

The purpose of the present study is to report trends in the types of staplers used and to evaluate the effectiveness (outcomes) and efficiency (resource utilization) associated with different types of staplers used in robotic SG.

Materials and Methods

Study Design and Ethics

This was a retrospective observational cohort study using a third-party licensed database and was designed and modified following "The Structure-Process-Outcomes Quality Framework" by A. Donabedian.[6,7] The database used for this study was de-identified in accordance with the HIPAA Privacy Rule, and therefore, this study was determined to be exempt from full board review by Sterling IRB (Atlanta, GA).

Data Source

Data for this study were extracted from the PINC AI™ Healthcare Data (PHD) database (Premier, Inc., Charlotte, NC),[8] encompassing the years 2018–2022, inclusive. The PHD database contains service-level, all-payer data from standard hospital discharge billing files, representing more than 1400 US-based hospitals and health-care systems, and an estimated 25% of annual US inpatient admissions. Data include hospital and visit characteristics; admitting and attending physician specialties; health-care payers; and patient data, including demographics, disease states, diagnoses, costs, medications, and device information. The PHD contains charge master and hospital charge files, which allowed identification of robotic surgical procedures and surgical products through text search; neither the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program database nor other claims databases have this charge information and therefore the PINC AI™ Healthcare database was required to facilitate the present study.

Patient Selection

Patients were included if they underwent elective primary SG in a hospital inpatient setting, performed using a robotic system (Intuitive Surgical, Sunnyvale, CA) with either a bedside stapler (BS; Signia™, Endo-GIA™, or Tri-staple™; Medtronic PLC, Boston, MA) or the latest version of a robotic stapler (RS; Sureform™; Intuitive Surgical, Sunnyvale, CA). Patient cases were excluded if they were not elective, did not have staplers recorded in the charge file, included use of both BS and RS, used staplers not studied, were missing key data variables, or if their records indicated zero costs (Figure 1).

Variables and Outcome Measures

Baseline characteristics collected included patients' demographic, clinical, payer, and provider characteristics. International Classification of Disease (ICD) version 10 codes were used to identify procedure, primary diagnosis (Appendix A), and Charlson Comorbidities Index (CCI) score.[9] Robotic surgery was identified using ICD-10 procedure

