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Robotic Rectal Cancer Resection: A Retrospective Multicenter Analysis

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Dr. Alessio Pigazzi was appointed the chief of Colon and Rectal Surgery at Weill Cornell Medical Center/NewYork-Presbyterian in 2020. His research focuses on minimally invasive techniques to improve recovery after cancer surgery, postoperative chemotherapy and the relationship between diet and colorectal cancer.

In this article, Dr. Pigazzi and his co-authors share their findings from an extensive study about robotic rectal resection (surgical procedure to remove part of the rectum) that was conducted at seven different institutions. The study aimed to find conclusive evidence that robotic surgery is a safe and feasible option for rectal cancer resection.

The data collected from several surgeons at different institutions indicates that robotic-assisted minimally invasive surgery is safe and can be performed according to the best practices for cancer treatment. The evidence shows that it is an excellent treatment option, including for patients with challenging cases.

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ORIGINAL ARTICLE – COLORECTAL CANCER

Robotic Rectal Cancer Resection: A Retrospective Multicenter Analysis

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ABSTRACT

Background. Conventional laparoscopy has been applied to colorectal resections for more than 2 decades. However, laparoscopic rectal resection is technically demanding, especially when performing a tumor-specific mesorectal excision in a difficult pelvis. Robotic surgery is uniquely designed to overcome most of these technical limitations. The aim of this study was to confirm the feasibility of robotic rectal cancer surgery in a large multicenter study.

Methods. Retrospective data of 425 patients who underwent robotic tumor-specific mesorectal excision for rectal lesions at seven institutions were collected. Outcome data were analyzed for the overall cohort and were stratified according to obese versus non-obese and low versus ultra-low resection patients.

Results. Mean age was 60.9 years, and 57.9 % of patients were male. Overall, 51.3 % of patients underwent neoadjuvant therapy, while operative time was 240 min, mean blood loss 119 ml, and intraoperative complication rate 4.5 %. Mean number of lymph nodes was 17.4, with a positive circumferential margin rate of 0.9 %. Conversion rate to open was 5.9 %, anastomotic leak rate was 8.7 %, with a mean length of stay of 5.7 days. Operative times were significantly longer and re-admission rate higher for the obese population, with all other parameters comparable. Ultra-low resections also had longer operative times.

Conclusion. Robotic-assisted minimally invasive surgery for the treatment of rectal cancer is safe and can be performed according to current oncologic principles. BMI seems to play a minor role in influencing outcomes. Thus, robotics might be an excellent treatment option for the challenging patient undergoing resection for rectal cancer.

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Traditionally, surgical treatment of colorectal cancer has been performed through a median laparotomy with the usual morbidity associated with major open surgery. The last 2 decades have witnessed a progressive expansion of minimally invasive surgery in colorectal cancer resections, providing benefits of improved cosmetic outcome, shorter hospital stay, and faster return to normal functioning.[1–4]

However, the use of laparoscopy in rectal cancer has not yet achieved wide application as standard approach for patients with rectal cancer.[5–8] The technical complexity of laparoscopic total mesorectal excision (TME), the long learning curve, and concern that those difficulties could jeopardize oncologic results remain limiting factors for laparoscopic rectal surgery.[9] However, multiple trials and recent meta-analysis have shown that a TME can be safely performed laparoscopically, with lower morbidity and mortality, decreased length of stay, but longer operating room times, and conversion rates up to 20 %.[1–7,10–15] Several studies have demonstrated that additional challenging conditions, such as high body mass index (BMI), can lead to increased operative times, postoperative morbidity, and conversion rates.[16,17]

Laparoscopy has well-accepted limitations, such as disruption of the natural coupling between the surgeon's hands and eyes by the interposition of an independently moving camera. Other obstacles to natural motion include the fulcrum effect and the loss of two of the six degrees of freedom of the surgeon's hand.[18] Robotic assistance with the da Vinci® Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA, USA) can overcome some of the obstacles of standard laparoscopy. Robotic surgery provides several advantages, namely three-dimensional visualization, articulated instrumentation, and a stable camera platform, which all lead to improved surgical ergonomics and cognitive and physical stress reduction.[19–21] It allows the surgeon to regain the two lost degrees of freedom by introducing wristed instruments. The value of using six degrees of freedom becomes most evident in complex surgical procedures, particularly if performed within a confined space such as the pelvis.[18–22] Several studies report excellent oncological and clinical outcomes for robotic rectal surgery, with potential advantages over conventional laparoscopy and open surgery.[23–29]

The aim of this study was to evaluate the feasibility, oncologic safety, and short-term outcomes of robotic rectal cancer resection in a large series collected from multiple institutions and surgeons.

