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ORIGINAL ARTICLE

A Comparison of Pathologic Outcomes of Open, Laparoscopic, and Robotic Resections for Rectal Cancer Using the ACS-NSQIP Proctectomy-Targeted Database: a Propensity Score Analysis

Richard Garfinkle[1] · Maria Abou-Khalil[1] · Sahir Bhatnagar[2] · Nathalie Wong-Chong[1] · Laurent Azoulay[2,3,4] · Nancy Morin[1] · Carol-Ann Vasilevsky[1] · Marylise Boutros[1]

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Abstract

Background There is ongoing debate regarding the benefits of minimally invasive techniques for rectal cancer surgery. The aim of this study was to compare pathologic outcomes of patients who underwent rectal cancer resection by open surgery, laparoscopy, and robotic surgery using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) proctectomy-targeted database.

Methods All patients from the 2016 ACS-NSQIP proctectomy-targeted database who underwent elective proctectomy for rectal cancer were identified. Patients were divided into three groups based on initial operative approach: open surgery, laparoscopy, and robotic surgery. Pathologic and 30-day clinical outcomes were then compared between the groups. A propensity score analysis was performed to control for confounders, and adjusted odds ratios for pathologic outcomes were reported.

Results A total of 578 patients were included—211 (36.5%) in the open group, 213 (36.9%) in the laparoscopic group, and 154 (26.6%) in the robotic group. Conversion to open surgery was more common among laparoscopic cases compared to robotic cases (15.0% vs. 6.5%, respectively; $p = 0.011$). Positive circumferential resection margin (CRM) was observed in 4.7%, 3.8%, and 5.2% ($p = 0.79$) of open, laparoscopic, and robotic resections, respectively. Propensity score adjusted odds ratios for positive CRM (open surgery as a reference group) were 0.70 (0.26–1.85, $p = 0.47$) for laparoscopy and 1.03 (0.39–2.70, $p = 0.96$) for robotic surgery.

Conclusions The use of minimally invasive surgical techniques for rectal cancer surgery does not appear to confer worse pathologic outcomes.

Keywords Pathologic outcomes · Rectal cancer · Laparoscopy · Robotic surgery · Open surgery · NSQIP · Proctectomy · Database · Propensity score analysis

The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP 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.

✉ Marylise Boutros
mboutros@jgh.mcgill.ca

[1] Division of Colon and Rectal Surgery, Jewish General Hospital, McGill University, 3755 Cote Ste Catherine, G-317, Montreal, Quebec H3T 1E2, Canada

[2] Department of Epidemiology, Biostatistics, and Occupational Health, McGill University, Montreal, Canada

[3] Gerald Bronfman Department of Oncology, McGill University, Montreal, Canada

[4] Centre for Clinical Epidemiology, Lady Davis Institute, Jewish General Hospital, Montreal, Canada

Introduction

Surgical resection remains the mainstay of treatment for patients with rectal cancer. Since the description of the total mesorectal excision (TME) technique in the late 1980s,[1] the importance of a good quality surgical resection has become increasingly paramount. Various parameters exist to measure the oncologic success of a proctectomy performed for rectal cancer, including circumferential resection margin (CRM), distal resection margin (DRM), and TME excision quality, with circumferential margin positivity and incomplete TME excision repeatedly associated with increased local recurrence and worse overall survival.[2–4]

The use of minimally invasive surgical (MIS) techniques for colorectal surgery, including laparoscopy and robotic surgery,

has become increasingly popular.[5,6] However, their uptake in rectal cancer surgery is tempered by the relative complexity of the operation and questionable benefits in short-term postoperative and pathologic outcomes.[7] Laparoscopy has been compared to open resection for rectal cancer in multiple large, multicenter randomized controlled trials (RCTs). While two earlier trials demonstrated short-term benefits and equivalent oncologic outcomes with laparoscopy[8,9], more recent RCTs were unable to demonstrate non-inferiority in pathologic outcomes, casting a new doubt in the use of this technique for rectal cancer.[10,11] Further adding to the controversy is the composite pathologic primary outcome used in the latter two trials,[12] which may have contributed to the conclusions. Robotic surgery has also been advocated in the treatment of rectal cancer, particularly for low-lying tumors in the difficult pelvis.[13,14] While many observational studies support its use, recent results from the ROLARR trial reported no benefits in morbidity or pathologic outcomes with the robot compared to conventional laparoscopy.[15] Given the substantially increased cost of robotic surgery,[16–18] its current role in rectal cancer surgery remains undefined.