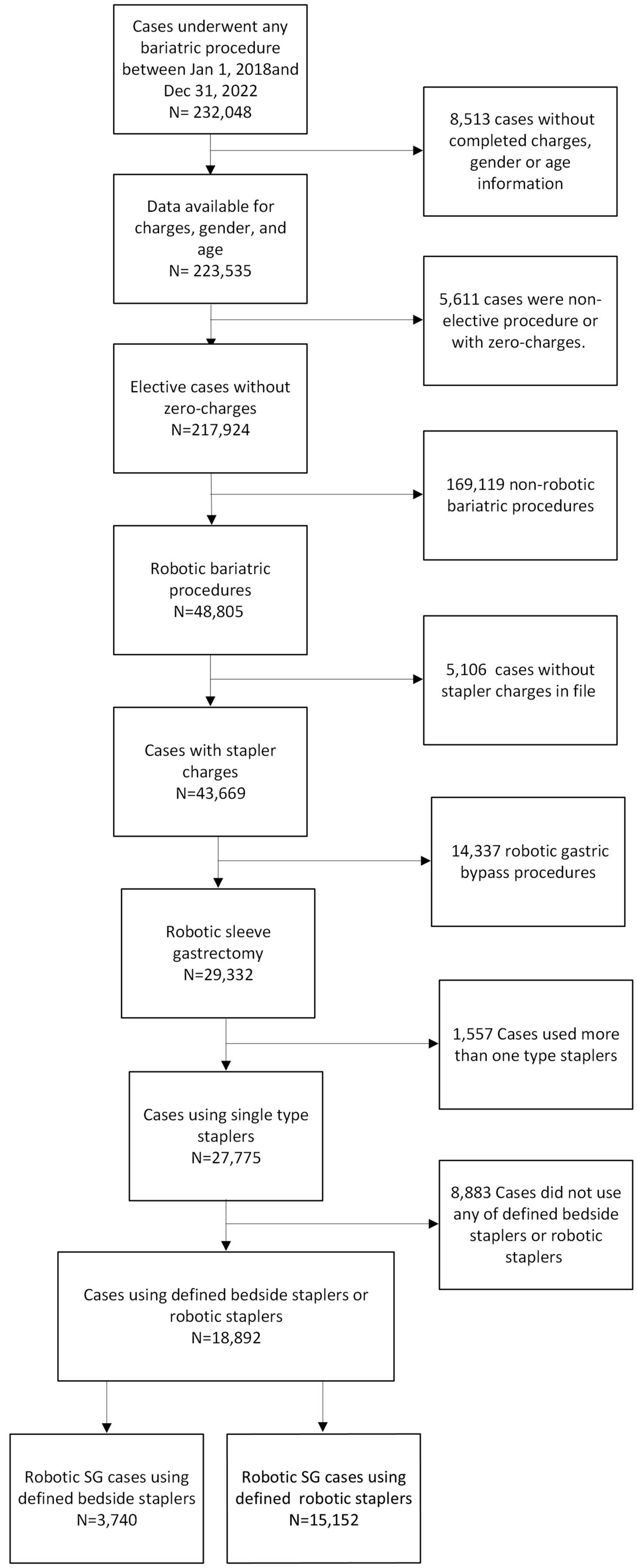

Figure 1 Subject selection and disposition.

or Current Procedural Terminology (CPT) codes, or text searching through hospital charges (Appendix B). Additionally, the hospital charge files were used to identify the type of staplers by either product numbers or names, or a combination of product numbers and names, through full-text searching.

The primary clinical outcome measures included incidence rates of intensive care unit visits and complications, including blood transfusion, bleeding, and anastomotic leak. We used CPT codes and ICD-10 procedure and diagnosis codes to identify patient complications (Appendix C). The health-care resource utilization measures included total inpatient costs, ORT, and length of stay (LOS).

Analytical Methods

All analyses were conducted using SAS 9.4 and Stata 18.0 using 2-sided statistical tests ($\alpha = 0.05$). Costs from before the year 2022 were converted to 2022 US dollars using the Consumer Price Index for Hospital Services.[10]

Descriptive analysis was used to report the proportion of cases for categorical variables, including the difference between the patient and provider characteristics based on the BS and RS group and the clinical complications for the outcome. The mean and standard deviation were reported for continuous variables, which included the total inpatient costs, ORT, and LOS.

Bivariate analyses, such as the chi-square or Fisher's exact test and the *t*-test or ANOVA, were used to examine the balance of the baseline covariates and cost variations among covariate subcategories. Multivariable generalized linear models (GLM) with respective binomial or gamma distribution and log-link function were used to obtain adjusted clinical outcomes and resource utilization variations between BS and RS. The covariates adjusted for in the GLM were determined by bivariate analysis when covariates had a p-value < 0.2. In addition, the Hosmer–Lemeshow's goodness of fit test was used to test model fit for dichotomous clinical outcomes. Adjusted costs and outcomes were reported as differences with 95% confidence interval (CI) or as odds ratios (OR) with 95% CI.

Propensity-score matching (PSM) methods were used for sensitivity analysis to test the robustness of the multivariable GLMs. Propensity scores were calculated based on baseline covariates, including patients and provider characteristics that may be associated with outcomes. The caliper was set to 0.2, and nearest-neighbor 1:1 without replacement matches methods were used.[11]

Results

Baseline Characteristics and Procedural Trends

About 18,892 RSG procedures met all eligibility criteria and were included in the analysis (Figure 1). Of those, robotic staplers were used in 15,152 (80.2%) and bedside staplers were used in 3740 (19.8%) of procedures. There were numerous statistically significant differences in baseline patient age, race and ethnicity, payer, CCI, APR-DRG disease severity, and provider's location, region, volume, teaching status, bed size, and volume between the two groups (Table 1).

