Original Article

Effects of Enhanced Recovery after Surgery Implementation on Surgical Outcomes in Patients with Rectal Cancer: A Single-center Experience

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Key Words
Robotic surgery;
Rectal cancer;
Enhanced Recovery After Surgery (ERAS)

Background/Objective. The Enhanced Recovery After Surgery (ERAS) program was designed to reduce surgical stress and improve postoperative recovery. Although ERAS has been applied widely, only a few studies have explored the associated outcomes when applied to robotic rectal surgery. Here, we compared ERAS-related outcomes in patients undergoing robotic versus laparoscopic surgery for rectal cancer.

Methods. We retrospectively collected the data of patients who received elective laparoscopic or robotic colorectal cancer surgery under a modified ERAS protocol. Postoperative length of stay (LOS) was the primary outcome; ERAS-related results, complications, 14-day emergency room (ER) visit, and 30-day mortality were secondary outcomes.

Results. In total, 304 patients at our institution underwent surgery for colorectal cancer between January 2022 and April 2024. Of these patients, 30 were deemed eligible for inclusion in our analysis. These patients were divided into robotic surgery and laparoscopic surgery groups. The robotic surgery group had non-significantly longer mean postoperative LOS than did the laparoscopic surgery group (mean: 11.4 ± 8.5 vs. 9.8 ± 6.3 days, median: 8 [7-10.75] vs. 8 [7-10] days, $p = 0.421$). The laparoscopic surgery group underwent earlier foley catheter removal (3.8 ± 2.8 vs. 2.3 ± 2.8 days, $p = 0.038$). The robotic surgery group was more likely to use parenteral nutrition (73.3% vs. 26.7%, $p < 0.001$), albeit for a shorter duration (4.86 ± 4.09 vs. 7.13 ± 5.11 days, $p = 0.22$). Complication rate, 14-day ER visit, 30-day mortality, and pathologic outcomes between the groups did not significantly differ. Subgroup analysis revealed results similar to those of the main analysis.

Conclusion. Robotic surgery could be an alternative choice for patients with middle to low rectal cancer under modified ERAS protocol.

[*J Soc Colon Rectal Surgeon* (*Taiwan*) *2026;37:10-22*]

Colorectal cancer (CRC) was the third most common cancer and the second leading cause of cancer-related mortality globally in 2022.[1] In Taiwan, CRC was the second most common cancer (excluding breast cancer in women) and the third leading cause of cancer-related mortality in 2021.[2] Surgical resection is

Received: April 2, 2025. Accepted: June 4, 2025.
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the cornerstone of CRC treatment. Numerous studies, including recent meta-analyses, have demonstrated that minimally invasive surgery (MIS), such as laparoscopic surgery, affords significant advantages over conventional open surgery, including shorter postoperative hospital stays, lower complication rates, and faster bowel function recovery, while not compromising oncological outcomes.[3-8] The evolution of MIS has led to further reductions in perioperative physiological stress and enhancements in the benefits of the Enhanced Recovery After Surgery (ERAS) protocol.

ERAS is a multimodal, integrated approach to perioperative care that was designed to minimize surgical stress and promote faster recovery in patients undergoing surgery. Since 2001, the ERAS Society has published numerous guidelines tailored to various cancer surgical procedures, including the first CRC-specific guideline in 2005.[9] The ERAS protocol has been widely adopted worldwide and adapted to accommodate local conditions and practices.[10,11] The colorectal ERAS guidelines recommend MIS as the preferred surgical approach for colorectal resections because of its clear advantages in promoting faster recovery, reducing postoperative pain, and minimizing overall complications.[12] Furthermore, MIS facilitates the implementation of key components of ERAS, such as the use of nonopioid analgesics and the optimization of fluid management, that contribute to shorter hospital stays when combined with ERAS care.[13]

In rectal cancer surgery, the anatomical challenges posed by the tumor's location deep within the narrow pelvic space can limit the efficacy of laparoscopic approaches. Restricted dexterity, limited visualization, and susceptibility to instrument tremors, all associated with laparoscopy, can hinder precise dissection. Application of robotic surgery may resolve these limitations. In particular, robotic systems can provide a stable, three-dimensional view, along with enhanced dexterity through multijointed instruments and reduced tissue trauma because of precise movements, possibly improving surgical outcomes. Despite these advantages, recent studies have reported conflicting results, with robotic surgery showing outcomes comparable to laparoscopic surgery.[14-20] Moreover, although the application of ERAS protocols in robotic rectal surgery remains underexplored, studies thus far have largely supported the integration of robotic surgery with ERAS care.[21,22]

Robotic surgery was introduced at our institution in 2011 for urological, gynecological, and colorectal procedures. In 2016, we implemented the ERAS protocol into our clinical practice, incorporating selected components into a modified institutional protocol. In the current study, we compared short-term and ERAS-related outcomes in patients with rectal cancer undergoing robotic surgery with a modified ERAS protocol with rectal cancer patients receiving laparoscopic surgery.

