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Differences in effectiveness and use of robotic surgery in patients undergoing minimally invasive colectomy

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Abstract

Background—We compared patient outcomes of robot-assisted surgery (RAS) and laparoscopic colectomy without robotic assistance for colon cancer or nonmalignant polyps, comparing all patients, obese versus non-obese patients, and male versus female patients.

Methods—We used the 2013–2015 American College of Surgeons' National Surgical Quality Improvement Program data to examine a composite outcome score comprised of mortality, readmission, re-operation, wound infection, bleeding transfusion, and prolonged postoperative ileus. We used propensity scores to assess potential heterogeneous treatment effects of RAS by patient obesity and sex.

Results—In all, 17.1% of 10,844 of patients received RAS. Males were slightly more likely to receive RAS. Obese patients were equally likely to receive RAS as non-obese patients. In comparison to nonRAS, RAS was associated with a 3.1% higher adverse composite outcome

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score. Mortality, reoperations, wound infections, sepsis, pulmonary embolisms, deep vein thrombosis, myocardial infarction, blood transfusions, and average length of hospitalization were similar in both groups. Conversion to open surgery was 10.1% lower in RAS versus nonRAS patients, but RAS patients were in the operating room an average of 52.4 minutes longer. We found no statistically significant differences ($p > 0.05$) by obesity status and gender.

Conclusions—Worse patient outcomes and no differential improvement by sex or obesity suggest more cautious adoption of RAS.

MESH

colon cancer; robotic surgical procedures; comparative effectiveness research; mortality

Introduction

Laparoscopic colectomy has gained widespread acceptance for resection of colorectal cancer (CRC), with better short term complication rates and similar long-term outcomes relative to conventional open surgery.^{1,2} With the increasing use of robotic surgery in CRC as part of laparoscopic surgery,³ it is timely to ask if this expensive technology is being used appropriately by maximizing patient outcomes and minimizing complications and costs, particularly among specific patient subgroups. The key is to strike a balance between the potential benefits of RAS, its high costs, and patient preferences.⁴

Variation in the use of RAS may reflect differences in the availability of robotic devices and optimizing patient selection in complex or technically challenging situations in order to identify patients most likely to benefit.⁵ For example, the narrow male pelvis makes laparoscopy technically challenging, and the robot may help in overcoming this limitation by allowing better visualization deep in the pelvis.⁶ However, unlike the examination of the effectiveness of robotic surgery in subgroups of patients with other cancers (e.g., obese patients with endometrial cancer⁷ and high-risk prostate cancer),^{8,9} the effectiveness in specific colon cancer patients remains unknown. Overweight and male CRC patients may especially benefit if RAS can help avoid conversion to open surgery compared to normal weight and female patients. Obesity is also a risk factor for wound infection and anastomotic leaks.¹⁰ Moreover, the prevalence of obesity in colon cancer patients continues to be large and is a significant burden on the healthcare system.¹¹

Our purpose was to describe characteristics of colectomy patients that received RAS or LC. We then examined differences in effectiveness of RAS versus laparoscopic colectomy without robot assistance (nonRAS), comparing subgroups of patients: male versus female patients and obese versus nonobese patients. Knowledge of the effectiveness of RAS for specific colectomy patients will help make informed decisions about the use of this technology in minimally invasive surgery.

Materials and methods

Data Source

Our cohort was constructed using the 2013–2015 American College of Surgeons' National Surgical Quality Improvement Program (ACS-NSQIP) Participant Use File and Targeted Colectomy File. Preoperative patient comorbidities, preoperative laboratory results, intraoperative procedure characteristics, and 30-day postoperative mortality rates and complications were abstracted by trained reviewers. Additional details are described elsewhere (<https://www.facs.org/quality-programs/acs-nsqip>).

Patient selection

All patients who underwent colectomy as indicated for colon cancer (with or without obstruction) or nonmalignant polyps were eligible for inclusion. Patients with ASA class five or who underwent emergent colectomy were excluded from the analysis. Patients who underwent robotic only or robotic with open assist procedures were classified in the RAS group. Patients who underwent laparoscopic surgery only or laparoscopic surgery with hand assisted procedures were classified in the LC group.