The annual number of robotic SG cases more than doubled during the study period, from 3419 procedures in 2018 to 8759 procedures in 2022 (Figure 2). As the number of robotic SG procedures increased, the proportion of robotic SG procedures performed using integrated robotic staplers also increased, from 4.1% of cases in 2018 to 72.5% of cases in 2022 (Cochran Armitage trend test, $p < 0.001$). The proportion of robotic cases using BS declined over the same period.

In a sensitivity analysis, 5348 cases representing (2674 matched pairs) were used for post-PSM outcomes examinations. The standardized difference between BS and RS was reported (Appendix D).

Clinical Outcomes

Based on an analysis of unadjusted procedure-related complications, only bleeding showed a significant difference between the two stapler types (Table 2). However, after adjusting for patient and provider characteristics using a multivariable GLM (Table 3), robotic staplers were shown to be associated with a greater risk of blood transfusion compared to bedside staplers [OR: 1.55; 95% CI = 1.02–2.36; p = 0.04]. Similarly, after the application of propensity-score matching, the increased risk of transfusion was even more pronounced [OR: 3.02; 95% CI: 1.35–6.73; p = 0.007]. The risks of bleeding, anastomotic leak, and ICU visits were not significant in the GLM or propensity-matching analyses.

Table 1 Baseline Patient and Provider Characteristics

Characteristic, %	Bedside Stapler N = 3740	Robotic Stapler N = 15,152	p-value
Age category			**<0.001**
<40	37.3	42.8	
40 – 54	39.2	38.5	
55 - 64	15.0	13.6	
65+	8.6	5.1	
Female sex	80.9	81.0	0.892
Race and ethnicity			**<0.001**
Non-Hispanic White	55.7	47.5	
Non-Hispanic Black	23.6	20.3	
Hispanic	8.1	18.1	
Other/unknown	12.7	14.2	
Payer			**<0.001**
Medicare	17.0	12.0	
Medicaid	18.8	27.5	
Private/commercial	55.1	53.6	
Others	9.1	6.9	
Primary diagnosis of obesity (ICD-10 DX: E66.01)	97.7	98.0	0.158
Charlson Comorbidity Index score			**<0.001**
0 - 2	92.2	93.9	
3+	7.8	6.1	
APR-DRG severity score			**<0.001**
Minor	65.4	81.9	
Moderate/major/extreme	34.7	18.1	
Provider region			**<0.001**
Northeast	17.0	38.7	
Midwest	13.1	13.8	
South	48.0	38.7	
West	22.0	8.9	
Provider setting			**<0.001**
Urban	2.2	3.5	
Rural	97.8	96.5	
Provider bed size			**<0.001**
<300	36.1	45.5	
300 – 499	8.1	25.6	
500+	55.9	28.9	
Teaching hospital	43.5	60.0	**<0.001**
Hospital bariatric procedure volume			**<0.001**
Low ≤ 75th percentile	20.3	37.0	
High > 75th percentile	79.7	63.0	
Surgeon bariatric procedure volume			**0.001**
Low ≤ 75th percentile	17.4	20.7	
High > 75th percentile	82.7	79.3	

Note: p-value ≤ 0.05 demonstrated statistical significance are in bold.
Abbreviation: APR-DRG, All Patient Refined-Diagnosis Related Group.

Resource Use

In the unadjusted analysis, all measures of resource utilization that were evaluated—including overall costs, ORT, and length of stay—were significantly different between groups (Table 2). Total costs and ORT were higher in the RS group compared to the BS group, but LOS was shorter ($p < 0.001$ for all comparisons).

The differences remained statistically significant after adjustment in both the GLM and PSM sensitivity analyses (Table 3). When controlled for patient and provider characteristics, procedures in the BS group were associated with