The purpose of this study was to compare short-term and pathologic outcomes of patients who underwent rectal cancer resection by open surgery, laparoscopy, and robotic surgery using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) proctectomy-targeted database. Our a priori hypothesis was that there was no difference in pathologic outcomes between the three operative approaches.

Methods

The ACS-NSQIP database is a North American initiative that generates prospectively collected Health Insurance Portability and Accountability Act (HIPAA)-compliant surgical outcomes data. Trained clinical reviewers collect many variables in several categories, including demographics, surgical profiles, preoperative data, and 30-day postoperative outcomes. The proctectomy-targeted patient user file (PUF) further includes proctectomy-specific pre- and postoperative variables. A recent quality assessment audit was performed and reported that the ACS-NSQIP has implemented audit and training procedures that are highly effective in collecting robust data with reliability and accuracy that is constantly improving.[19]

Patient Identification

After Institutional Review Board approval, we identified all patients from the 2016 ACS-NSQIP proctectomy-targeted PUF who underwent elective proctectomy for rectal cancer, according to *Current Procedural Terminology* (CPT) codes ("low anterior resection": 45111, 45112, 45119, 44145, 44146, 44207, 44208, 45397; "abdominoperineal resection": 45110, 45395) and *International Classification of Disease* (ICD) codes ("malignant neoplasm of rectum": ICD-9-CM 154.1, or ICD-10-CM C20). Patient data from the proctectomy-targeted PUF was then linked to the general PUF for demographic and general operative and postoperative data, and only patients with data in both databases were further included. Patients with preoperative T4 tumors, metastatic disease (M1), and emergency resections were excluded. Patients with missing pathologic margin status and missing data on preoperative T stage or tumor location were also excluded. Margin data was missing in 10–15% of patients who would have otherwise been included into the cohort, but this was non-differential to operative approach (9.4% vs. 13.8% vs. 15.4% of open, laparoscopic, and robotic resections, respectively; $p = 0.15$).

Operative Approach

Patients were divided into three groups based on initial operative approach, which is collected by the ACS-NSQIP from the surgeon's operative report and is a variable provided in the proctectomy-targeted PUFs. The open group included those cases coded as open (planned); the laparoscopic group those cases coded as either laparoscopic or laparoscopic with unplanned conversion to open; and the robotic group those cases coded as either robotic or robotic with unplanned conversion to open. As such, the primary analysis was based on an "intention-to-treat" approach based on the initial operative approach. All procedures performed by endoscopic surgery, Natural Orifice Transluminal Endoscopic Surgery (NOTES), Single Incision Laparoscopic Surgery (SILS), "other" MIS approaches, or hybrid approaches were also excluded.

Potential Confounders

Data collected for this study included patient demographics, preoperative medical comorbidities, and preoperative tumor and treatment characteristics. Specifically, tumor location [upper (> 10 cm from anal verge), middle (5–10 cm from anal verge), or lower (< 5 cm from anal verge) third of rectum], preoperative clinical stage, and the use of chemoradiotherapy within 90 days of the operation were collected. Operative details included operative approach, the procedure performed [low anterior resection (LAR) or abdominoperineal resection (APR)], and operative time. Given the low number of anticipated events (positive CRM) but multiple confounders, a propensity score analysis was performed, collapsing the confounders into a single variable.[20] Confounders were chosen a priori or based on differences observed on univariate analysis, which included: age, gender, race, body

mass index (BMI), ASA > 3, tumor location, clinical stage, neoadjuvant chemoradiotherapy, and procedure.