PATIENTS AND METHODS

This was a multicenter, retrospective chart review of consecutive cases of robotic-assisted rectal resection performed by participating surgeons at their respective institutions. It included all consecutive cases per surgeon from December 2008 through October 2013, until 30 days prior to Institutional Review Board (IRB) approval. First cases within the expected learning curve were included by all but two surgeons.

The study was funded by Intuitive Surgical, Inc. under cooperative clinical trial agreement; funding was used to support IRB approval and data collection. The authors had full control of the study design, methods used, analysis of data, and manuscript production. The study investigators have a past or current contract with Intuitive Surgical, Inc. for proctoring and case observation support.

Patients

All patients with a primary rectal cancer within 15 cm from the anal verge who were seen by a robotic cancer surgeon and who were determined to be a candidate for robotic-assisted resection were included. These patients underwent robotic-assisted, tumor-specific mesorectal excision with primary anastomosis with or without diverting loop ileostomy.

The IRB of each participating surgical institution approved (or provided approval exemption of) the study protocol and granted an informed consent waiver for use of de-identified information from existing medical records. Patient data were kept confidential and handled in accordance with the Health Insurance Portability and Accountability Act of 1996. All data were collected and stored in a centralized database (OpenClinica© 2004–2009, Akaza Research LLC and collaborators).

Patient demographic and operative characteristics, procedure-related morbidity and mortality, pathologic examination, and short-term oncologic outcomes were collected. Operative time was the time from first skin incision to placement of the last skin stitch. Robotic operative time was the time spent by the operating surgeon on the console, robotic docking time was not recorded, and no re-docking was performed. Obesity was defined as a BMI $\geq$30 kg/m^2, according to the World Health Organization definition.[30] Clinical leak was defined as an anastomotic dehiscence verified by any of the following: imaging [computed tomography (CT) or barium enema], change in drainage material, operative intervention showing drainage, endoscopic evidence of anastomotic dehiscence, or signs of sepsis. Intra- and postoperative complications were stratified into minor (Clavien I or II, conservative treatment) and major (Clavien III or IV, invasive treatment) complications.[31]

Institutions

Seven institutions with 16 surgeons contributed their cases to this study. The volume of cases performed per surgeon, as well as previous laparoscopic experience, is presented in detail in Table 1.

Oncologic Assessment

Rectal adenocarcinoma was staged according to the 7th edition of the American Joint Committee on Cancer (AJCC) staging manual.[32] Patients' preoperative workups were per surgeon preference. Adequate local staging was by pelvic magnetic resonance imaging (MRI) and/or endorectal ultrasound. When neoadjuvant chemoradiotherapy was indicated, the patient received a 4- to 5-week radiation course of 45–50 Gy dose with systemic fluorouracil-based chemotherapy. Patients underwent surgery 6–12 weeks after neoadjuvant treatment. Pathologic examination included disease tumor-node-metastasis (TNM) classification, number of lymph nodes harvested, margin status, and completeness of mesorectum. Last follow-up visit and disease status, including distant or local recurrences, were recorded at the time of data acquisition.

TABLE 1 Surgeons and their institutions, robotic case volume, and laparoscopic experience

Surgeon	Robotic study case volume	Laparoscopic experience
1	47	H
2	7	M
3	4	L
4	81	L
5	29	M
6	27	H
7	23	M
8	13	L
9	13	L
10	60	H
11	1	L
12	42	L
13	27	H
14	33	H
15	32	M
16	37	H

H high laparoscopic experience: >100 cases, *M* moderate laparoscopic experience: 50–100 cases, *L* low laparoscopic experience: <50 cases

Surgical Technique

A robotic approach was offered to all patients who required rectal resection with cancer-specific mesorectal excision. All study surgeons perform robotic rectal resection as their preferred approach for rectal cancer cases, independent of patients' previous abdominal surgeries or BMI.