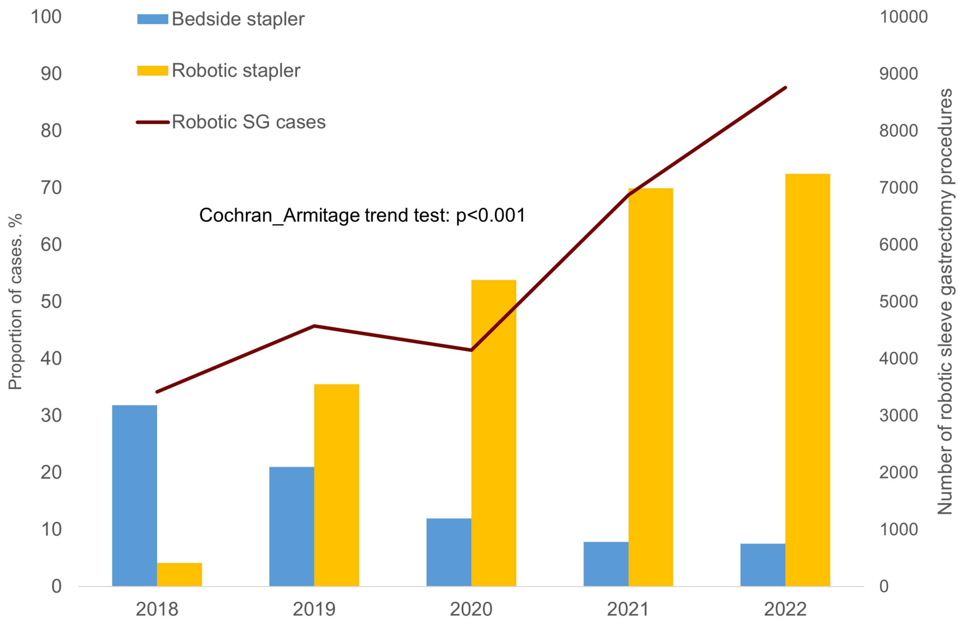

Figure 2 Adoption of bedside and robotic staplers, by year.

a $3084 reduction in cost [95% CI = $2860 - $3309] and a 21-minute (18.6–23.5 minutes) reduction in ORT. The difference in LOS was smaller (0.1 days) after GLM adjustment in comparison to the results of unadjusted analysis but remained statistically significant. The findings of the propensity-matching sensitivity analysis were consistent with the GLM analysis.

Discussion

In this claims-based analysis of 5 years of stapler utilization during robotic SG procedures, we found that RS utilization increased from 2018 to 2022 along with the increased RSG utilization. The use of BS was associated with greater effectiveness and efficiency, as evidenced by the association between BS use and a lower risk of blood transfusion, lower costs, and reduced ORT compared to RS. The only disadvantage of the BS was that it was associated with a slightly longer LOS, although the difference between the two staplers may not be clinically significant.

The finding of the increased trend of use of RS compared to BS was similar to a study by Samreen et al, which used PHD data from 2019–2021.[12] Our study provided further validation of the growth trend of RS use. Robotic-assisted SG has gained popularity in recent years, particularly since the COVID-19 pandemic, along with other robotic-assisted

Table 2 Complications and Resource Utilization by Stapler Type, Unadjusted

Complication	Bedside N = 3740	Robotic N = 15,152	p-value
Clinical complications			
Blood transfusion	28 (0.7%)	97 (0.6%)	0.46
Bleeding	122 (3.3%)	157 (1.0%)	**<0.001**
Anastomotic leak	5 (0.1%)	28 (0.2%)	0.50
ICU visit	16 (0.4%)	77 (0.5%)	0.53
Resource utilization			
Total costs, USD	$13,135 ± $5600	$15,292 ± $5682	**<0.001**
Operating room time, min	117 ± 63	131 ± 51	**<0.001**
Length of stay, d	2 ± 1.3	1 ± 0.7	**<0.001**

Note: p-value ≤ 0.05 demonstrated statistical significance are in bold.

