Comparative Analysis of Surgical Approaches for Rectal Cancer: A Retrospective Cohort Study on Short-Term and Pathologic Outcomes in Open, Laparoscopic and Robot-assisted Procedures

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ABSTRACT

Background: In rectal cancer surgery, the evolution of treatment paradigms has spurred advancement in surgical techniques, however, the advantage of minimally invasive techniques over open surgery remains an ongoing controversy. This is a retrospective cohort study that evaluated the short-term and pathologic outcomes of rectal cancer resections performed by open, laparoscopic and robot-assisted approaches at St. Luke's Medical Center - Quezon City and St. Luke's Medical Center - Global City, Philippines.
Methods: Patients with rectal adenocarcinoma (cT1-3NxM0) who underwent surgical resection between July 2018 and June 2023 were selected. Primary outcomes were severe post-operative morbidity, classified as Clavien Dindo Classification (CDC) grades III and IV, and positive circumferential resection margins (CRM). Secondary outcomes included conversion to open, operative time, 30-day unplanned re-operation rates, 30-day post-operative mortality, length of hospital stay and pathologic outcomes of positive distal resection margins and adequate lymph node yield.
Results: This study included 158 patients: 69 (44%) underwent open surgery, 63 (40%) laparoscopic surgery and 26 (16%) robot-assisted surgery. Severe post-operative morbidity rates were 8.7%, for open, 11.11% for laparoscopic and 7.69% for robot-assisted surgeries, with no statistically significant differences (p=0.106). Positive CRM rates were comparable across all groups: 14.49% in open, 7.94% in laparoscopic and 7.69% in robot-assisted surgeries (p=0.456). Secondary short-term and pathologic outcomes were largely consistent across groups though, laparoscopic and robot-assisted surgeries resulted in a one-day reduction in hospital stay compared to the open approach.
Conclusion: All three surgical modalities have shown comparable short-term and pathologic outcomes, including post-operative morbidity and positive CRM rates. However, both the laparoscopic and robot-assisted approaches are associated with a reduction in hospital stay by one day.

Key words: rectal cancer, open, laparoscopic, robotic, total mesorectal excision

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The surgical management of rectal cancer has witnessed significant advancements over the past few decades aimed at improving patient outcomes, minimizing morbidity, enhancing postoperative recovery and improving pathologic outcomes. The traditional open surgery, characterized by a large abdominal incision, is linked to greater trauma, increased blood loss, worse postoperative pain and extended hospital stay.[1] This led to the adoption of laparoscopic surgery as a viable alternative resulting in reduced blood loss, less postoperative pain, shorter hospital stays and faster recovery.[2] Although laparoscopic surgery is superior in many ways to open surgery, the fulcrum of long and straight instruments has its limitations, especially during complex procedures like Total Mesorectal Excision (TME) dissection. Such limitations include restricted instrument movement, lack of tactile feedback, potential for postoperative complications and worse oncologic outcomes.[3,4] Robotic surgery has emerged as a newer technique that overcomes the challenges posed by laparoscopic surgery. It gives the additional advantages of enhanced dexterity and greater degrees of movement by its endowristed instruments, improved depth of visualization by its three dimensional high-definition images, a stable camera platform, and fixed traction by a third arm, all of which contribute to improved surgeon ergonomics while sitting. For institutions with access to a robotic surgery platform, this makes it a viable option for rectal cancer procedures, particularly when performing complete TME dissection in anatomically challenging pelvis, such as in males or patients who have received neoadjuvant radiation.[3,5]

There remains a controversy over the optimal surgical approach for rectal cancer - open, laparoscopic or robot-assisted. Several studies have compared these techniques in terms of oncological outcomes, postoperative recovery and complications.[2,4,6] Randomized controlled trials (RCTs) comparing open and laparoscopic surgeries have contradicting results, thus there is still no recommendation as to the preferred technique. The COREAN and COLOR II trials demonstrated the feasibility of laparoscopic surgery in treating rectal cancer leading to shorter postoperative stay, no difference in postoperative complication rates, with no observed adverse pathological outcomes including positive CRM, lymph node harvest and distal resection margins.[7,8] In contrast, the two most current RCTs, namely ALaCaRT and ACOSOG Z6051 trials, did not establish the non-inferiority of laparoscopic surgery compared to open surgery.[9,10]

Retrospective studies and RCTs have compared robot-assisted surgery to laparoscopic surgery and have shown that robotic surgery is a safe and feasible approach to rectal cancer with comparable short-term outcomes without compromising pathologic outcomes.[3,11,12] The ROLARR Trial compared robotic-assisted surgery with laparoscopic resection and found no significant difference in conversion rates to open surgery, post-operative complications, length of hospital stay and CRM rates.[12] While some meta-analysis studies have suggested that robotic-assisted surgery may offer advantages in terms of reduced blood loss and shorter hospital stays, other studies showed no significant difference in terms of oncological outcomes when compared to laparoscopic surgery.[5,11]