Materials and Methods

This retrospective cohort study was approved by the Taipei Medical University Hospital Joint Institutional Review Board.

From January 2020 to April 2022, adult patients who underwent surgery for CRC at our hospital were identified. Patients were excluded if they (1) were not diagnosed of rectal cancer, (2) had a tumor at the rectosigmoid junction, (3) underwent open or tran-anal surgery, (4) lacked data on the desired outcomes, or (5) received emergent surgery due to obstruction, perforation of bleeding. Patients were divided into two groups on the basis of the surgical approach used: robotic or laparoscopic. Finally, to ensure comparability, the two groups were 1:1 matched based on the statistician's calculation. Because robotic surgery is predominantly used for patients with middle to low rectal cancer at our institution, we conducted a subgroup analysis of the included patients. To minimize potential bias and ensure a more accurate comparison, we excluded patients with upper rectal cancer in both groups from the subgroup analysis.

The surgery of rectal cancer was followed standard procedure to achieve adequate distal margin and complete mesorectal excision. In robotic group, da Vinci Xi Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) was utilized for pelvic dissection. Once the distal margin has been reached, the endoscopic linear stapler (Endo GIA) was used to transect

the rectum and pulled out the abdomen for tumor resection. The remaining rectal segment was put back intra-corporeal and colo-rectal anastomosis was established by circular stapler via anal canal. As for laparoscopic group, the whole dissection was done by traditional laparoscopic instrument. The transection was also performed by endoscopic linear stapler (Endo GIA) stapler and the colo-rectal anastomosis was established by circular stapler via anal canal. The surgeries were several performed by experienced, skilled colorectal surgeons. There was no cases part of robotic surgery learning curve.

We basically followed most items of 2018 version of colorectal ERAS guideline in this study. For example, preadmission information, education and counselling were provided in the outpatient department. Pre-operative nutrition risk assessment was done used Nutrition Risk Screening score (NRS 2002). Anemia was corrected before surgery to reach hemoglobin level of 8.0 g/dL. Postoperative nausea and vomiting (PONV) prophylaxis was given, and we avoid long-acting sedative medications to prevent psychomotor and cognitive impairment. Intraoperatively, cooperation with anesthesiologist was achieved by control intra-abdominal pressure at 10-12 mmHg level. Anesthesiologist used cerebral function monitoring to manipulate the anesthetic depth. Body fluid management was optimized by near-zero fluid balance and avoiding organ hypoperfusion. Hypothermia was prevented by air-heated body blanket covering and the use of body temperature management system. Apart from the strictly followed part of conventional guideline mentioned above, our institution's ERAS protocol differs from conventional ERAS protocols for CRC surgery in several key ways.[11] In conventional ERAS, bowel preparation could be avoided, our patients undergo bowel preparation 2 days preoperatively and receive antibiotics 1 day preoperatively. In aspect of preoperative diet, solid food intake is restricted starting at midnight on the day of surgery, with allowance of clear liquids 2 h before the procedure in our modified protocol. Conventional ERAS protocol supported carbohydrate drinks up to 2 hours before surgery, but in our protocol, no carbohydrate drinks are administered preoperatively. Intraoperatively, the use of drainage tubes is not avoided completely in our practice. Foley catheters are planned to be removed within the first 24 h postoperatively according to patient clinical condition, depend on surgeons' judgment. To stimulate gut motility, oral water intake is initiated as early as 2 h postoperatively, followed by clear-liquid diet administration and intravenous fluid discontinuation on the first postoperative day. The clear-liquid diet is maintained for 2 days, after which patients shift to a low-residual soft diet. Parenteral nutrition is avoided as possible, which would be administered on the basis of clinical judgment. Oral opioid analgesics was prohibited, and self-controlled epidural or spinal opioid analgesia is not routinely used. The difference of our modified ERAS protocol between the conventional ERAS guidelines was summarized in Table 1.[12] In this study, because of the variability in care preferences among surgeons, slight deviations from the modified ERAS protocol were deemed acceptable.