Table 3 Adjusted Complications (Odds Ratios) and Resource Utilization (Absolute Differences)[a]

	Main GLM Model[b] (N = 18892)		**Sensitivity Analysis[c] (N = 5348, 2674 Pairs)**	
Clinical complications	OR (95% CI)	p-value	OR (95% CI)	p-value
Blood transfusion	1.55 (1.02, 2.36)	**0.04**	3.02 (1.35, 6.73)	**0.007**
Bleeding	0.72 (0.52, 1.01)	0.06	1.24 (0.82, 1.86)	0.30
Anastomotic leak	2.25 (0.86, 5.93)	0.10	1.33 (0.30, 5.97)	0.74
ICU visit	1.82 (1.00, 3.29)	0.051	2.01 (0.86, 4.70)	0.11
Resource utilization	Diff (95% CI)	p-value	Diff (95% CI)	p-value
Total costs, USD	$3084 ($2860, $3309)	**<0.001**	$2820 ($2494, $3146)	**<0.001**
Operating room time, min	21.1 (18.6, 23.5)	**<0.001**	14.0 (10.3, 17.6)	**<0.001**
Length of stay, d	−0.15 (−0.21, −0.10)	**<0.001**	−0.1 (−0.16, −0.04)	**<0.001**

Notes: [a]Reference: Bedside staplers; [b]Multivariable general linearized models were adjusted for type of stapler, gender, race and ethnicity, payer, comorbidity, APR-severity, provider's region, location (urban/rural), bed size, annual bariatric surgery volume, and surgeon's annual volume. [c]The sensitivity analysis was conducted using 1:1 propensity-score matching without replacement and a caliper of 0.2. p-value ≤ 0.05 demonstrated statistical significance are in bold.
Abbreviations: BS, bedside stapler; CI, confidence interval; Diff, difference (robotic - bedside); GLM, general linearized model; OR, odds ratio.

procedures.[13] Additionally, the RS are integrated into the surgical robotic platform, allowing the primary surgeon to maintain control throughout the procedure, which may contribute to increased clinician preference. Finally, the bundled sale of RS as part of a proprietary robotic system kit may provide better business incentives for hospitals to procure RS, even if it may not offer better clinical benefits.

Our results are consistent with and complement the findings of others who have recently assessed and compared the clinical effectiveness and efficiency associated with the use of laparoscopic bedside staplers during robotic procedures.

With respect to the clinical effectiveness evaluation, our analysis of a larger dataset confirms prior studies' findings that use of BS during robotic procedures reduces the likelihood of blood transfusion.[4,5] One study published in 2024 by Clapp et al evaluated the effectiveness of BS compared with *RS* during robotic-assisted SG or gastric bypass procedures, using a nationwide hospital-based database.[4] Out of 1603 (22.1%) cases that used BS and 5665 (77.9%) that used RS in the year 2021, the risk of blood transfusion was higher in the RS cohort in the main analysis, although the statistical significance of the difference disappeared in a sensitivity analysis. Another study investigating the cost drivers of RSG also found that the use of laparoscopic bedside staplers compared to robotic staplers had fewer associated blood transfusions.[5] Our study yielded conflicting results in incidence rates of ICU visits compared to BS and RS in the main and sensitivity analyses. This also aligns with the findings of prior studies.[4,5] There were no significant differences in the incidence rates of bleeding and anastomotic leak between the BS and RS groups, which were also consistent with the findings of prior studies.[4,5]

Further, in terms of the efficiency of the staplers used in RSG, our study expands on prior work by examining patient case data spanning a 5-year period and demonstrated that the patients who underwent RSG with RS were significantly more likely to experience higher costs and increased ORT compared with patients who underwent RSG with BS. One study compared BS and RS used in both RSG and gastric bypass. The study showed that RS increased the average inpatient cost of a bariatric procedure by $1273 compared with BS.[4] In another study, Clapp et al found that robotic staplers (including Intuitive™ Endowrist™ and Sureform™) were a cost driver compared to laparoscopic bedside staplers, regardless of brand. RSG using RS increased total inpatient costs by $2692 (95% CI: $2517 - $2867) compared with laparoscopic BS.[5] Our study showed an even larger gap in average total inpatient costs ($3084) between RS and BS used in RSG.