A study by Garfinkle et al. (2018) utilizing the ACS-NSQIP database compared open, laparoscopic and robot surgeries for rectal cancer. The findings indicated that the overall postoperative morbidity, positive CRM rates, negative distal resection margins and lymph node yield were similar across the three surgical approaches. However, the laparoscopic approach resulted in a reduced postoperative stay by one day, while the robotic approach resulted in a reduction of two days.[13] A retrospective study by Somashekhar et al. in 2020, evaluated the three surgical approaches which showed that robotic surgery led to shorter hospital stay, improved CRM, lymph node yield, distal resection margin and a lower rate of conversion to open surgery.[1] Despite these advantages, the high cost associated with robotic surgery necessitates further studies to definitively establish its role in rectal cancer surgery.

The significance of this research lies in its potential to bridge the existing knowledge gaps on the different surgical approach for rectal cancer. By being the first study in the country to juxtapose open, laparoscopic and robot-assisted surgeries, it aims to offer a local perspective on rectal cancer surgery treatment and its implications on short-term and pathologic outcomes.

Objectives of the Study

The general objective of the study was to compare the short-term and pathological outcomes of patients who underwent rectal cancer resection surgeries by open, laparoscopic and robot-assisted approach.

The specific objectives of the study were as follows:

1. To assess the primary short-term surgical outcomes among patients who underwent open, laparoscopic and robot-assisted rectal cancer resection surgeries based on their postoperative complications and primary pathologic outcomes based on circumferential resection margin positivity.
2. To compare secondary short-term outcomes among patients, focusing on the conversion to open surgery, length of operative time, 30-day unscheduled reoperations, 30-day postoperative mortality and length of hospital stay.
3. To analyze the secondary pathologic outcomes by their positive distal resection margin and lymph node yield.
4. To compare the outcomes of robot against open surgery, and robot against laparoscopic surgery.

METHODS

This is a retrospective cohort study comparing the short-term surgical and pathologic outcomes among rectal cancer patients who have undergone resection surgery by open, laparoscopic and robot-assisted modalities. Between July 2018 and June 2023, a total of 158 rectal adenocarcinoma patients above 18 years of age who underwent surgical resection conducted by a general or colorectal surgeon were retrospectively identified from the database of St. Luke's Medical Center - Quezon City and - Global City, Metro Manila, Philippines. This study included all patients with a clinical diagnosis of rectal adenocarcinoma stage cT1-3NxM0 identified on preoperative pelvic MRI with chest and abdominal CT scan or whole-body PET scan. Excluded from the study were patients with T4 rectal adenocarcinoma with involved CRM on preoperative imaging (CT scan or MRI), presence of distant metastasis (M1) at the time of diagnosis, patients admitted for emergency rectal surgery or presented with acute obstruction or bowel perforation, benign rectal lesions, rectal tumor other than adenocarcinoma, anal canal carcinoma, synchronous colorectal tumors requiring multi-segment resection, known hereditary colorectal carcinoma, recurrent rectal malignancy with prior surgical resection for colon or rectal cancer and patients with incomplete or missing medical records.

The patients' data and medical records were individually collected from patients' files via online healthcare system. This included patients characteristics (age, sex, Body Mass Index (BMI), American Society of Anesthesiologists (ASA) Classification, comorbidities, previous surgery to the abdomen), neoadjuvant radiation/chemoradiation, clinical Tumor, Node Metastasis (TNM) stage, tumor location from the anal verge (FAV), post-operative morbidity according to Clavien Dindo Classification (CDC), length of stay in days, 30-day unscheduled reoperation and 30-day post-operative mortality. Tumor location was categorized based on its distance from anal verge from proctoscopy or colonoscopy– Low for tumors 5 cm and below from the anal verge, Middle for tumors 5.1 to 10 cm from the anal verge, and High for tumors 10.1 to 15 cm from the anal verge.[14]

From the operative records, the following data were collected – planned surgical procedure, additional surgical procedure done, creation of stoma, conversion to open surgery, and length of operative time in minutes. Conversion to open refers to the need for any abdominal incision larger than originally planned, apart from those required for specimen extraction. The surgeries were conducted by general and colorectal surgeons, and the level of surgical expertise in minimally invasive surgeries was not classified during the study.

From the histopathology records, the following data were collected – circumferential resection margin positivity, distal resection margin in centimeters, number of lymph nodes harvested, pathologic TNM stage, tumor size and AJCC Tumor Regression Grade[15] for patients with neoadjuvant radiation/chemoradiation. A positive CRM is when the minimum distance between the radial resection margin and tumor tissue is within 1mm of the CRM.[16] A positive distal resection margin is when the minimum distance between the distal resection from the tumor is within 1mm. Tumors were classified according to TNM staging for rectal cancer using the latest TNM Classification from the 8th edition of the American Joint Committee on Cancer (AJCC) Staging Manual.[15]

Outcomes

The primary outcomes of interest were severe post-operative complications classified as CDC III and IV and positive CRM. Secondary outcomes included conversion to open, length of time of operation in minutes, 30-day unscheduled reoperation, 30-day post-operative mortality, length of stay in days, positive distal resection margin and adequate lymph node yield.