We retrospectively collected data on the included patients' demographics, medical histories, clinical characteristics, cancer staging, intraoperative blood loss, operative duration, ostomy creation, surgical approach, ERAS-related outcomes, complications, and pathologic findings from our electronic medical records. Postoperative recovery, measured as postoperative length of stay (LOS), was considered the primary endpoint. Secondary endpoints included ERAS-related outcomes, such as time to foley catheter removal, time to first mobilization, time to oral intake, and time to drain removal, as well as the incidence of postoperative complications, morbidity, emergency room (ER) visit within 14 days of discharge, and surgical mortality within 30 days. Postoperative complications were categorized and graded using the Clavien-Dindo classification system.

Data analysis was performed using SPSS Statistics (version 30.0.0.0; IBM). Categorical variables were presented as counts and proportions; continuous variables were expressed as means ± standard deviations. Postoperative LOS values were reported as medians and interquartile ranges (IQRs). Select continuous variables were further stratified into subgroups for analysis. The chi-square test was used to assess the independence of categorical variables. When sample

Table 1. Comparison of present study's modified ERAS protocol with conventional ERAS protocol

Conventional ERAS protocol	Our modified ERAS protocol
Preoperative	
Preadmission patient education and counseling	Preadmission education and pre-anesthesia consultation
Preoperative nutrition evaluation	Identical with conventional ERAS
Anemia management	Identical with conventional ERAS
No bowel preparation	Oral bowel preparation 2 days preoperatively
Preoperative oral carbohydrate or no fasting	No solid food after midnight on the day of surgery; only clear liquids up to 2 h preoperatively
Preoperative long-acting sedative medication	Identical with conventional ERAS
Thrombosis prophylaxis	Use of well-fitting compression stockings and intermittent pneumatic compression from start until the end of surgery
Antibiotic prophylaxis before incision	Single-dose cephalosporin (1,000 mg) 15-30 min before incision; additional dose if surgery is > 4 h long
PONV prophylaxis	Identical with conventional ERAS
Intraoperative	
Epidural or spinal anesthesia	Identical with conventional ERAS
Use of upper-body forced-air heating cover	Use of upper-body forced-air heating cover
Use of nasogastric tube intraoperatively	No use of nasogastric tube intraoperatively
Resection-site drainage	Use of drainage tubes is not avoided completely
Intraoperative fluid and electrolyte therapy	Identical with conventional ERAS
Postoperative	
Termination of urinary drainage within 24 h of surgery	Identical with conventional ERAS
Gut motility stimulation	Identical with conventional ERAS
Postoperative epidural analgesia	Identical with conventional ERAS
Patient weight check on postoperative day 1	No patient weight check on postoperative day 1
Use of nonopiate oral analgesics or nonsteroidal anti-inflammatory drugs	Identical with conventional ERAS
Termination of intravenous fluid infusion	Termination of intravenous fluid infusion on postoperative day 1
Perioperative oral nutrition	Clear liquid diet for 1-2 days, followed by low-residual soft food intake
Audit of compliance and outcomes	Audit of compliance and outcomes
Early mobilization	Early mobilization

sizes were too small or conditions for the chi-square test were not met, we used Fisher's exact test. Differences in continuous variables were evaluated using Student's *t* test. All statistical tests were two-tailed, with a significance threshold set at $p < 0.05$.

Results

We identified 304 patients who underwent elective surgery for CRC between January 2020 and April 2022. After applying the exclusion criteria, a total of 60 patients was then enrolled in our study, with 30 patients in each group.

Table 2 summarizes the baseline characteristics of each group. The groups consisted predominantly of men (83.3% and 76.7%, respectively; $p = 0.519$). The mean age was approximately 61 years (62.9 ± 10.5 and 60.2 ± 11.2 years, respectively; $p = 0.335$). Most patients had normal body mass index (BMI), with the mean BMI being near the upper limit of normal (23.8 ± 3.2 and 24.0 ± 3.3 kg/m^2, respectively; $p = 0.775$). Significantly more patients had a history of prior abdominal surgery in the laparoscopic group than in the robotic surgery group (46.7% vs. 13.3%, $p = 0.005$). The between-group differences in smoking status, hypertension, diabetes mellitus, and chronic kidney disease requiring dialysis were nonsignificant. Tumor location differed significantly between the groups: tumors were located closer to the anal verge in the ro-