Outcomes

The primary outcome was positive CRM. Secondary outcomes included positive DRM, a composite outcome of negative CRM and negative DRM, and number of lymph nodes evaluated. Other outcomes of interest included 30-day postoperative outcomes, including surgical site infection (SSI), anastomotic leak, postoperative ileus, length of stay (LOS), readmissions, and NSQIP-defined major morbidity (defined as any of the following conditions: organ space or deep SSIs, wound dehiscence, septic shock, sepsis, reintubation, reoperation, myocardial infarction, cardiac arrest, acute renal failure, pneumonia, deep vein thrombosis, or urinary tract infection). Data on other 30-day medical and surgical morbidities were also reviewed.

Statistical Analysis

A two-tailed Student' *t* test was used to compare the mean of continuous normally distributed variables, and χ^2 trend tests were used to compare the distribution of categorical variables. Univariate analyses were performed to identify differences in preoperative and demographic characteristics among the three groups, as well as differences in 30-day and pathologic outcomes. The twang package in R was used to implement generalized boosted regression modeling to estimate propensity scores with more than two treatment arms.[21,22] We verified that there was significant overlap between propensity scores in each of the three groups, and significant pairwise differences in the predictors of operative approach were eliminated after propensity score adjustment. A logistic regression model was then run with the outcome of interest as the dependent variable (positive CRM, positive DRM, negative CRM/DRM), and operative approach and the propensity score as the independent variables. The adjusted odds ratio for each outcome by operative approach was then reported. Additionally, an "as-treated" analysis of the three operative approaches was performed by removing all unplanned conversions from the group to which they were originally assigned and placed in the open surgery group. Statistical significance was set at an alpha = 0.05. All statistical analyses were performed with R v3.4.1 (R Development Core Team. 2017. *R: A Language and Environment for Statistical Computing*. Vienna, Austria) and STATA v12.1 (StataCorp. 2011. *Stata Statistical Software: Release 12*. College Station, TXL StateCorp LP).

Results

In 2016, a total of 578 patients who underwent resection for rectal cancer and who met inclusion criteria were identified from the ACS-NSQIP proctectomy-targeted database: 211 (36.5%) in the open group, 213 (36.9%) in the laparoscopic group, and 154 (26.6%) in the robotic group. Of the 213 laparoscopic cases, 181 (85.0%) were coded as laparoscopic and 32 (15.0%) as laparoscopic with unplanned conversion to open. Of the 154 robotic cases, 144 (93.5%) were coded as robotic and 10 (6.5%) as robotic with unplanned conversion to open. Conversion to unplanned laparotomy was more common among laparoscopic cases compared to robotic cases (15.0% vs. 6.5%, $p = 0.011$). Table 1 describes patient demographics and comorbidities. Patients in each group were similar in mean age (63.4 vs. 63.8 vs. 61.9 years, $p = 0.39$) and in proportion of male patients (60.2% vs. 59.6% vs. 68.8%, $p = 0.15$). Patients in the open surgery group were slightly less healthy than their MIS counterparts, demonstrating a higher proportion of ASA scores of 3 or 4 (67.6% vs. 54.9% vs. 62.3, $p = 0.027$). BMI was similar between groups (28.7 vs. 27.3 vs 28.0 kg/m^2, $p = 0.067$), as were all important medical comorbidities.

Table 2 presents tumor and operative characteristics. Over one-half of patients in each group had low rectal tumors (53.1% vs. 54.5% vs. 53.2%, $p = 0.26$), and there were similar proportions of LARs and APRs performed, with more patients who underwent APR compared to LAR with each operative approach (59.2% vs. 53.5% vs. 61.7%, $p = 0.26$). Based on preoperative staging, most tumors were locally advanced (clinical stage II or III), and there was a similar use of neoadjuvant chemoradiotherapy for all groups (62.1% vs. 54.0% vs. 55.2%, $p = 0.20$). There was also no difference in final pathologic T stage, including rates of (y)pT3 and (y)pT4 tumors. Both laparoscopic and robotic resections were associated with longer mean operating room time compared to open resections (268.5 vs. 296.3 vs. 295.6 min, $p = 0.023$).