Sample Size Estimation

Ali et al. (2020) provided the estimation of complication rates. They reported the percentage of severe postoperative complications for laparoscopic surgery as 73%, while for robot-assisted surgery, it is reported as 43%.[17] Utilizing a two-sample proportion test formula for a statistically significant comparison with an alpha error of 5% and power of 80%, the sample size was calculated using an enrollment ratio of 2:2:1 for open, laparoscopic and robot-assisted surgery groups. The required sample size for the open surgery group was 52, while that for the laparoscopic surgery group and robot-assisted surgery group were 52 and 26, respectively. This resulted in a total sample size of 130 patients with adequate statistical power to detect differences in severe postoperative complications among the three surgical approaches while minimizing the risk of type I and type II errors.

Statistical Analysis

Descriptive statistics was used to summarize the demographic and clinical characteristics of the patients. Frequencies and proportions were used for categorical variables, median and inter quartile range for non-normally distributed continuous variables and mean and SD for normally distributed continuous variables. Independent Sample T-test, Mann-Whitney U test and Fisher's Exact/Chi-square test were used to determine the difference of mean, rank and frequency, respectively, between Robot-assisted patients versus Open and Laparoscopic. One-way ANOVA, Kruskal-Wallis test and Chi-square/Fisher's exact test were used to determine the difference of mean, median and frequency, respectively, among different planned surgery. All statistical tests were two-tailed test. The Shapiro-Wilk test was used to test the normality of the continuous variables. Missing values were neither replaced nor estimated. Null hypotheses were rejected at 0.05α-level of significance. STATA 13.1 was used for data analysis.

RESULTS

Patient Demographics

Between 2018 and 2023, a total of 158 patients with rectal adenocarcinoma underwent surgical resection and were included in this study, of whom 69 (44%) underwent open surgery, 63 (40%) underwent laparoscopic surgery and 26 (16%) underwent robot-assisted surgery.

The patient characteristics are detailed in Table 1. The average age of the patients was 62 ± 12 years, and there was no significant difference in age distribution across the three surgical groups (p=0.735). Of the entire cohort, 59% were male. Notably, a significantly higher percentage of males (81%) underwent robot-assisted surgery in comparison to laparoscopic surgeries (p=0.017).

There were no significant differences in the general characteristics of patients when considering factors such as BMI, ASA classification, history of previous abdominal surgery and other co-morbidities across the three surgical methods. However, there was a lower prevalence of diabetes mellitus in patients who underwent robot-assisted surgery (7.69%, p=0.011).

In terms of tumor location, the majority of tumors were located in the mid rectum across all groups (43% for open, 36.5% for laparoscopic and 53.85% for robot-assisted, p=0.041). Over half of the patients in each group presented with locally-advanced tumors during the preoperative clinical staging and were categorized as clinical Stage II and III (p=0.0534). Neoadjuvant therapy was common to patients in the

Table 1. Patient demographics of rectal cancer patients who had open, laparoscopic and robot-assisted surgical resection.

	Planned Surgery				**p-value[1]**	**p-value[2]**	**p-value[3]**
	Total (n=158)	**Open (n=69, 44%)**	**Laparoscopic (n=63, 40%)**	**Robot-assisted (n=26, 16%)**			
	Frequency (%); Mean ± SD						
Age, years	61.61 ± 12.31	62.14 ± 12.81	61.71 ± 12.02	59.92 ± 11.99	0.735	0.445	0.524
Sex					0.041	0.054	0.017
Male	94 (59.49)	40 (57.97)	33 (52.38)	21 (80.77)			
Female	64 (40.51)	29 (42.03)	30 (47.62)	5 (19.23)			
BMI					0.657	0.676	0.603
Underweight	7 (4.43)	6 (7.25)	2 (3.17)	0			
Normal	85 (53.8)	38 (55.07)	31 (49.21)	16 (61.54)			
Overweight	54 (34.18)	22 (31.88)	23 (36.51)	9 (34.62)			
Obese I/II	12 (7.59)	4 (5.8)	7 (11.11)	1 (3.85)			
ASA classification					0.657	0.928	0.316
Class I	7 (4.43)	5 (7.25)	2 (3.17)	0			
Class II	85 (53.8)	38 (55.07)	31 (49.21)	16 (61.54)			
Class III	54 (34.18)	22 (31.88)	23 (36.51)	9 (34.62)			
Class IV	12 (7.59)	4 (5.8)	7 (11.11)	1 (3.85)			
Comorbidities							
Hypertension	88 (55.7)	39 (56.52)	33 (52.38)	16 (61.54)	0.717	0.816	0.488
Diabetes mellitus	49 (31.01)	26 (37.68)	21 (33.33)	2 (7.69)	0.011	0.005	0.015
Cardiac	22 (13.92)	10 (14.49)	6 (9.52)	6 (23.08)	0.229	0.362	0.101
Pulmonary	15 (9.49)	5 (7.25)	6 (9.52)	4 (15.38)	0.446	0.251	0.470
Previous Abdominal Surgery					0.881	0.817	1.000
Yes	56 (35.44)	26 (37.68)	21 (33.33)	9 (34.62)			
No	102 (64.56)	43 (62.32)	42 (66.67)	17 (65.38)			
Location of Tumor FAV					0.407	0.507	0.151
Upper Rectal							
Mid Rectal	44 (27.85)	18 (26.09)	22 (34.92)	4 (15.38)			
Lower Rectal	67 (42.41)	30 (43.48)	23 (36.51)	14 (53.85)			
	47 (29.75)	21 (30.43)	18 (28.57)	8 (30.77)			
Clinical TNM Stage					0.534	0.501	0.514
Stage 0	2 (1.27)	0	2 (3.17)	0			
Stage I	30 (18.99)	11 (15.94)	14 (22.22)	5 (19.23)			
Stage II	52 (32.91)	25 (36.23)	21 (33.33)	6 (23.08)			
Stage III	74 (46.84)	33 (47.83)	26 (41.27)	15 (57.69)			
Neoadjuvant RT/ ChemoRT					0.138	0.113	0.060
Yes	64 (40.51)	27 (39.13)	22 (34.92)	15 (57.69)			
No	94 (59.49)	42 (60.87)	41 (65.08)	11 (42.31)			