Table 2. Preoperative baseline clinical characteristics

	Robotic (n = 30)	Laparoscopic (n = 30)	*p*
Sex			0.519
Male	25 (83.3)	23 (76.7)	
Female	5 (16.7)	7 (23.3)	
Age (years)	62.9 ± 10.6	60.2 ± 11.2	0.335
≤ 50	4 (13.3)	5 (16.7)	0.926
50-65	14 (46.7)	14 (46.6)	
> 65	12 (40)	11 (36.7)	
BMI (kg/m^2)	23.8 ± 3.2	24.0 ± 3.3	0.775
≤ 18.5	2 (6.7)	1 (3.3)	0.496
18.5-25	18 (60)	18 (60)	
25-30	10 (33.3)	9 (30)	
> 30	0	2 (6.7)	
Smoke			1
Y	3 (10)	4 (13.3)	
N	27 (90)	26 (86.7)	
HTN			1
Y	9 (30)	9 (30)	
N	21 (70)	21 (70)	
DM			0.166
Y	3 (10)	7 (23.3)	
N	27 (90)	23 (76.7)	
Dialysis			1
Y	0	0	
N	30 (100)	30 (100)	
History of abdominal surgery			0.005**
Y	4 (13.3)	14 (46.7)	
N	26 (86.7)	16 (53.3)	
History of ostomy			0.351
Y	1 (3.3)	2 (6.7)	
N	29 (96.7)	28 (93.3)	
Lesion location (AAV, cm)	6.4 ± 3.2	9.3 ± 4.55	0.006**
Clinical T			0.481
1	1 (3.3)	2 (6.7)	
2	2 (6.7)	2 (6.7)	
3	26 (86.7)	22 (73.3)	
4	1 (3.3)	4 (13.3)	
Clinical N			0.256
0	3 (10)	7 (23.3)	
1	14 (46.7)	9 (30)	
2	13 (43.3)	14 (46.7)	
M			1
0	27 (90)	27 (90)	
1	3 (10)	3 (10)	
Clinical stage			0.5
I	1 (3.3)	4 (13.3)	
II	2 (6.7)	3 (10)	
III	24 (80)	20 (66.7)	
IV	3 (10)	3 (10)	
Preoperative bowel preparation			1
Y	29 (96.7)	30 (100)	
N	1 (3.3)	0	

Table 2. Continued

	Robotic (n = 30)	Laparoscopic (n = 30)	*p*
Preoperative antibiotics use			1
Y	29 (96.7)	30 (100)	
N	1 (3.3)	0	
Neoadjuvant chemoradiation therapy			1
Y	25 (83.3)	25 (83.3)	
N	5 (16.7)	5 (16.7)	
ASA class			0.313
I	0	0	
II	27 (90)	23 (76.7)	
III	3 (10)	6 (20)	
IV	0	1 (3.3)	

Note. The categorical data is presented with number (percentage). Numerical data is presented with mean ± standard deviation.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Y = yes; N = no; SD = standard deviation; BMI = body mass index; HTN = hypertension; DM = diabetes mellitus; AAV = above the anal verge; ASA = American Society of Anesthesia.

botic surgery group than in the laparoscopic surgery group (6.4 ± 3.2 vs. 9.3 ± 4.5 cm above the anal verge, $p = 0.006$). Preoperatively, most patients in the robotic and laparoscopic surgery groups were classified as having T stage III (86.7% and 73.3%, respectively; $p = 0.481$) and clinical stage III (80.0% and 66.7%, respectively; $p = 0.500$). The differences in N stage between the groups were nonsignificant ($p = 0.256$).

Table 3 presents the intraoperative data and ERAS-related short-term clinical outcomes of the study. Robotic surgery was associated with a significantly longer operative time than was laparoscopic surgery (345.6 ± 77.3 vs. 284.3 ± 98.2 min, $p = 0.009$). In addition, ostomy creation was more frequently performed in the robotic surgery group than in the laparoscopic surgery group (70.0% vs. 43.3%, $p = 0.037$). The between-group difference in intraoperative blood loss was nonsignificant. Drainage tubes were routinely inserted in nearly all patients, with a nonsignificant difference between the robotic and laparoscopic surgery groups (100% and 93.3%, respectively; $p = 0.472$).