Table 3 presents 30-day postoperative outcomes. There were no significant differences between the three groups in most postoperative morbidities, including SSI, anastomotic leak, postoperative ileus, NSQIP-defined major morbidity, re-operation, and 30-day mortality. However, postoperative pneumonia rates were statistically highest in the laparoscopic group (0.5% vs. 3.3% vs. 0%, $p = 0.011$). Median postoperative LOS was lowest after robotic surgery (6.0 vs. 5.0 vs. 4.0 days, $p < 0.001$), and 30-day re-admission rates were not statistically different (13.3% vs. 13.1% vs. 21.4%, $p = 0.053$).

Table 4 presents pathologic outcomes among the three groups by "intention-to-treat" analysis. On univariate analysis, there were no differences in positive CRM (4.7% vs. 3.8% vs. 5.2%, $p = 0.79$), positive DRM (1.4% vs. 0% vs. 1.3%, $p = 0.23$), the combination of negative CRM and negative DRM (93.8% vs. 96.2% vs. 93.5%, $p = 0.42$), or the mean

Table 1 Preoperative and demographic characteristics by operative approach

	Open $n = 211$	Laparoscopic $n = 213$	Robotic $n = 154$	p
Age, mean (±SD)	63.4 (12.2)	63.8 (13.3)	61.9 (13.5)	0.39
Male gender	127 (60.2)	127 (59.6)	106 (68.8)	0.15
Race				0.12
White	153 (72.5)	150 (70.4)	117 (76.0)	
Black	11 (5.2)	9 (4.2)	12 (7.8)	
Other	9 (3.3)	14 (6.6)	17 (11.0)	
ASA				*0.027**
1 or 2	68 (32.4)	96 (45.1)	57 (37.7)	
3 or 4	142 (67.6)	117 (54.9)	96 (62.3)	
BMI (kg/m^2), mean (±SD)	28.7 (6.4)	27.3 (5.8)	28.0 (6.1)	0.067
Diabetes mellitus	35 (16.6)	41 (19.2)	25 (16.2)	0.69
Smoker	31 (14.7)	42 (19.7)	28 (18.2)	0.38
Dyspnea	13 (6.2)	12 (5.6)	4 (2.6)	0.27
Functionally dependent	2 (0.9)	0	1 (0.6)	0.39
COPD	11 (5.2)	5 (2.3)	3 (1.9)	0.14
CHF	0	0	1 (0.6)	0.25
Hypertension	102 (48.3)	99 (46.5)	63 (40.9)	0.36
Preoperative dialysis	1 (0.5)	1 (0.5)	1 (0.6)	0.97
Steroid use	7 (3.3)	1 (0.5)	2 (1.3)	0.071
Bleeding disorder	4 (1.9)	7 (3.3)	4 (2.6)	0.67
> 10% weight loss	9 (4.3)	11 (5.2)	10 (6.5)	0.64

Data are expressed as n (%) or as mean (±SD) where specified

ASA American Society of Anesthesiologist, *BMI* body mass index, *COPD* chronic obstructive pulmonary disorder, *CHF* congestive heart failure

* Statistically significant

number of lymph nodes evaluated (16.9 vs. 16.6 vs. 15.6, $p = 0.29$). On multivariate regression, propensity score adjusted odds ratios for positive CRM (using open surgery as a reference) were 0.70 (95% CI 0.26–1.85, $p = 0.29$) for laparoscopy and 1.03 (95% CI 0.39–2.70, $p = 0.96$) for robotic surgery (Table 5). Among the 42 patients with unplanned conversion from either MIS technique, there was only one positive CRM (2.4%) and no positive DRM. In the subgroup "as-treated" analysis, there remained no difference between any of the three techniques after propensity score adjustment for any of the pathologic margin outcomes (Table 5). A sensitivity analysis of the "as-treated" analysis, whereby converted patients were removed from their original group but not included in the open surgery group, revealed no major differences from the data presented.