Note: p-value[1] = Open vs Laparoscopic vs Robot-assisted; p-value[2] = Open vs Robot-assisted; p-value[3] = Laparoscopic vs Robot-assisted robot-assisted group (57.69%), compared to the open (39.13%) and laparoscopic groups (34.92%), this difference was not statistically significant (p=0.138).

Operative Parameters

Table 2 details the operative parameters for each group. All surgical methods predominantly utilized the low anterior resection technique, followed by anterior resection. The least common procedure was abdominoperineal resection (p=0.180).

Within the laparoscopic group, there was a conversion rate of 9.52% to open surgery. In contrast, no conversions were observed in the robot-assisted group. Despite this, there was no statistically significant difference between the two groups in terms of conversion rate (p=0.175).

The median operative duration was longest for the robot-assisted group at 341 minutes, followed by the laparoscopic group at 324 minutes, and the open surgery group at 307 minutes. This variance in operative times was not statistically significant (p=0.051) across all groups, but on comparative analysis between robot-assisted and open surgery, robotic surgery had a longer operative time (p=0.038).

Additional procedures and stoma creation were carried out with comparable frequencies across all three surgical modalities, with p-values of 0.816 and 0.096, respectively. However, when comparing robotic and laparoscopic surgery, more patients in robotic surgery had temporary stoma creation than in laparoscopic surgery (p=0.036)

Short-term Outcomes

Table 3 details the short-term outcomes across the treatment groups. Severe post-operative events, classified as CDC III and IV, were observed to be similar among all groups (8.7% for open surgery, 11.11% for laparoscopic and 7.69% for robot-assisted, p = 0.11).

The 30-day post-operative complications: ileus, anastomotic leak, sepsis, 30-day unscheduled reoperations and 30-day postoperative mortality rates, were consistent across all three surgical modalities. In the open surgery group, three patients had anastomotic leaks necessitating re-operations. Other common complications in this group included sepsis and pneumonia. In the laparoscopy group, ileus and anastomotic leak were encountered, while reoperations were performed for anastomotic leak and stoma necrosis. Meanwhile, in the robot-assisted group, morbidities arose from stroke and one patient needed re-operation for positive surgical margin. Only one mortality was recorded, which occurred in the open surgery group. An elderly male underwent a low anterior resection with a temporary ileostomy.

Table 2. Operative parameters of rectal cancer patients who had open, laparoscopic and robot-assisted surgical resection.

	Planned Surgery				p-value¹	p-value²	p-value³
	Total (n=158)	**Open (n=69, 44%)**	**Laparoscopic (n=63, 40%)**	**Robot-assisted (n=26, 16%)**			
	Frequency (%); Median (IQR)						
Procedure Type					0.180	0.361	0.106
Anterior Resection	44 (27.85)	17 (24.64)	23 (36.51)	4 (15.38)			
Low Anterior Resection	89 (56.33)	38 (55.07)	32 (50.79)	19 (73.08)			
Abdomino-perineal Resection	25 (15.82)	14 (20.29)	8 (12.7)	3 (11.54)			
Conversion to open					0.175	-	0.175
Yes	6 (6.74)	-	6 (9.52)	0			
No	83 (93.26)	-	57 (90.48)	26 (100)			
Additional Procedure					0.816	0.595	0.580
Yes	35 (22.15)	15 (21.74)	13 (20.63)	7 (26.92)			
No	123 (77.85)	54 (78.26)	50 (79.37)	19 (73.08)			
Stoma					0.096	0.140	**0.036**
None	51 (32.28)	21 (30.43)	26 (41.27)	4 (15.38)			
Temporary Stoma	81 (51.27)	34 (49.28)	28 (44.44)	19 (73.08)			
Permanent Stoma	26 (16.46)	14 (20.29)	9 (14.29)	3 (11.54)			
Length of operative time, minutes	321 (240 to 420)	307 (223 to 385)	324 (249 to 461)	341 (300 to 400)	0.051	**0.038**	0.591