The mesorectal excision was performed with the da Vinci System in all cases, and with a sharp dissection technique using either robotic scissors or the robotic hook cautery. A TME with transection of the rectum at the level of the pelvic floor was performed for cancers of the mid to low rectum. For tumors of the upper rectum, the mesorectum was prepared to about 5 cm distal to the tumor where the mesorectum was divided, together with the rectum in a partial mesorectal excision (PME). Surgical technique was otherwise not standardized and involved either a total robotic or hybrid (laparoscopic/robotic) approach. All surgeons performed a medial-to-lateral mobilization of the left and sigmoid colon with high ligation of either the entire inferior mesentery artery trunk or the superior rectal artery only, selective ligation of the inferior mesenteric vein, and selective mobilization of the splenic flexure. The anastomosis was either stapled with a circular stapler inserted transanally or hand-sewn as a coloanal anastomosis with intersphincteric resection for very low tumors. The specimens were removed either through a small suprapubic incision or transanally. Creation of a loop ileostomy was performed at the surgeon's discretion. Bowel preparation, preoperative antibiotic administration, and thrombosis prophylaxis were performed in accordance with the participating institutions' protocols, with antibiotics not given longer than 24 h after surgery per Surgical Care Improvement Project (SCIP) guidelines.[33] All conversions were to an open approach.

Statistical Analysis

All statistical analyses were conducted using SAS version 9.2.1 (SAS Institute Inc., Cary, NC, USA). Continuous variables were expressed as means and standard deviations, while discrete variables were expressed as proportions and percentages. Data were stratified on the basis of BMI, with comparisons made between obese and non-obese patients. A two-sided p value of <0.05 was considered statistically significant. Logistic regression predicted risk factors for the likelihood of an anastomotic leak, conversion of the surgical approach, and a postoperative complication. This was carried out using a forward selection method with a significance level of 0.05 for entry into the model.

RESULTS

Data of 425 patients from seven sites were collected for this analysis. Overall, 16 surgeons operated on the patients, with a mean case load of 28.3 (±17.5) cases per surgeon, from December 2008 to October 2013, with some surgeons being higher-volume surgeons then others (see Table 1).

The clinical characteristics of all 425 patients are listed in Table 2. The majority of tumors were less than 12 cm (77.4 %). The mean BMI was 27.7 kg/m^2, and 126 patients (29.6 %) with a BMI >30 kg/m^2 were considered obese. The BMI difference between obese and non-obese patients was statistically significant ($p < 0.0001$).

Table 3 presents intraoperative characteristics and complications. Protective ileostomy was performed in 56 % of patients. The mean operative time was 240 (±96.0) min. Obese patients had a significantly longer operative time ($p = 0.024$) despite no difference in overall procedures performed or difference in intraoperative complications. The overall conversion rate was 5.9 %, with no significant difference between the obese and non-obese groups.

There were no differences in major perioperative morbidities or mortalities in obese and non-obese patients ($p = 0.88$), with one death in the low-BMI group. Overall anastomotic leak rate was 8.7 %. We observed a 5.4 % complication rate from the diverting loop-ileostomy,

TABLE 2 Demographic and preoperative characteristics of all, obese, and non-obese patients

Variable	All patients ($n = 425$)	BMI <30 kg/m^2 ($n = 299$)	BMI ≥30 kg/m^2 ($n = 126$)	*p* value
Age (years; mean ± SD)	60.9 ± 12	61.5 ± 12.3	59.4 ± 11.3	0.100
Sex [*n* (%)]				
Female	179 (42.1)	132 (44.2)	47 (37.3)	0.231
Male	246 (57.9)	167 (55.8)	79 (62.7)	
BMI (kg/m^2; mean ± SD)	27.7 ± 5.9	24.7 ± 3.2	34.9 ± 4.7	<0.0001
ASA classification [*n* (%)]				
I	35 (8.6)	26 (9.2)	9 (7.1)	0.168
II	203 (49.9)	152 (53.7)	51 (40.5)	
III	161 (39.6)	98 (34.6)	63 (50.0)	
IV	8 (2.0)	7 (2.5)	1 (0.8)	
Missing	18 (4.2)	16 (3.8)	2 (1.6)	
Previous abdominal surgery [*n* (%)]	154 (36.2)	112 (37.5)	42 (33.3)	0.505
Neoadjuvant therapy [*n* (%)]	218 (51.3)	153 (51.2)	65 (51.6)	1.00
Tumor location [*n* (%)]				
Upper rectum (12–15 cm)	84 (20.3)	57 (19.5)	27 (22.3)	0.118
Mid rectum (6–12 cm)	196 (47.5)	133 (45.6)	63 (52.1)	
Low rectum (≤6 cm)	133 (2)	102 (34.9)	31 (25.6)	
Missing	12 (2.8)	7 (2.3)	5 (4.0)	