Patient outcomes

Outcomes included conversion, operation time, anastomotic leakage, mortality, readmission, re-operation, length of stay, wound infection, transfusion, prolonged postoperative ileus, sepsis, myocardial infarction, deep vein thrombosis, and pulmonary embolism. Conversion occurred when the laparoscopic procedure (robotic or nonrobotic) was converted to an unplanned open surgery. Re-operation was defined as any unplanned return to the operating room for a surgical procedure, for any reason, within 30 days of the colectomy at any hospital or surgical facility. All-cause mortality was defined as deaths within 30 days following colectomy. Readmission was defined as any readmission (to the same or another hospital), for any reason, within 30 days of the colectomy. A wound infection included superficial or deep incisional surgical site infection or any other wound infection. Postoperative bleeding occurrence was defined as any transfusion given from the start of the colectomy to 72 hours post operation. Because of the infrequent occurrence for some of the postoperative outcomes, we constructed a composite outcome of mortality, readmission, re-operation, wound infection, bleeding occurrence, and prolonged postoperative ileus. Patients with at least one adverse outcome were contrasted to those without any such adverse outcomes.

Covariates

Covariates included patient sex, age, Hispanic ethnicity, race, body mass index (BMI), ASA grouping, smoking status, number of chronic comorbid conditions (congestive heart failure, hypertension, chronic obstructive pulmonary disease, shortness of breath, weight loss >10%, bleeding disorder, transfusion), patient functional status, mechanical bowel preparation, AJCC staging, and probability of morbidity. Covariates were selected based on previous studies.^{12,13} The patient's most recent height and weight documented in the medical record within the 30 days prior to the colectomy or at the time the patient was being considered a

candidate for surgery was used to calculate BMI. Patients were classified as obese (BMI ≥ 30 kg/m²) or nonobese (BMI < 30 kg/m²).

Statistical analysis

We determined the extent to which the variables that made up the composite variable loaded on a single factor using factor analysis and a polychoric correlation matrix because traditional factor analysis relies on continuous variables. We used Chi-square tests to determine statistical significance between patients in the RAS group and those who received LC without robotic assistance. We calculated adjusted odds ratios (OR) and 95% confidence intervals (CI) using multivariable logistic regression to identify factors associated with RAS use. Adjusted odds ratios > 1 represent increased use of RAS while odds ratios < 1 represent decreased use of this surgery. All factors were entered into the model regardless of their statistical significance.

We used 1:1 propensity score matching to obtain patient groups with comparable characteristics to assess the effect of RAS on patient outcomes. Variables included in the propensity score included all aforementioned covariates. We calculated standardized differences for all covariates before and after matching; a standardized difference of less than -0.1 or greater than 0.1 was used as a marker for imbalance.¹⁴ We also compared the means and variances of the covariates after matching in order to determine the balance between both groups. We calculated the average treatment effect among the treated (ATT) and associated 95% confidence intervals to describe the effectiveness of RAS versus LC, focusing on absolute differences.

To assess potential heterogeneous treatment effects of RAS by sex, we first matched patients who received RAS to those who received LC. Matching was done in a 2:1 ratio using optimal matching on the propensity score, $e(x)$, with a caliper of $0.25 \times \text{sd}(e(x))$.¹⁵ Once patients were matched, we ran separate regressions in the robotic and nonrobotic groups to predict respective outcomes. The coefficients for male versus female patients were compared between the two models to assess treatment heterogeneity due to these factors.¹⁶ A similar approach was used to assess treatment heterogeneity due to obesity.

We conducted a series of analyses to challenge the robustness of the findings. First, we conducted a formal sensitivity analysis to assess the extent to which the initial indication for colectomy (colon cancer, nonmalignant polyps) might explain our results. Second, we compared patients with RAS and LC only, excluding those with assistive procedures. Third, we examined the ATT using inverse probability weighting and nearest neighbor propensity score matching. Alpha was set at 0.05.

Results

Patients

Data were collected on 66,031 patients with colectomies in the 2013–2015 NSQIP data. Of those, primary indication for 36,734 patients was colectomy for colon cancer with or without obstruction or for nonmalignant polyps. Of those, 1,968 patients had ASA class five or had emergency surgery and were excluded from further analysis. In all, 21,689 patients received

open surgery and were excluded also. Of the remaining 13,077 patients, 2,233 patients received RAS and 10,844 patients received laparoscopic surgery without robotic assistance and comprised the study population. Table 1 shows that patients were predominantly white (71.1%) and non-Hispanic (84.0%). About one out of three patients were obese. Most patients had ASA class two or three (93.0%), were nonsmokers (85.9%), and had at least one comorbid condition (59.8%). The variables comprising the composite outcome loaded on a single factor based on the eigenvalues, screeplot, and goodness of fit statistics, with factor loadings ranging from 0.4 to 0.7.