Note: p-value¹ = Open vs Laparoscopic vs Robot-assisted; p-value² = Open vs Robot-assisted; p-value³ = Laparoscopic vs Robot-assisted

Table 3: Postoperative short-term outcomes of rectal cancer patients who had open, laparoscopic and robot-assisted surgical resection.

	Planned Surgery				p-value[1]	p-value[2]	p-value[3]
	Total (n=158)	Open (n=69, 44%)	Laparoscopic (n=63, 40%)	Robot-assisted (n=26, 16%)			
	Frequency (%); Median (IQR)						
Postop Morbidity/ Clavien Dindo Classification					0.106	0.400	0.272
None	62 (39.24)	22 (31.88)	30 (47.62)	10 (38.46)			
Class I	30 (18.99)	14 (20.29)	8 (12.7)	8 (30.77)			
Class II	51 (32.28)	27 (39.13)	18 (28.57)	6 (23.08)			
Class III	12 (7.59)	3 (4.35)	7 (11.11)	2 (7.69)			
Class IV	3 (1.9)	3 (4.35)	0	0			
30-day Postop Complications							
Ileus	42 (26.58)	21 (30.43)	17 (26.98)	4 (15.38)	0.333	0.193	0.285
Pulmonary	15 (9.49)	7 (10.14)	6 (9.52)	2 (7.69)	0.936	1.000	1.000
Surgical site infection	13 (8.23)	9 (13.04)	3 (4.76)	1 (3.85)	0.151	0.276	1.000
Anastomosis leak							
Sepsis	9 (5.7)	4 (5.8)	5 (7.94)	0	0.340	0.572	0.316
Renal Failure	9 (5.7)	5 (7.25)	4 (6.35)	0	0.381	0.318	0.317
Acute voiding	8 (5.06)	3 (4.350	4 (6.35)	1 (3.85)	0.831	1.000	1.000
difficulties	6 (3.8)	1 (1.45)	3 (4.76)	2 (7.69)	0.320	0.181	0.627
Others							
	7 (4.43)	4 (5.8)	2 (3.17)	1 (3.85)	0.756	1.000	1.000
Unscheduled Reoperation					0.378	1.000	0.429
Yes	12 (7.59)	4 (5.8)	7 (11.11)	1 (3.85)			
No	146 (92.41)	65 (94.2)	56 (88.89)	25 (96.15)			
Postop Mortality					0.523	1.000	-
Yes	1 (0.63)	1 (1.45)	0	0			
No	157 (99.37)	68 (98.55)	63 (100)	26 (100)			
Length of stay, number of days	7 (5 to 8)	7 (6 to 9)	6 (5 to 8)	6 (5 to 7)	**0.047**	**0.017**	0.790

Note: p-value[1] = Open vs Laparoscopic vs Robot-assisted; p-value[2] = Open vs Robot-assisted; p-value[3] = Laparoscopic vs Robot-assisted

The patient developed severe sepsis secondary to an anastomotic leak and was admitted at the ICU. A Hartmann's procedure was performed five days postoperatively, unfortunately the patient died on the 13th day after the initial surgery.

In terms of length of hospital stay, patients who received minimally invasive procedures (laparoscopic or robot-assisted) had a median hospital stay that was one day shorter than those who underwent open surgery (6 days for both minimally invasive methods vs. 7 days for open surgery, p = 0.047).

Pathologic Outcomes

Table 4 presents the pathologic outcomes for each of the three surgical groups. The incidence of positive CRM was consistent across all surgical modalities, with rates of 14.49% for open surgery, 7.94% for laparoscopic, and 7.69% for robot-assisted (p = 0.46). There were no significant differences between the three groups with regards distal resection margin (p=0.954), mean tumor size (p=0.322), pathologic tumor stage (p=0.76), pathologic lymph node stage (p=0.911), number of lymph nodes retrieved (p=0.953), adequacy of lymph node yield (p=0.92) and tumor regression grade (p=0.245).

In terms of pathologic TNM staging, more than half of the patients across all groups were classified as having pathologic Stage II or III or were identified as locally advanced upon final histopathological evaluation (p=0.715).

DISCUSSION

This study represents the first local comparison of open, laparoscopic and robot-assisted methods, for the treatment of rectal cancer.