Discussion

The present study is the first to use the ACS-NSQIP proctectomy-targeted database to analyze rectal cancer pathologic outcomes by operative approach. This multicenter retrospective study compared open, laparoscopic, and robotic rectal cancer resections and found no difference in the major pathologic endpoints of the rectal cancer specimens by approach. Positive CRM was low in all three groups, ranging from 3.8 to 5.2%, and the composite outcome of negative CRM and negative DRM was achieved in 93.5 to 96.2% of patients. There was also no difference observed in mean lymph node harvest, and all three operative approaches surpassed the recommended number of 12 lymph nodes resected. Finally, despite similar 30-day postoperative complication rates, LOS was shorter in each of the MIS groups compared to open surgery. Ultimately, this data adds to the rapidly evolving literature on the use of MIS techniques for rectal cancer surgery and supports their continued application from a clinical outcomes standpoint.

The controversy surrounding laparoscopy in rectal cancer surgery is an ongoing matter of debate, and the results of several RCTs have set the current landscape. The COLOR II trial reported a positive CRM in 10% of cases with both open and laparoscopic TME—higher than in the current study—but used a cutoff of < 2 mm to declare an involved margin.[8] However, in low rectal tumors, laparoscopy resulted in a significantly reduced positive CRM rate of 9% compared to 22% with open surgery. The COREAN trial, published several years earlier, included only patients with locally advanced tumors who received neoadjuvant radiotherapy.[9] They demonstrated impressively low CRM positive rates of 3% and 4% with laparoscopy and open surgery, respectively. An

Table 2 Tumor, treatment, and operative characteristics by operative approach

	Open $n = 211$	Laparoscopic $n = 213$	Robotic $n = 154$	p
Tumor location				0.26
Upper rectum	20 (9.5)	26 (12.2)	9 (5.8)	
Middle rectum	79 (37.4)	71 (33.3)	63 (40.9)	
Lower rectum	112 (53.1)	116 (54.5)	82 (53.2)	
Procedure				0.26
LAR	99 (46.5)	59 (38.3)	86 (40.8)	
APR	125 (59.2)	114 (53.5)	95 (61.7)	
Clinical TNM stage				0.41
I	28 (13.8)	37 (17.9)	17 (11.8)	
II	82 (40.4)	70 (33.8)	58 (40.3)	
III	93 (45.8)	100 (48.3)	69 (47.9)	
Neoadjuvant chemoradiotherapy	131 (62.1)	115 (54.0)	85 (55.2)	0.20
Pathologic TNM stage				0.53
0	26 (12.9)	16 (7.8)	15 (10.1)	
I	64 (31.8)	77 (37.7)	59 (39.9)	
II	50 (24.9)	53 (26.0)	27 (18.2)	
III	60 (29.9)	57 (27.9)	46 (31.1)	
IV	1 (0.5)	1 (0.5)	1 (0.7)	
Pathologic T stage				
(y)pT0	33 (15.6)	17 (8.0)	18 (11.7)	0.050
(y)pT1	24 (11.4)	19 (8.9)	17 (11.0)	0.68
(y)pT2	57 (27.0)	71 (33.3)	58 (37.7)	0.089
(y)pT3	83 (39.3)	93 (43.7)	50 (32.5)	0.095
(y)pT4	9 (4.3)	6 (2.8)	7 (4.5)	0.63
Pathologic N stage				
(y)pN0	144 (68.2)	151 (70.9)	104 (67.5)	0.75
(y)pN1–2	61 (28.9)	58 (27.2)	47 (30.5)	0.79
Unplanned conversion to open	Not applicable	32 (15.0)	10 (6.5)	*0.011**
Operative time, min, mean (±SD)	268.5 (113.3)	296.3 (117.5)	295.6 (115.4)	*0.023*
Wound classification				0.33
Clean contaminated	172 (81.5)	178 (83.6)	137 (89.0)	
Contaminated	33 (15.6)	30 (14.1)	16 (10.4)	
Dirty	6 (2.8)	5 (2.3)	1 (0.6)	

Data are expressed as n (%) or as mean (±SD) where specified

LAR low anterior resection, *APR* abdominoperineal resection, *TNM* tumor-node-metastasis

* Statistically significant

important outlier in the COREAN trial was the mean BMI of 24 in each group, compared to 28 in the current study, which likely reflects the difference between an Asian and North American population. While higher BMI has been inconsistently associated with higher local recurrence rates and CRM positivity,[23–25] it does predict a more technically challenging operation with higher conversion rates from laparoscopy,[26,27] which may be associated with worse pathologic outcomes.[28] In the current study, unplanned conversion from laparoscopic (15%) or robotic (6.5%) surgery leads to a positive CRM in only 2.4% of cases, but it is difficult to draw any conclusions from this subgroup given the small number of patients. Of 170 patients randomized to laparoscopic surgery in the COREAN trial, only 2 were converted to open.