A study by Samreen et al examined variation in outcomes between laparoscopic powered staplers used in laparoscopic sleeve gastric (LSG) and RS (Sureform™) used in robotic GS.[12] The estimation of adjusted mean ORT for RS was 132.6 minutes, which was similar to our estimation (132.9 minutes, Table 4). Interestingly, the ORT of laparoscopic staplers used in LSG for operating room time in the study was 113.4 minutes, which was surprisingly close to our

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Table 4 Adjusted Resource Utilization, Absolute Values for Each Group[a]

Resource Utilization	Bedside Stapler		Robotic Stapler	
Main GLM model[a] (N = 18892)	Mean (95% CI)	p-value	Mean (95% CI)	p-value
Total costs, USD	$12,462 ($12,250, $12,603)	**<0.001**	$15,510 ($15,410, $15,611)	**<0.001**
Operating room time, min	111.8 (109.8, 113.8)	**<0.001**	132.9 (131.9, 133.8)	**<0.001**
Length of stay, d	1.49 (1.44, 1.54)	**<0.001**	1.34 (1.32, 1.35)	**<0.001**
Sensitivity analysis[b] (N = 5348; 2674 pairs)	Mean (95% CI)	p-value	Mean (95% CI)	p-value
Total costs, USD	$13,424 ($13,224, $13,624)	**<0.001**	$16,244 ($15,986, $16,501)	**<0.001**
Operating room time, min	120.3 (117.8, 122.7)	**<0.001**	134.2 (131.5, 136.9)	**<0.001**
Length of stay, d	1.53 (1.48, 1.58)	**<0.001**	1.43 (1.39, 1.46)	**<0.001**

Notes: [a]Multivariable general linearized models were adjusted for type of stapler, gender, race and ethnicity, payer, comorbidity, APR-severity, provider's region, location (urban/rural), bed size, annual bariatric surgery volume, and surgeon's annual volume. [b]The sensitivity analysis was conducted using 1:1 propensity scores matching without replacement and a caliper of 0.2; p-value ≤ 0.05 demonstrated statistical significance are in bold.
Abbreviations: CI, confidence interval; GLM, general linearized model.

estimation for bedside staplers used in robotic GS (111.8 minutes, Table 4). This further suggests that the operating room efficiency (reduction in ORT) was associated with the type of stapler used (BS or RS) but may not be related to the approach of the procedures (laparoscopic or robotic).

Lastly, in alignment with several prior studies' findings, RGS patients who used RS had a shorter average length of stay, than those who used BS.[4,12] While this difference was statistically significant, the absolute values of the mean differences in the two groups were very small and may not amount to a clinically significant difference.

Taken together, these findings could provide new perspective regarding the relative resource-utilization benefits of BS versus RS. In the context of achieving equivalent or better clinical outcomes and reduced resource utilization, the cost-saving benefits of BS represent a sensible choice for providers and health-care systems to deliver better and more efficient care to patients.

Limitations

This study is subject to the limitations commonly associated with retrospective database analyses, including the possibility of miscoding for diagnosis and procedures using billing codes or otherwise low-quality records. Reliance on coding, text strings, and product numbers and brand names may result in missed cases. Furthermore, information regarding stapler firing, staple height, and staple line reinforcement, number of stapler reloads used, and number of instrument changes during the robotic SG were unavailable or incomplete and therefore could not be factored into the outcomes analysis. Additionally, there are no details of cost information. In a result, we cannot compare the cost of the stapler parts (handler, reload, and line reinforcement) among different types of staplers. The leasing contract or purchase costs of robotic platform were not available, nor was information regarding whether the staplers were included in the institutional contract, which may also affect the costs of staplers. Lastly, we were unable to account for stapler learning curves when analyzing clinical outcomes and costs.

Conclusion

Robotic staplers have been adopted rapidly for robotic SG procedures in recent years and are the most common tool for RSG. However, our study demonstrated that the use of BS during RSG was more clinically effective and more efficient in terms of healthcare resource utilization while also being cost-saving. Bedside staplers should be considered as a potentially cost-effective option for RSG procedures in the context of a resource-constrained healthcare environment.

Ethics Approval and Informed Consent

The database used for this study was de-identified in accordance with the HIPAA Privacy Rule, and therefore, this study was determined exempt from full board review by Sterling IRB.

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Author Contributions
All authors (IWP and ZAS) made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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IWP and ZAS are employees of Medtronic, PLC. The authors report no other conflicts of interest in this work.

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