RAS use

Of all laparoscopic surgeries for colon cancer or nonmalignant polyps, 17.1% were performed with robotic assistance. In a multivariable model containing all variables (Table 1), patients were more likely to receive RAS if they were male (OR: 1.18), underwent surgery in 2015 (OR: 2.79), had preoperative mechanical bowel preparation (OR: 1.39), or had TNM stage 0 colon cancer (OR: 1.50). Patients were less likely to receive RAS if they were age 75 or older (OR 0.56), African American (OR: 0.70), had right-sided disease (OR=0.35), were diagnosed with stage IV cancer (OR: 0.70), or had at least three comorbid conditions. Obese patients were equally likely to receive RAS as nonobese patients (OR: 0.98). The interaction between sex and BMI in predicting RAS use was not statistically significant ($p=0.087$). The adjusted percentage of RAS use was highest among nonobese males (17.5%), followed by obese males (17.2%), nonobese females (15.2%), and obese females (14.9%).

Unmatched outcomes

Of all patients, 22.1% experienced at least one adverse postoperative outcome (Table 2), which was higher in RAS (23.5%) versus nonRAS patients (21.8%). Overall, mortality was 0.8%, which was similar in RAS (0.6%) versus nonRAS patients (0.9%). In all, 7.9% of patients were readmitted within 30 days, which was higher in RAS patients (9.3%) versus nonRAS patients (7.6%). Overall, 3.3% of patients were reoperated, which was higher in RAS patients (4.4%) versus nonRAS patients (3.1%). Wound infections were similar in RAS patients (3.5%) versus nonRAS patients (3.5%). No differences existed between RAS and nonRAS patients in occurrence of sepsis, pulmonary embolism, deep vein thrombosis, and myocardial infarction. Ileus was prolonged in RAS patients (10.4%) versus nonRAS patients (8.7%). Of all patients, 5.5% required blood transfusion, which was similar between RAS (4.8%) and nonRAS patients (5.6%). Length of stay was an average of 5.3 days, which was similar for RAS (5.1 days) and nonRAS patients (5.3 days). In all, 7.5% of patients were converted to open surgery, but this was much lower in the RAS (5.7%) versus the nonRAS group (18.6%). Length of operation was on average 178.5 minutes, but RAS patients were longer in the operating room (235.6 minutes) than nonRAS patients (166.7 minutes). Anastomotic leak occurred in 2.6% of all patients and was higher in RAS (3.6%) than nonRAS patients (2.3%).

Propensity-score matched outcomes

The percentage of patients who experienced at least one of the composite outcomes was 3.1% higher in RAS versus nonRAS patients (Table 2). For every 32 patients treated with

RAS, there was one additional adverse postoperative outcome. Mortality was similar in both patient groups. The percentage of patients readmitted within 30 days was 1.4% higher in RAS versus nonRAS patients. Reoperation rates were similar between both groups (0.7%) as were wound infections (−0.3%). No difference existed between both groups in the percentage of patients with prolonged ileus (1.8%), developing sepsis (0.1%), pulmonary embolisms (0.0), deep vein thrombosis (−0.2), myocardial infarction (0.1%), needing blood transfusion 0.4%, or mean lengths of stay (−0.2). The percentage of patients converted to open surgery was 10.1% lower in RAS versus nonRAS patients. However, RAS patients were in the operating room an average of 52.4 minutes longer. The percentage of RAS patients with anastomotic leaks was similar for both groups of patients. For all comparisons, RAS and nonRAS patients were well balanced after matching based on the standardized differences as well as the means and variances of the covariates.

Heterogeneity in RAS effectiveness

Table 3 shows that composite outcomes and length of stay were similar among obese and nonobese patients in propensity-adjusted analysis ($p=0.848$ and $p=0.412$, respectively). The average length of time of operation was statistically greater among RAS versus nonRAS for both obese and nonobese patients; however, the difference between RAS and nonRAS was similar among obese and nonobese patients ($p=0.437$). Conversion to open surgery was lower in RAS versus nonRAS for both obese and nonobese patients. This difference, however, did not vary by obesity status ($p=0.068$).

Table 4 shows that postoperative outcomes and length of stay were similar among male and female patients in propensity-adjusted analysis ($p=0.367$ and $p=0.195$, respectively). The average length of operation time was statistically greater among RAS versus nonRAS; however, the difference was similar between genders ($p=0.411$). Conversion to open surgery was lower for RAS versus nonRAS patients, but was similar between males and females ($p=0.380$).