Results of the ACOSOG Z6051 and ALaCaRT trials somewhat dampened the optimism surrounding laparoscopic rectal cancer surgery when they were simultaneously published in 2015.[10,11] Despite demonstrating statistical equivalence on CRM positivity between laparoscopy and open surgery (12% vs. 8% in ACOSOG Z6051, 7% vs. 3% in ALaCaRT, respectively), both trials used a composite of pathologic endpoints—negative CRM, negative DRM, and complete TME excision—as their primary outcome, and could not definitively clear their respective non-inferiority margins with

Table 3 Thirty-day postoperative outcomes by operative approach

	Open $n = 211$	Laparoscopic $n = 213$	Robotic $n = 154$	p
Superficial SSI	16 (7.6)	9 (4.2)	8 (5.2)	0.31
Deep SSI	0	0	1 (0.6)	0.25
Organ space SSI	10 (4.7)	12 (5.6)	11 (7.1)	0.62
Wound dehiscence	4 (1.9)	1 (0.5)	3 (1.9)	0.36
Anastomotic leak	3 (1.4)	5 (2.3)	4 (2.6)	0.70
Postoperative ileus	43 (20.4)	31 (14.6)	23 (14.9)	0.21
Pneumonia	1 (0.5)	7 (3.3)	0	*0.011**
Urinary tract infection	3 (1.4)	5 (2.3)	5 (3.2)	0.51
Pulmonary embolism	1 (0.5)	1 (0.5)	1 (0.6)	0.97
Deep vein thrombosis	1 (0.5)	0	2 (1.3)	0.23
Acute renal failure	0	2 (0.9)	0	0.18
Stroke	1 (0.5)	2 (0.9)	0	0.46
Cardiac arrest	1 (0.5)	0 (0.0)	1 (0.6)	0.54
NSQIP major morbidity	27 (12.8)	28 (13.1)	23 (14.9)	0.93
Sepsis	6 (2.8)	5 (2.3)	2 (1.3)	0.61
Septic shock	1 (0.5)	4 (1.9)	0	0.12
Unplanned re-intubation	4 (1.9)	4 (1.9)	0	0.23
Re-operation	9 (4.3)	8 (3.8)	6 (3.9)	0.96
Mortality	1 (0.5)	1 (0.5)	0	0.69
Length of stay, days, median (Q1-Q3)	6.0 (5.0–8.0)	5.0 (4.0–7.0)	4.0 (3.0–5.0)	*< 0.001**
Hospital re-admission	28 (13.3)	28 (13.1)	33 (21.4)	0.053

Data are expressed as n (%) or median (Q1-Q3) where specified

SSI surgical site infection, *NSQIP* National Surgical Quality Improvement Program

* Statistically significant

laparoscopy. The use of composite outcomes in RCTs is not without criticism, as they may dilute or blunt individual outcome effects.[29] Furthermore, it is single pathologic outcomes that have been correlated with long-term oncologic outcomes[2–4]; until the long-term results are published from either trial, the clinical interpretation of this composite outcome remains unknown.