The robotic surgery group exhibited a nonsignificantly longer mean postoperative LOS than did the laparoscopic surgery group (11.4 ± 8.5 vs. 9.8 ± 6.3 days, median: 8 [7-10.75] vs. 8 [7-10] days; $p = 0.421$). Foley catheters were removed significantly earlier in the laparoscopic surgery group (3.8 ± 2.8 vs. 2.3 ± 2.8 days, $p = 0.038$). Although the robotic surgery group required parenteral nutrition more frequently (73.3% vs. 26.7%, $p < 0.001$), its duration was nonsignificantly shorter (4.86 ± 4.09 vs. 7.13 ± 5.11 days, $p = 0.220$). Both groups demonstrated similar times to mobilization (1.67 ± 1.21 vs. 2.27 ± 1.95 days, $p = 0.157$) and resumption of oral diet (1.43 ± 0.77 vs. 1.23 ± 0.68 days, $p = 0.291$).

Table 4 summarizes morbidity and mortality data. Neither group demonstrated 30-day surgical mortality. The overall morbidity rates were comparable between the robotic and laparoscopic surgery groups. In the robotic surgery group, complications including PONV, postoperative ileus, anastomotic leakage, surgical site infection, and reoperation occurred in 26.6% (8/30), 3.3% (1/30), 10% (3/30), 3.3% (1/30), and 3.3% (1/30) of the patients, respectively. Similarly, in the laparoscopic surgery group, PONV, postoperative ileus, anastomotic leakage, surgical site infection, and reoperation occurred in 16.7% (5/30), 10% (3/30), 3.3% (1/30), 3.3% (1/30), and 3.3% (1/30) of the patients, respectively. No significant differences were observed in complication rates between the groups.

Table 5 summarizes the patients' pathologic data. The mean number of harvested lymph nodes was comparable between the robotic and laparoscopic surgery groups (20.7 ± 8.42 vs. 19.7 ± 8.54, $p = 0.671$). Similarly, the number of positive lymph nodes did not significantly differ between the groups (2.1 ± 3.36 vs. 2.0 ± 2.49, $p = 0.896$). Pathologic staging was also similar between the groups ($p = 0.528$). These results indicate

Table 3. Intraoperative and short-term ERAS outcomes

	Robotic (n = 30)	Laparoscopic (n = 30)	*p*
Operation time (min)	345.6 ± 77.3	284.3 ± 98.2	0.009**
Conversion to open			1
Y	0	0	
N	30 (100)	30 (100)	
Blood loss (mL)			0.073
< 10	15 (50)	22 (73.4)	
10-500	15 (50)	7 (23.3)	
> 500	0	1 (3.3)	
Blood transfusion			1
Y	1 (3.3)	1 (3.3)	
N	29 (96.7)	29 (96.7)	
Ostomy creation			0.037*
Y	21 (70)	13 (43.3)	
N	9 (30)	17 (56.7)	
Drain			0.472
Y	30 (100)	28 (93.3)	
N	0	2 (6.7)	
Immediate ICU transfer			0.350
Y	1 (3.3)	4 (13.3)	
N	29 (96.7)	26 (86.7)	
Postoperative LOS (days)			
Mean ± SD	11.4 ± 8.5	9.8 ± 6.3	0.421
Median [IQR]	8 [7-10.75]	8 [7-10]	
Time to Foley removal (POD)	3.83 ± 2.77	2.30 ± 2.83	0.038*
Time to mobilization (POD)	1.67 ± 1.21	2.27 ± 1.95	0.157
Time to diet (POD)	1.43 ± 0.77	1.23 ± 0.68	0.292
Time to drain remove (POD)	8.73 ± 6.16	11.58 ± 10.16	0.207
PPN/TPN use			< 0.001***
Y	22 (73.3)	8 (26.7)	
N	8 (26.7)	22 (73.3)	
PPN/TPN days	4.25 ± 2.62	6 ± 5.1	0.220

Note. The categorical data is presented with number (percentage). Numerical data is presented with mean ± standard deviation.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Y = yes; N = no; SD = standard deviation; IQR = interquartile range; ICU = intensive care unit; POD = postoperative day; PPN/TPN = peripheral/total parenteral nutrition; LOS = length of stay.

no significant differences in pathologic outcomes.