SD standard deviation, *BMI* body mass index, *ASA* American Society of Anesthesiology

including dehydration, obstruction at the ileostomy site, and re-admission. Interestingly, there was a statistically significant higher re-admission rate for obese patients (18.3 vs. 9.4 %, respectively; $p = 0.016$) despite no difference in overall postoperative complications. The mean length of stay was 5.7 (±4.8) days. Postoperative data are listed in Table 4.

Details of tumor staging are presented in Table 5. The mean number of harvested lymph nodes was 17.4 (± 8.7), and the overall mean distal resection margin was 3.0 cm (±2.0), with a mean distal margin for the upper rectal cancers of 4.1 cm (±2.4), and 2.4 cm (±1.9) for the ultra-low cancers ($p < 0.0001$). Positive circumferential resection margin (CRM) [$n = 4$] was 0.9 %. Macroscopic assessment of the mesorectum showed a complete mesorectum in 67.8 % of patients, with an incomplete mesorectum in only 1.4 % of patients, with the rest being either nearly complete or missing. Obesity was unrelated to the number of lymph nodes harvested ($p = 0.59$) or the ability to achieve negative resection margins or a complete mesorectum ($p = 0.62$). At a mean follow-up of 13.9 months (±11), 58.4 % of patients were disease-free, and no port-site recurrence was reported. Local recurrence in the pelvis occurred in seven patients (1.7 %).

A total of 133 patients had ultra-low rectal cancers (≤6 cm), with the mean distance from the anal verge for this subgroup being 4.3 cm (±1.5). Overall, they had a higher rate of neoadjuvant chemoradiation ($p < 0.0001$), longer operating room times (270.9 ± 102 vs. 225.2 ± 89.1; $p < 0.001$), and more protective ileostomies (95.5 %). Intraoperative and postoperative complications were similar. Leak rate was similar in ultra-low rectal cancers (7.5 vs. 9.3 %; $p = 0.689$). The mesorectum was intact in 89.3 % of cases and a positive CRM was seen in 1.5 versus 0.7 % of rectal cancers >6 cm ($p = 0.586$). Conversion rate remained very low at 6.0 %, with no difference to higher rectal cancers.

In a logistic regression model that looked at which factors predict postoperative complications, tumor location ≤6 cm, male sex, and intraoperative complications were the only independent predictors of postoperative complications. Circumferential margins, neoadjuvant therapy, or high BMI and prior laparoscopic experience were not predictors of postoperative complications.

DISCUSSION

Robotic surgical systems have been the subject of great interest since their introduction into colorectal surgery at the beginning of this century. The use of robotics for the treatment of rectal cancer is a feasible approach, with potential advantages in the narrow pelvis when compared with open surgery and conventional laparoscopy.[9,18,20–26,34] To the best of our knowledge, this multicenter series represents the largest number of robotic-assisted rectal cancer resections with TME or PME to date. This study was specifically designed to review the data of multiple surgeons practicing in different clinical settings and with different degrees of experience.

A key principle in rectal surgery is the concept of a sharp mesorectal excision and oncologic adequacy of the specimen, as reflected in the completeness of the mesorectum and the CRM status.[35,36] In our experience, the robotic system allows for a very clear visualization of the presacral plane all the way to the pelvic floor, even in an obese male. The United Kingdom Medical Research Council (MRC) CLASICC trial, one of the earliest randomized trials comparing laparoscopic surgery with open colorectal surgery, showed a higher positive CRM rate for

TABLE 3 Operative characteristics and intraoperative complications of all, obese, and non-obese patients