The primary short-term outcome in this study is severe post-operative morbidity classified as Clavien Dindo Class III and IV, which ranged from 7.7 to 11.1% across all groups with no statistically significant difference between the three groups (p=0.333). Regarding 30-day post-operative mortality, our study showed no difference across all groups (p=0.523). The findings of this study were consistent with published trials comparing open and laparoscopic surgeries, or laparoscopic and robot surgeries. RCTs comparing open and laparoscopic surgery, such as the COREAN

Table 4: Pathologic outcomes of rectal cancer patients who had open, laparoscopic and robot-assisted surgical resection.

	Planned Surgery				p-value[1]	p-value[2]	p-value[3]
	Total (n=158)	**Open (n=69, 44%)**	**Laparoscopic (n=63, 40%)**	**Robot-assisted (n=26, 16%)**			
	Frequency (%); Mean ± SD						
Circumferential Resection Margin					0.456	0.502	1.000
Positive	17 (10.76)	10 (14.49)	5 (7.94)	2 (7.69)			
Negative	141 (89.24)	59 (85.51)	58 (92.06)	24 (92.31)			
Distal Margin, cm	3.02 ± 1.79	2.79 ± 1.56	3.20 ± 1.78	3.2 ± 2.33	0.377	0.330	0.992
Distal Margin					0.954	0.821	1.000
Positive	5 (3.27)	1 (1.45)	2 (3.17)	2 (8.33)			
Negative	153 (96.84)	68 (98.55)	61 (96.83)	24 (92.31)			
Tumor stage					0.757	0.881	0.862
T0	13 98.23)	4 (5.8)	7 (11.11)	2 (7.69)			
T1	7 (4.43)	3 (4.35)	2 (3.17)	2 (7.69)			
T2	49 (31.01)	18 (26.09)	23 (36.51)	8 (30.77)			
T3	82 (51.9)	41 (59.42)	28 (44.44)	13 (50)			
T4	7 (4.43)	3 (4.35)	3 (4.76)	1 (3.85)			
Tumor Size	3.77 ± 1.98	4 ± 2.05	3.69 ± 1.86	3.31 ± 2.07	0.322	0.161	0.421
Lymph node stage					0.911	0.821	0.750
N0	83 (52.53)	38 (55.07)	32 (50.79)	13 (50)			
N1	39 (24.68)	16 (23.19)	15 (23.81)	8 (30.77)			
N2	36 (22.78)	15 (21.74)	16 (25.4)	5 (19.23)			
Pathologic TNM Stage					0.715	0.980	0.765
None							
Stage I	11 (6.96)	3 (4.35)	7 (11.11)	1 (3.85)			
Stage II	36 (22.78)	18 (26.09)	12 (19.05)	6 (23.08)			
Stage III	36 (22.78)	17 (24.64)	13 (20.63)	6 (23.08)			
	75 (47.47)	31 (44.93)	31 (49.21)	13 (50)			
Number of Lymph Nodes Harvested	15 (1 to 40)	15 (9 to 40)	15 (1 to 37)	15 (8 to 28)	0.953	0.953	0.982
Lymph node harvested					0.920	1.000	0.717
Less than 12							
12 or more	17 (10.76)	8 (11.59)	6 (9.52)	3 (11.54)			
	141 (89.24)	61 (88.41)	57 (90.48)	23 (88.46)			
AJCC tumor regression grade					0.245	0.213	0.350
Stage 0	13 (20.31)	3 (11.11)	8 (36.36)	2 (13.33)			
Stage 1	11 (17.19)	5 (18.52)	3 (13.64)	3 (20)			
Stage 2	20 (31.25)	7 (25.93)	6 (27.27)	7 (46.67)			
Stage 3	20 (31.25)	12 (44.44)	5 (22.73)	3 (20)			

Note: p-value[1] = Open vs Laparoscopic vs Robot-assisted; p-value[2] = Open vs Robot-assisted; p-value[3] = Laparoscopic vs Robot-assisted

and COLOR II trials, have shown comparable perioperative complication and postoperative mortality rates between the two approaches.[7,8] The most recent RCTs comparing laparoscopic and open surgery, specifically the ALaCaRT and ACOSOG Z6051 trials, have revealed no significant difference in severe post-operative complications, and 30-day postoperative mortality. The feasibility of robotic surgery as compared to laparoscopic surgery was first studied in a RCT by Kim et al. (2017). The study found that robotic surgery is feasible, safe and has comparable short-term outcomes including morbidity.[3] The ROLARR trial showed that robot-assisted surgery is comparable to laparoscopic surgery, with similar rates of post-operative complications, and 30-day mortality.[12] The most recent RCT, the COLRAR Trial (2023), though it ended prematurely due to inadequate data accrual, showed similar post-operative complication rates between robot-assisted and laparoscopic surgery (12% vs. 8.3%).[20] Results of these RCTs support the use of robot surgery as equally safe and feasible as laparoscopic surgery in terms of short-term outcomes. The same findings are further reinforced by a retrospective study using the ACS-NSQIP database, which compared the three techniques- open, laparoscopic and robot-assisted surgeries- and presented similar post-operative morbidity rates across all groups.[21]