The cohort of patients in the present study is mostly comparable to those of the major trials. The majority had locally advanced tumors and most patients had mid-to-low tumors. In both the ACOSOG Z6051 and the COREAN trial, nearly 100% of patients received neoadjuvant therapy, compared to 60% and 50% for COLOR II and ALaCaRT, respectively. The use of chemoradiotherapy in the present series (54–62%),

Table 4 Unadjusted pathologic outcomes by operative approach

	Open $n = 211$	Laparoscopic $n = 213$	Robotic $n = 154$	p
CRM				0.79
Positive	10 (4.7)	8 (3.8)	8 (5.2)	
Negative	201 (95.3)	205 (96.2)	146 (94.8)	
DRM				0.23
Positive	3 (1.4)	0	2 (1.3)	
Negative	208 (98.6)	213 (100.0)	152 (98.7)	
Negative CRM and DRM	198 (93.8)	205 (96.2)	144 (93.5)	0.42
Number of lymph nodes evaluated, mean (±SD)	16.9 (8.8)	16.6 (7.4)	15.6 (7.6)	0.29

Data are expressed as n (%) or as mean (±SD) where specified

CRM circumferential resection margin, *DRM* distal resection margin

Table 5 Propensity score adjusted odds ratios for pathologic outcomes by operative approach: (a) "intention-to-treat" analysis and (b) "as-treated" analysis

	Propensity score adjusted OR	95% confidence intervals	*p*
A:			
CRM positive			
Laparoscopic vs. open	0.70	0.26–1.85	0.29
Robotic vs. open	1.03	0.39–2.70	0.96
Robotic vs. laparoscopic	1.47	0.53–4.10	0.46
DRM positive			
Laparoscopic vs. open	N/A*	N/A*	N/A*
Robotic vs. open	0.74	0.12–4.55	0.75
Robotic vs. laparoscopic	N/A*	N/A*	N/A*
CRM/DRM negative			
Laparoscopic vs. open	1.93	0.76–4.87	0.17
Robotic vs. open	1.05	0.44–2.48	0.92
Robotic vs. laparoscopic	0.54	0.20–1.44	0.22
B:			
CRM positive			
Laparoscopic vs. open	0.79	0.29–2.16	0.65
Robotic vs. open	1.23	0.47–3.17	0.68
Robotic vs. laparoscopic	1.54	0.53–4.48	0.42
DRM positive			
Laparoscopic vs. open	N/A*	N/A*	N/A*
Robotic vs. open	0.95	0.15–5.84	0.96
Robotic vs. laparoscopic	N/A*	N/A*	N/A*
CRM/DRM negative			
Laparoscopic vs. open	1.65	0.63–4.31	0.31
Robotic vs. open	1.00	0.42–2.37	0.99
Robotic vs. laparoscopic	0.52	0.19–1.44	0.21

OR odds ratio, *CRM* circumferential resection margin, *DRM* distal resection margin

*N/A = not applicable—since there was no positive DRM in the laparoscopic group, an effect size could not be estimated

despite a high proportion of low advanced tumors, could be reflective of the modern trend towards more selective radiotherapy use since the results of MERCURY were published.[30] To our surprise, APR was more commonly performed than LAR in the present cohort. This observation may be explained by the fact that this cohort of patients had a very high proportion of low rectal tumors. Unlike the major trials, contribution to the ACS-NSQIP database is not from selected experts in rectal cancer surgery, thus fewer ultra-low sphincter-sparing procedures would be expected. In addition, this could simply be an over-representation of APRs within the proctectomy-targeted database. When we queried patients with a rectal cancer diagnosis within the general ACS-NSQIP database, the breakdown of LAR to APR was 71 to 29%. As such, the inflated APR rate only arises when matching patients from the proctectomy-targeted database to the general database. This should serve as a reminder that contribution to the proctectomy-targeted ACS-NSQIP database may not be a random sample of those hospitals contributing to the general database. Notwithstanding this anomaly, surgical procedure was accounted for in the propensity score and was equally distributed among the three groups.

With the oncologic equality of laparoscopy for rectal cancer seemingly in question, robotic surgery has addressed many of the technical challenges of laparoscopy. Proponents of robotic surgery cite the high-definition images, increased degrees of freedom, and surgeon motion filter for tremor-free surgery, all of which contribute to improved ergonomics and precision surgery in a confined space.[31] The ROLARR trial, comparing robotic to laparoscopic surgery for rectal cancer, demonstrated no advantage in favor of robotic surgery.[15] The positive CRM rate was 5.1% for robotic surgery, which compares well with the present study. A recent review of the National Cancer Database reported a positive CRM in 4.8% of robotic resections, and similarly could not demonstrate a protective effect for robotic surgery on multivariate analysis compared to open surgery.[32] These findings were echoed in a recent systematic review and meta-analysis of RCTs comparing robotic and laparoscopic surgery, where only conversion rate (less) and operative time (more) differed with robotic surgery.[33] From a value-

based perspective, this may be insufficient gain to justify the costs of robotic surgery, which likely need to be reduced before widely endorsing this technique for rectal cancer.[16]