Sensitivity analyses

Our findings were robust with respect to the reason for colectomy (malignant or nonmalignant polyps), different methods of propensity score matching, and the definition of the RAS and nonRAS groups when excluding assistive procedures (results not shown).

Discussion

To our knowledge, this is the first and largest study to examine differences in the use and effectiveness of RAS in minimally invasive surgery, specifically focused on differences by sex and obesity. In matched analysis, RAS patients had worse outcomes and longer average operation times, but lower conversion to open surgery compared with nonRAS patients. Both groups were similar in terms of mortality, wound infections, transfusions, and length of stay. Differences between RAS and nonRAS were similar in obese versus nonobese patients and in male versus female patients.

Studies to date comparing RAS and nonRAS consist predominantly of single-institution studies, meta-analyses, claims-based analysis, and reviews. Many studies were limited by

small sample sizes, resulting in unstable estimates of many patient outcomes. Similar to other larger studies,^{6,17} RAS patients experienced lower conversion rates compared to nonRAS patients. However, unlike other studies that have shown that complications were similar between RAS and nonRAS patients,^{17,18} our data show significantly higher complication rates (readmission, reoperation, prolonged ileus, anastomotic leak) in RAS versus nonRAS patients. Surgeons may opt for more challenging cases in teaching hospitals that perform the majority of RAS³ or RAS is starting to be adopted in smaller hospitals that are performing laparoscopic procedures that are associated with higher technical difficulty and a learning curve. This may have resulted in adverse patient outcomes compared to nonRAS patients in our study. Thirty-day patient follow up beyond index hospitalization and large sample size may also have contributed to differences between our results and other studies. Similar to many^{6,19–21} but not all studies,^{17,22} we observed no difference in average length of stay between RAS and LC patients.

Some have suggested that, at least in endometrial or uterine cancer, obesity may be an indication for receiving robotic surgery.^{23,24} Our results show that obese patients had similar outcomes as nonobese patients. Our results confirm the findings of small studies conducted at single institutions.^{25,26} Thus, it is unlikely that increasing RAS among obese patients will disproportionately reduce their high conversion rates and may actually harm them because of the higher rate of adverse patient outcomes in all RAS patients.

Robotic surgery may help overcome the limitation of the narrow male pelvis by allowing better visualization.⁶ Although males were slightly more likely to receive robotic surgery, there were no differences in any of the investigated outcomes. Thus, although visualization may be better using a robotic system in males, this did not result in better patient outcomes when using RAS compared with female patients.

Our study is the largest patient series not based on claims data and includes multiple hospitals reporting on many different types of patient outcomes. Our study included nearly twice as many RAS patient as a recent meta-analysis²⁷, which may yield more stable estimates of RAS on patient outcomes. In their 2012–2014 NSQIP analysis, Dolejs and colleagues¹³ found few differences in patient outcomes but failed to use causal models. We believe that our matched propensity score analysis maximized causal inferences.¹¹ Rigorous nonrandomized evaluations are needed to determine which patients benefit from RAS approaches.²⁸ High-quality observational studies can provide information on treatment effectiveness in particular subpopulations.²⁹

We also recognize the limitations of our findings. For example, even though we included more than 13,000 patients, some outcomes were relatively infrequent, resulting in large confidence intervals. To mitigate the impact of this concern, we constructed a composite outcome, which may be less likely to reflect this limitation. In addition, we were only able to control for variables available in the NSQIP data and some characteristics of hospitals or surgeons were not available because of confidentiality concerns. We recognize this limitation although it is unlikely to impact our findings since adjusting for surgeon case counts and hospital volume did not alter findings in other studies.¹⁷ Furthermore, we recognize that the NSQIP typically includes data from larger hospitals, limiting

generalizability to smaller hospitals not part of the NSQIP, and these data are not a nationally representative sample. However, the vast majority of robotic surgery is performed by surgeons at teaching hospitals and at centers with higher patient volumes.³ Also, we did not have any information about which hospitals had implemented enhanced recovery after surgery programs. In addition, the NSQIP data precludes the analysis of differences in cost, although most studies have shown higher costs associated with RAS.^{18,28} Finally, we recognize that the effectiveness of RAS may vary within the large range of BMIs that is included in our definition of obesity (BMI 30 kg/m²), but the sample size was insufficient to examine RAS effectiveness in patients with BMI 40 kg/m².