Pathologic outcomes are a critical component of rectal cancer surgery with significant implications in prognosis. A CRM of <1mm was introduced as an important prognostic factor for local recurrence, distant metastasis, and increased risk of cancer-specific mortality in rectal cancer.[14,16,22] In our study, the incidence of positive CRM was observed to be at 14.49% in the open group, 7.94% in the laparoscopy group, and 7.69% in the robot-assisted group. The rate of CRM positivity is slightly higher, specifically in the open group compared to existing literature mentioned, which ranges from 0% to 12%. A study by Rickles et al. (2015), which included 16,619 rectal cancer patients from the National Cancer Database in the United States, reported a positive CRM rate of 17.2%. They identified significant predictors of positive CRM on multivariable analysis namely, advanced clinical T and N stage, tumors >2cm, mucinous adenocarcinomas and signet ring cell carcinomas, high tumor grade, presence of lymphovascular and perineural invasion, and operative approach. Notably, their findings indicated that the laparoscopic approach posed a 22% lower risk of positive CRM compared to the open approach.[20] Additional potential confounding factors that could contribute to the increased occurrence of positive CRM, besides variations in surgical approach, warrant investigation. In our study, there was no statistically significant difference in CRM positivity across all treatment groups (p=0.456), aligning consistently with the outcomes reported in majority of the trials. RCTs such as the COREAN and COLOR II trials, have shown no significant difference in pathologic outcomes, including CRM positivity rate, lymph node harvest, and distal resection margin. When comparing CRM positivity, the COREAN trial revealed a rate of 4% in the open group and 3% in the laparoscopic group, while the COLOR II trial reported 10% for both groups.[7,8] Notably, the high CRM positive rate in the COLOR II trial was recorded due to a cut-off of <2mm[8]. Non-inferiority RCTs, such as the ALaCaRT and ACOSOG Z6051 trials, failed to support the non-inferiority of laparoscopic to open surgery, albeit results showed statistical equivalence in pathologic outcomes. CRM positivity was observed to be 3% in open surgery and 7% in laparoscopic surgery in the ALaCaRT trial, and 7.7% in open surgery and 12.1% in laparoscopic surgery in the ACOSOG Z6051 trial[9,10]. For robot-assisted surgery, RCTs by Kim et al. (2017) and the ROLARR trial reported comparable CRM positivity between robotic and laparoscopic surgery for rectal cancer. Specifically, CRM positivity in the trial by Kim et al. was 5.5% in the laparoscopy group and 6.1% in the robot group, while in the ROLARR trial, CRM positivity was 6.2% in the laparoscopy group and 5.1% in the robotic group.[3,12] In the COLRAR trial, a sub-analysis of positive CRM rates showed a lower rate in the robotic group at 0% compared to the laparoscopy group at 6.1% (p=0.031).[18] Additionally, a study using the ACS-NSQIP database comparing open, laparoscopic, and robotic surgery demonstrated no difference in pathologic outcomes, including positive CRM, negative distal resection margin, and adequate lymph node harvest.[13]

All groups retrieved an adequate number of lymph nodes, ranging from 88 to 90%, with each group yielding a mean of 15 lymph nodes, exceeding the recommended 12 lymph nodes by AJCC[15]. The results of this study align with the outcomes observed in the COREAN and COLOR II trials, where comparable lymph node yields were documented for both open and laparoscopic surgery approaches.[7,8] The RCT by Kim et al. noted a higher number of lymph node yield in the robotic group compared to the laparoscopy group (18 vs 15, p=0.04).[3] The findings of our research underscore the proficiency in surgical technique for both minimally invasive procedures with adequate lymph node yield. There was no significant difference among the three groups concerning the distal resection margin. This indicates that the quality of oncologic resection, in terms of distal margin clearance and lymph node retrieval, remains consistent across the surgical techniques.

The operative time was longer for robot-assisted surgeries when compared to open surgery (p=0.038), but not longer than laparoscopic surgery (p=0.591). This could highlight the intricate nature of robotic procedures, such as docking and undocking of the patient cart during the procedure, and improvement in the surgeon's learning curve associated with robotic platforms. However, no disparity was observed in the formation of stomas among the three groups (p=0.096). Nevertheless, when comparing laparoscopic surgery to robot-assisted procedures, it became evident that temporary stoma creation occurred more frequently in the robot-assisted surgery group than in the laparoscopy group (p=0.036). This discrepancy is attributed to the routine practice of creating temporary stomas in all low anterior resections within the robot-assisted group, whereas in the laparoscopy group, eight patients did not undergo the creation of a temporary stoma. However, two of these patients experienced anastomosis leakage, necessitating re-operation and eventual stoma placement.