Variable	All patients ($n = 425$)	BMI <30 kg/m^2 ($n = 299$)	BMI ≥30 kg/m^2 ($n = 126$)	p value
Diverting stoma formation [n (%)]	238 (56.0)	162 (54.2)	76 (60.3)	0.291
Additional procedures [n (%)]				
Overall	102 (24)	76 (25.4)	26 (20.6)	0.292[a]
Bowel resection	16 (15.7)	12 (15.8)	4 (15.4)	
Endoscopy	31 (30.4)	24 (31.6)	7 (26.9)	
Gynecologic procedures	17 (16.7)	15 (19.7)	2 (7.7)	
Adhesiolysis	4 (3.9)	3 (4.0)	1 (3.9)	
Others	34 (33.3)	22 (28.9)	12 (46.1)	
Operative time (min; mean ± SD)	240 ± 96	233 ± 95	257 ± 97	0.024
Estimated blood loss (ml; mean ± SD)	119 ± 164	110 ± 138	140 ± 211	0.091
Transfusions [n (%)]	5 (1.2)	4 (1.3)	1 (0.8)	1.000
Conversion [n (%)]	25 (5.9)	16 (5.4)	9 (7.1)	0.629
Intraoperative complications [n (%)]				
Overall	19 (4.5)	14 (4.7)	5 (4.0)	1.000[a]
Bowel injury	7 (1.7)	6 (2.0)	1 (0.8)	
Genitourinary injury	5 (1.2)	3 (1.0)	2 (1.6)	
Bleeding	2 (0.5)	2 (0.7)	0 (0.0)	
Anastomotic complication	3 (0.6)	1 (0.3)	2 (1.6)	
Other	2 (0.5)	2 (0.7)	0 (0.0)	

SD standard deviation, *BMI* body mass index

[a] p value refers to the difference in the overall rates

TABLE 4 Early postoperative outcomes (≤30 days postoperative) of all, obese, and non-obese patients

Variable	All patients ($n = 425$)	BMI <30 kg/m^2 ($n = 299$)	BMI ≥30 kg/m^2 ($n = 126$)	p value
Patients with major postoperative complications[a] [n (%)]	35 (8.2)	25 (8.4)	10 (7.9)	0.884
List of events/ complications				
Bleeding	3	2	1	
Infection	6	6	0	
Gastrointestinal	5	3	2	
Wound	0	0	0	
Urinary/kidney	1	1	0	
Pulmonary	5	4	1	
Cardiovascular	1	0	1	
Systemic	2	2	0	
Anastomotic leak	18	12	6	
Death	1	1	0	
Other	0	0	0	
Patients with minor postoperative complications[b] [n (%)]	117 (27.5)	81 (27.1)	36 (28.6)	0.847
List of events/ complications				
Bleeding	0	0	0	
Infection	3	3	0	
Gastrointestinal	49	37	12	
Wound	16	9	7	
Urinary/kidney	29	23	6	
Pulmonary	1	1	0	
Cardiovascular	9	6	3	
Systemic	2	2	0	
Anastomotic Leak	19	11	8	
Other	12	7	5	
Patients with complications related to ileostomy [n (%)]	23 (5.4)	15 (5.0)	8 (6.4)	0.640
Anastomotic leak overall[c] [n (%)]	37 (8.7)	23 (7.7)	14 (11.1)	0.34
Length of stay (days; mean ± SD)	5.7 ± 4.8	5.7 ± 5.1	5.4 ± 4	0.517
Re-admission [n (%)]	51 (12.0)	28 (9.4)	23 (18.3)	0.0160

BMI body mass index, *SD* standard deviation, *ICU* intensive care unit, *TPN* total parenteral nutrition

[a] Complication classified as Clavien score III or higher (requiring surgical, endoscopic, or radiologic intervention, ICU management or death)

[b] Complication classified as Clavien scores I and II (any deviation from the normal postoperative course, including pharmacological treatment, blood transfusion, TPN, or opening of wound at bedside)