Conclusion

In summary, RAS patients had higher readmission, prolonged ileus, leakage, and longer average operation times, but lower conversion to open surgery compared with nonRAS patients. The effect of RAS was similar in obese versus nonobese patients and in male versus female patients. Worse patient outcomes and no differential improvement by sex and obesity suggest the need for more cautious adoption of this technology.

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Table 1

Patient characteristics by laparoscopic surgery, with or without robot assistance, 2013–2015.

Patient characteristic	Total (n=13,077)	Robot-assisted laparoscopic surgery (n=2,233)	Laparoscopic surgery without robot assistance (n=10,844)	Adjusted odds ratio 95% CI
Sex *				
Male	49.6	55.1	48.5	1.18 (1.07; 1.30)
Female	50.4	44.9	51.5	1.00
Age group (years) *				
< 45	5.5	6.9	5.3	1.00
45–54	17.4	22.4	16.4	1.00 (0.80; 1.25)
55–64	24.8	26.7	24.4	0.84 (0.68; 1.05)
65–74	27.8	27.8	28.0	0.80 (0.64; 1.01)
75+	24.5	17.4	26.0	0.56 (0.44; 0.72)
Race *				
White	71.1	69.0	81.0	1.00
African American	10.9	11.4	8.2	0.70 (0.59; 0.83)
Other	4.8	4.9	4.5	0.63 (0.50; 0.80)
Unknown	13.3	14.7	6.3	0.73 (0.57; 0.93)
Hispanic ethnicity *				
No	84.0	92.7	82.2	1.00
Yes	3.8	3.8	3.8	0.80 (0.62; 1.04)
Unknown	12.2	3.5	14.0	0.30 (0.22; 0.40)
Body mass index *				
30 kg/m ²	33.7	36.5	33.1	0.98 (0.88; 1.09)
<30 kg/m ²	65.8	63.4	66.3	1.00
Unknown	0.5	0.1	0.6	
ASA category *				
1	2.6	1.7	2.8	1.00
2	45.0	45.5	45.0	1.14 (0.76; 1.70)
3	48.0	50.4	47.5	1.02 (0.66; 1.57)
4	4.2	2.5	4.6	0.63 (0.37; 1.06)
Unknown	0.2	0.0	0.2	
Current smoker				
Yes	14.1	14.4	14.0	0.87 (0.75; 1.00)
No	85.9	85.6	86.0	1.00
Preoperative mechanical bowel preparation *				
Yes	59.1	67.2	57.4	1.39 (1.22; 1.57)
No	24.9	17.6	26.3	1.00
Unknown	16.1	15.2	16.3	1.12 (0.95; 1.33)
Cancer location *				

Patient characteristic	Total (n=13,077)	Robot-assisted laparoscopic surgery (n=2,233)	Laparoscopic surgery without robot assistance (n=10,844)	Adjusted odds ratio 95% CI
Left	31.1	54.3	26.3	1.00
Right	28.8	19.1	30.8	0.35 (0.30; 0.39)
Other	40.1	26.7	42.9	0.29 (0.25; 0.35)
AJCC stage *				
0	1.8	3.0	1.6	1.50 (1.07; 2.11)
I	12.2	15.6	11.5	1.17 (0.96; 1.42)
II	11.8	11.0	10.7	1.00
III	11.7	13.3	11.4	0.95 (0.78; 1.16)
IV	3.0	2.8	3.1	0.70 (0.51; 0.97)
Unknown	35.8	35.2	35.9	0.92 (0.77; 1.08)
Nonmalignant	26.6	19.1	25.8	1.29 (1.03; 1.62)
Number of comorbid conditions *				
0	40.2	43.5	39.5	1.00
1	36.9	35.7	37.2	0.91 (0.81; 1.03)
2	17.5	16.9	17.6	0.94 (0.80; 1.11)
3 or more	5.5	3.8	5.8	0.65 (0.49; 0.86)
Mean estimated prob. of morbidity (SD) *	11.0% (5.1)	10.7% (4.6)	11.0% (5.2)	

* p<0.05;

Other race includes American Indian, Alaskan Native, Native Hawaiian, Pacific Islander, or Asian; CI: confidence interval; SD: standard deviation

Cox-Snell R-square: 0.096

Patient outcomes by laparoscopic surgery with or without robot assistance, NSQIP 2013–2015.