Data from the ROLARR trial indicated comparable rates of conversion to open for laparoscopic and robot-assisted surgeries (12.2% vs 8.1%, p=0.16).[12]

Our study showed similar data with conversion rates to open surgery for both laparoscopic and robotic approaches (9.52% vs. 0%, p=0.175). Nevertheless, it is noteworthy that the conversion rate in our study was lower than that reported in the ROLARR trial, with no instances of conversion observed within the robotic-assisted surgery cohort.

In our study, it was observed that both laparoscopic and robot-assisted surgery resulted in a shorter hospital stay by one day compared to open surgery (6 days for both minimally invasive methods vs. 7 days for open surgery, p = 0.047). Similar findings were reported in the COREAN and COLOR II trials, where laparoscopic surgery resulted to a shorter post-operative stay by one day compared to open surgery.[7,8] The trials conducted by Kim et al. and the ROLARR trial demonstrated that the length of stay was similar for both laparoscopic and robot-assisted surgeries, consistent with the results of our study.[3,12] A retrospective study using the ACS-NSQIP database also revealed that laparoscopy and robot-assisted surgery resulted in a shorter length of stay by one and two days, respectively compared to open surgery.[21] These studies collectively indicate that minimally invasive surgical procedures offer the advantage of a reduced length of hospitalization due to smaller incisions, better post-operative pain and quicker return of bowel function.

Given the increasing body of evidence supporting the utility of robotic surgery in rectal cancer resection, further research is necessary to determine its oncologic advantages. This need is especially pertinent due to the high cost associated with this technology, which present substantial financial challenges for healthcare institutions and patients. Additionally, the adoption of robot-assisted surgery in rectal cancer management locally is not at par with other Asian countries, influenced by factors such as limited access to training programs, restricted accessibility of robotic platforms, and the substantial cost associated with implementing this advanced technology. In a study by Wang et al. (2023), they proposed an innovative training program that simultaneously trains surgeons in laparoscopic and robotic-assisted low anterior resection for rectal cancer. Their study underscores the potential of integrated training programs to facilitate the adoption of robot-assisted surgery in rectal cancer.[21]

Limitations of the Study

Several limitations are inherent in this study. Firstly, the study's retrospective observational design is susceptible to biases, including selection and information biases. Although robust statistical methods were utilized, the number of patients in each group varied significantly. For instance, the robot-assisted group constituted only 16% of the total population, potentially undermining the reliability of comparisons involving this group due to reduced statistical power. This highlights the importance to utilize robot-assisted surgeries to achieve adequate sample size, and to provide a more comprehensive analysis of outcomes. However, the higher costs and limited availability of robot-assisted surgery pose significant challenges to attaining a balanced proportion of cases compared to open and laparoscopic surgeries, especially in a private medical setting. It is also noteworthy that our cohort is specific to rectal cancer resection surgeries conducted since 2018, which aligns with the introduction of robot-assisted surgery for rectal cancer at our institution.

Second limitation pertains to the variability of preferred surgical techniques among participating surgeons and the range of surgical expertise available. Only a select number of surgeons are adept at minimally invasive rectal surgery procedures, and only one group of colorectal surgeons were trained in robot-assisted surgery for rectal cancer during the conduct of this study. Such differences might influence outcomes, yet they remain outside the purview of this study.

Third limitation is the non-incorporation of the completeness of the mesorectal excision grading in the analysis, primarily because of irregular and inconsistent reporting in the available medical records. The quality of completeness of mesorectal excision during TME is a critical component of rectal cancer surgery that impacts prognosis in terms of better local control, lower recurrence rates, and improved survival. A standardized approach to reporting histopathological findings is recommended, including the evaluation of TME quality according to the M.E.R.C.U.R.Y. grading.[21]

Fourth limitation is not including long-term oncologic outcomes, cost-analysis, preservation of autonomic nerves by urinary, and sexual function, and patient-reported outcome measures. Investigating these factors can provide a more holistic view of the advantages and disadvantages of each surgical method.

While this study provides valuable insights into the short-term and pathologic outcomes of open, laparoscopic, and robot-assisted surgeries for rectal cancer, it is imperative to recognize its limitations as a retrospective cohort study and interpret the findings in their appropriate context. Future studies should ideally utilize prospective or randomized controlled trials in high-volume centers to arrive at more robust conclusions.

CONCLUSION

Open, laparoscopic and robot-assisted surgeries for rectal cancer exhibit similar post-operative morbidity and CRM positivity. While the surgical and pathologic outcomes are comparable, shorter hospital stay was observed in laparoscopic and robot assisted surgeries. These findings underscore the potential applicability of robot-assisted surgery as a viable approach in rectal cancer surgery in addition to laparoscopy and open. The selection of surgical approach should be tailored to individual cases, considering factors such as patient demographics, cost, accessibility to laparoscopic or robotic platforms, and surgeon's proficiency in minimally invasive techniques.

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