The major impetus for the use of any MIS technique is often the short-term benefits: similar or fewer postoperative complications, shorter LOS, and an overall better recovery. All four RCTs comparing laparoscopic to open rectal cancer resection reported similar morbidity rates in the two groups. COLOR II, the COREAN trial, and ALaCaRT all reported earlier return of bowel function with laparoscopy; only COLOR II and the COREAN trial demonstrated a reduction in LOS by 1 day. ROLARR similarly demonstrated no decrease in morbidity with the robot compared to laparoscopy, and similar LOS. The present study demonstrated similar trends, with no differences observed in most postoperative complications, including a very low anastomotic leak rate reported with each approach. LOS was 1 day less with laparoscopy and 2 days less with robotic surgery (compared to open), consistent with observational data from high-volume centers,[13,16,34,35] but all of which is subject to selection bias. It is also important to consider that many factors outside of operative approach influence both postoperative morbidity and LOS, including the use of Enhanced Recovery Protocols and other institutional practices.[36, 37]

The major strength of this study is the fact that it is born out of a collaborative, multi-institutional effort to report on rectal cancer outcomes. This is the first year that ACS-NSQIP began reporting proctectomy-specific variables, which allows for a more modern North American audit of surgical and pathologic quality outside of a trial. As our collective national experience increases with each MIS technique, we may continue to observe more parity in 'real-life' surgical outcomes between the three operative approaches. ACS-NSQIP is also a validated and respected database that is often relied on to answer questions regarding surgical quality, which makes these results noteworthy. Notwithstanding the fact that RCTs remain the gold standard for comparing any two treatments, observational studies like the present one offer a different perspective using real-life experience. By using a national validated collaborative database, we were also able to evaluate three operative approaches in one analysis, which is much more cumbersome to perform in an RCT. Furthermore, unlike the recent National Cancer Database analysis, ACS-NSQIP included important variables such as BMI and tumor height.[32] We also used the propensity score method to adjust for the many confounders, in order to best isolate the impact of operative approach.

However, there are also limitations of this study, many of which are related to working with such a database. Although it is maintained by well-trained personnel and undergoes internal audit and quality assurance, data is recorded retrospectively and is subject to potential miscoding or omission of variables, which could be a source of information bias. ACS-NSQIP involvement by hospital is also completely voluntary, and thus, any analysis emanating from its use may not be generalizable. Furthermore, despite using a propensity score method, residual confounding may be present from variables not captured in the database. Institutional volume and individual surgeon skill with rectal cancer surgery may impact outcomes and are lacking from this analysis.[38–40] TME excision quality is an important pathologic outcome not recorded in this database and has been shown to impact long-term oncologic outcomes.[3] Lastly, given that this is the first year that proctectomy-targeted data was gathered, the cohort was limited to resections performed in 2016. It will be interesting to follow the results stemming from this database as it grows with each coming year.

Conclusion

Based on our findings, the use of MIS techniques for rectal cancer surgery does not appear to confer worse pathologic outcomes compared to open surgery. The major benefit attained with either laparoscopy or robotic surgery was a reduction in length of stay compared to open surgery. Aside from short-term clinical outcomes, other considerations should impact the decision to proceed with either MIS approach, such as individual experience with the technique and institutional costs. The results of this study should be interpreted alongside other large series reporting on rectal cancer outcomes and contributes to the important and growing body of evidence.

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Authors' Contribution RG, MAK, SB, NWC, LA, NM, CAV and MB have all met the following criteria for authorship:

-Substantial contributions to the conception or design of the work; or the acquisition, analysis or interpretation of data for the work, and

-Drafting the work or revising it critically for important intellectual content; and

-Final approval of the version to be published, and

-Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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