Table 2

Patient outcome	Total laparoscopic surgery (n=13,077)	Unmatched analysis		Propensity-matched analysis	
		Robot-assisted laparoscopic surgery (n=2,233)	Laparoscopic surgery without robot assistance (n=10,844)	Average treatment effect: RAS versus nonRAS (%)	Total number of patients (1:1 match)
Postoperative					
Composite outcome (%)**	22.1	23.5	21.8	3.1 (1.0; 5.2)	4,462
Mortality (%)	0.8	0.6	0.9	0.0 (−0.5; 0.3)	4,462
Readmission (%)	7.9	9.3*	7.6	1.4 (0.0; 2.9)	4,462
Reoperation (%)	3.3	4.4*	3.1	0.7 (−0.3; 1.8)	4,462
Wound infection (%)	3.5	3.5	3.5	−0.3 (−1.2; 0.7)	4,462
Sepsis (%)	2.2	2.4	2.2	0.1 (−0.7; 0.9)	4,462
Pulmonary embolism	0.4	0.5	0.4	0.0 (−0.5; 0.3)	4,462
Deep vein thrombosis	0.7	0.6	0.7	−0.2 (−0.6; 0.3)	4,462
Myocardial infarction	0.5	0.6	0.5	0.1 (−0.3; 0.5)	4,462
Prolonged postoperative ileus (%)	9.0	10.4*	8.7	1.8 (−0.3; 2.9)	4,456
Bleeding requiring blood transfusion (%)	5.5	4.8	5.6	0.4 (−0.7; 1.6)	4,462
Mean length of stay in days (median, SD)	5.3 (4, 5.2)	5.1 (4, 4.6)*	5.3 (4, 5.3)	−0.2 (−0.4; 0.1)	4,446
Peri-operative					
Conversion (%)	7.5	5.7*	18.6	−10.1 (−11.4; −8.7)	4,730
Mean length of operation in minutes (SD)	178.5 (90.0)	235.6 (104.4)*	166.7 (81.9)	52.4 (47.3; 57.5)	4,448
Anastomotic leak (%)	2.6	3.6*	2.3	0.7 (−0.2; 1.7)	4,450

* p<0.05 in unadjusted RAS versus LC comparison;

** Composite outcome includes readmission, reoperation, wound infection, blood transfusion, prolonged ileus, sepsis, myocardial infarction, deep vein thrombosis, pulmonary embolism, and mortality;
SD: standard deviation

Table 3

Effect of robotic surgery by obesity, NSQIP 2013–2015.*

Patient outcome	Obese patients		Nonobese patients		*** p
	RAS	nonRAS	RAS	nonRAS	
Composite adverse postoperative outcome (%)	24.1	22.8	23.5	21.3	0.848
Mean length of stay in days (SD)	5.1 (5.2)	5.4 (5.2)	5.0 (4.3)	5.3 (5.3)	0.412
Mean length of operation in min (SD)	245.5 (104.0)**	179.3 (86.9)	229.9 (104.2)**	160.2 (78.3)	0.437
Conversion (%)	8.3*	23.0	4.1*	16.1	0.068

* Obese: 30 kg/m²;

** p<0.05 in unadjusted analysis;

*** based on propensity score-matched patients comparing obese versus nonobese patients.

RAS: robot-assisted surgery; LC: laparoscopic colectomy; SD: standard deviation Composite outcome includes readmission, reoperation, wound infection, blood transfusion, prolonged ileus, sepsis, myocardial infarction, deep vein thrombosis, pulmonary embolism, and mortality

Table 4

Effect of robotic surgery by sex, NSQIP 2013–2015.

Patient outcome	Male patients		Female patients		p ^{**}
	RAS	nonRAS	RAS	nonRAS	
Composite adverse postoperative outcome (%)	26.2	24.1	20.7	19.7	0.380
Mean length of stay in days (SD)	5.5 (5.4)	5.5 (5.8)	4.6 (3.4) [*]	5.1 (4.9)	0.195
Mean length of operation in min (SD)	248.7 (112.2) [*]	177.2 (86.2)	219.4 (91.3) [*]	156.9 (76.4)	0.411
Conversion (%)	6.3 [*]	20.7	4.8 [*]	16.5	0.380

^{*} p<0.05 in unadjusted analysis;

^{**} based on propensity score-matched patients comparing obese versus nonobese patients.

RAS: robot-assisted surgery; LC: laparoscopic colectomy; SD: standard deviation Composite outcome includes readmission, reoperation, wound infection, blood transfusion, prolonged ileus, sepsis, myocardial infarction, deep vein thrombosis, pulmonary embolism, and mortality