[c] Combined anastomotic leak—includes all Clavien scores

anterior resection in the laparoscopic versus open surgery group (12 vs. 6 %).[3] While this higher CRM positivity did not change overall survival and local recurrence at 5 and 10 years, it has been directly attributed to the technical challenges of conventional laparoscopy in the pelvis.[3,4,9,14,37] The Color II trial, a non-inferiority phase III trial comparing open TME (OTME) with laparoscopic TME (LTME), showed a positive CRM (<2 mm) of 10 % in both groups.[10] The largest single-institution retrospective review of 579 laparoscopic proctectomies showed a CRM positivity rate of 2 %.[13] Arezzo et al. found CRM involvement in 7.9 % of laparoscopic and 6.9 % of open rectal cancer resections, with an overall relative risk of 1.00 (95 % confidence interval [CI] 0.73–1.35) in a recently published meta-analysis of 27 studies, including eight randomized controlled trials.[5] A recent meta-analysis of robotic TME (RTME) versus LTME reported CRM positivity from 1.5 to 4.5 %, with no difference between the groups.[34] Interestingly, Ghezzi et al. recently reported their series of RTME versus OTME, with no difference between CRM positivity (0 and 1.8 %, respectively) between groups.[38] Another recent RTME series by a single surgeon

TABLE 5 Staging, pathologic data, and postoperative follow-up of all, obese, and non-obese patients

Variable	All patients [$n = 425$]	BMI <30 kg/m^2 [$n = 299$]	BMI ≥30 kg/m^2 [$n = 126$]	p value
AJCC staging[a] [n (%)]				
I	125 (29.4)	81 (27.1)	44 (34.9)	0.456
II	103 (24.3)	75 (25.1)	28 (22.2)	
III	131 (30.8)	95 (31.8)	36 (28.6)	
IV	32 (7.5)	21 (7.0)	11 (8.7)	
Missing	34 (8.0)	27 (9.0)	7 (5.6)	
Pathologic tumor stage [n (%)]				
pT0	52 (12.2)	42 (14.1)	10 (7.9)	0.309
pT1	60 (14.1)	42 (14.1)	18 (14.3)	
pT2	119 (28.0)	76 (25.3)	43 (34.1)	
pT3	167 (39.3)	118 (39.5)	49 (38.9)	
pT4	13 (3.1)	10 (3.3)	3 (2.4)	
pTx	4 (0.9)	2 (0.7)	2 (1.6)	
Missing	10 (2.4)	9 (3.0)	1 (0.8)	
Pathologic nodal stage [n (%)]				
pN0	282 (66.4)	199 (66.6)	83 (65.9)	0.524
pN1	97 (22.8)	69 (23.1)	28 (22.2)	
pN2	42 (9.9)	28 (9.3)	14 (11.1)	
pNx	1 (0.2)	0 (0.0)	1 (0.8)	
Missing	3 (0.7)	3 (1.0)	0 (0.0)	
Lymph nodes resected (n; mean ± SD)	17.4 ± 8.7	17.2 ± 9.1	17.7 ± 7.6	0.589
Positive CRM [n (%)]	4 (0.9)	3 (1.0)	1 (0.8)	1.000
CRM (cm; mean ± SD)	1.0 ± 1.3	1.0 ± 1.2	1.0 ± 1.4	0.549
Distal resection margins (cm; mean ± SD)	3.0 ± 2.0	3.1 ± 2.0	2.9 ± 1.9	0.340
Tumor size (cm; mean ± SD)	3.1 ± 2.0	3.0 ± 2.0	3.3 ± 1.9	0.197
Mesorectum [n (%)]				
Complete	288 (67.8)	198 (66.2)	90 (71.4)	0.624
Nearly complete	32 (7.5)	23 (7.7)	9 (7.2)	
Incomplete	6 (1.4)	5 (1.7)	1 (0.8)	
Missing	99 (23.3)	73 (24.4)	26 (20.6)	
Last follow-up (months; mean ± SD)	13.9 ± 11.0	14.3 ± 11.2	13.3 ± 10.6	0.402
Adjuvant treatment [n (%)]	224 (53.1)	154 (52.0)	70 (55.6)	0.578
Disease status at last follow-up [n (%)]				
Remission	248 (58.4)	173 (57.9)	75 (59.5)	0.773
Active disease	43 (10.1)	30 (10.0)	13 (10.3)	
Deceased due to disease	13 (3.1)	10 (3.3)	3 (2.4)	
Deceased due to others	6 (1.4)	5 (1.7)	1 (0.8)	
Unknown	11 (2.6)	10 (3.3)	1 (0.8)	
Missing	104 (24.5)	71 (23.8)	33 (26.2)	
Local recurrence [n (%)]	7 (1.7)	4 (1.3)	3 (2.4)	0.427

BMI body mass index, *AJCC* American Joint Committee on Cancer, *CRM* circumferential resection margin

[a] AJCC staging manual, 6th edition

reported a CRM positivity of 2.5 %.[39] We were also able to show a very low positive CRM rate of 0.9 %, with obesity not adversely affecting the outcome.

Conversion to open surgery is another important parameter that is used as a surrogate for technical feasibility of minimally invasive approaches.[40] Rates of conversion for laparoscopic low anterior resection are reported to be between 7 and 34 %, with most studies being between 10 and 20 %.[2,3, 5–7,10,12,13] A recent nationwide analysis that included 115,648 laparoscopic and 2,143 robotic patients reported a significant reduction of conversion for robotic versus laparoscopic rectal resections (5.38 vs. 13.38 %).[41] Other reports of robotic mesorectal excision revealed conversion rates of 0–9.4 %.[9,22–29,34,42,43] We encountered an overall conversion rate of 5.9 %, which falls well within the reported numbers in the literature. This was accomplished despite a high number of obese patients (29.6 %). This is very important as several studies have demonstrated increased postoperative morbidity with conversion as well as a negative impact on overall and disease-free survival.[4,11]

Obesity in general adds to the technical difficulty of colorectal surgery due to distorted anatomy and fatty dissection planes.[44] Several authors described a higher incidence of short-term complications, longer operating times, and higher conversion rates in high BMI patients during laparoscopic surgery.[17,44–48] Obesity was one of the most common reasons for conversion in the laparoscopic rectal cancer arm reported in the CLASICC trial (26 %).[3] In their review of LTME, Bege at al. reported significantly higher conversion rates for obese patients (46 % vs. 12 % non-obese; $p < 0.001$).[48] Interestingly, a prolonged operative time ($p = 0.4$) and higher estimated blood loss was also seen in open TME in obese versus non-obese patients, with no difference in postoperative morbidity or oncologic outcomes.[44] Our data suggest that the technical advantages of robotic surgery can overcome most challenges posed by obesity, resulting in similar oncologic and postoperative outcomes as in non-obese patients as well as a low conversion rate. Only operating-room time remains longer.

Complications were low, with an overall rate of anastomotic leak of 8.7 %, which compares favorably with a large series of open and laparoscopic rectal resection.[2,3,6,7,10–13,15] Our low leak rate was despite a high number of mid-to-low rectal cancers requiring TME (329/425, 77.4 %). We did encounter an overall complication rate of 5.4 % related to the protective ileostomy. The rationale for creating a loop ileostomy is avoidance of septic complications associated with a high-risk anastomosis. This was reflected by the high rate of ileostomies placed independently by different surgeons in the ultra-low group (95.5 %). A recent review of the National Surgical Quality Improvement Program (NSQIP) database for morbidity of diverting ileostomy confirmed a reduced rate of reoperation but increased risk of acute renal insufficiency (odds ratio 2.4; 95 % CI 1.2–4.6; $p < 0.05$).[49] Future prospective studies on RTME, refinement of operative techniques, the use of fluorescence imaging, and new stapling technology may identify methods to decrease the risk of leakage and to allow for more selective creation of ileostomies.

Moreover, our study suggests that a proper oncologic resection can be achieved independent of the surgeon's practice environment. The logistic regression analysis did not show any relation of postoperative complications with the surgeon's previous laparoscopic experience. Our analysis included first robotic cases within the expected learning curve by all but two surgeons. Despite this wide range of experience of the participating surgeons, we were able to present comparable short-term outcomes. These findings suggest that robotics could be an equalizer for less-experienced laparoscopic surgeons, and improving minimally invasive mesorectal excision.

Despite these encouraging outcomes, there were some study shortcomings. These findings are based on retrospectively collected data without direct comparisons to open or laparoscopic surgery. The retrospective nature of these data creates a certain potential for bias and limitations to the generalization of findings.

Alternatively, the heterogeneity of participating surgeons demonstrates the feasibility of robotic cancer-specific mesorectal excision in a variety of approaches and setups. These data represent a cross-section of dedicated robotic colorectal cancer programs with excellent oncological and clinical outcomes, even in obese patients. We believe that the robotic approach will become the preferred surgical technique for rectal cancer once larger-scale prospective studies are available.

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