Table 6 presents our subgroup analysis results. After exclusion of patients with upper rectal cancer, tumor location was comparable between the robotic and laparoscopic groups (6.0 ± 2.9 vs. 6.8 ± 3.2 cm above the anal verge, $p = 0.401$). The results of other baseline characteristics remained largely consistent with those of the original groups (Table 6). Regarding intraoperative outcomes, ostomy creation rates were similar between the two groups after exclusion (71.4% vs. 55.0%, $p = 0.241$). In the subgroup analysis, robotic surgery was associated with a nonsignificantly longer mean postoperative LOS compared with laparoscopic surgery (mean: 11.5 ± 8.6 vs. 9.0 ± 6.0 days, median: 8 [7-10.75] vs. 8 [6-9.25] days, $p = 0.270$). The time to foley catheter removal was significantly shorter in the laparoscopic group (2.0 ± 2.1 vs. 3.75 ± 2.8 days, $p = 0.023$). Compared with the laparoscopic surgery group, the robotic surgery group demonstrated a significantly higher parenteral nutrition use rate (71.4% vs. 20.0%, $p < 0.001$) but a nonsignificantly shorter parenteral nutrition use duration (5.57 ± 4.93 vs. 8.25 ± 6.29 days, $p = 0.186$), consistent with the main analysis findings. The results for mortality and

Table 4. Morbidity and mortality results

	Robotic (n = 30)	Laparoscopic (n = 30)	*p*
PONV			0.347
Y	8 (26.7)	5 (16.7)	
N	22 (73.3)	25 (83.3)	
Postoperative ileus			0.605
Y	1 (3.3)	3 (10)	
N	29 (96.7)	27 (90)	
Anastomosis leakage			0.605
Y	3 (10)	1 (3.3)	
N	27 (90)	29 (96.7)	
Infection			1
Y	1 (3.3)	1 (3.3)	
N	29 (96.7)	29 (96.7)	
Bleeding			1
Y	0	0	
N	30 (100)	30 (100)	
Reoperation			1
Y	1 (3.3)	1 (3.3)	
N	29 (96.7)	29 (96.7)	
Postoperative complications by C-D classification			0.549
I	5 (16.7)	3 (10)	
II	2 (6.7)	4 (13.3)	
III	1 (3.3)	1 (3.3)	
IV	1 (3.3)	0	
14-day emergency room visit			1
Y	0	0	
N	30 (100)	30 (100)	
30-day mortality			1
Y	0	0	
N	30 (100)	30 (100)	

Note. The categorical data is presented with number (percentage). Numerical data is presented with mean ± standard deviation.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Y = yes; N = no; SD = standard deviation; IQR = interquartile range; POD = postoperative day; PPN/TPN = peripheral/total parenteral nutrition; LOS = length of stay; C-D = Clavien-Dindo.

Table 5. Pathologic outcomes

	Robotic (n = 30)	Laparoscopic (n = 30)	*p*
Positive LN number	2.1 ± 3.4	2.0 ± 2.5	0.896
Harvested LN number	20.7 ± 8.4	19.8 ± 8.5	0.672
Pathologic T			0.024
0	5 (16.7)	0	
1	0	5 (16.7)	
2	8 (26.7)	6 (20)	
3	16 (53.3)	16 (53.3)	
4	1 (3.3)	3 (3.3)	
Pathologic N			0.933
0	11 (36.6)	10 (33.3)	
1	14 (46.7)	14 (46.7)	
2	5 (16.7)	6 (20)	
Pathologic stage			0.528
0	1 (3.3)	0	
I	5 (16.7)	8 (26.7)	
II	5 (16.7)	2 (6.7)	
III	17 (56.6)	17 (56.6)	
IV	2 (6.7)	3 (10)	

Note. The categorical data is presented with number (percentage). Numerical data is presented with mean ± standard deviation.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
SD = standard deviation; LN = lymph node.

morbidity rates were also similar to those reported in the main analysis. Taken together, the subgroup analysis revealed that excluding upper rectal cancer patients did not significantly alter the overall trends observed in the main analysis.

Discussion

The current findings demonstrated that the short-term recovery outcomes were comparable between robotic and laparoscopic rectal surgery performed under perioperative modified ERAS protocols. Most ERAS parameters, except time to foley catheter removal, exhibited similar performance between the groups; in particular, the laparoscopic surgery group required earlier foley catheter removal. The robotic surgery group received parenteral nutrition support more frequently, albeit for a shorter duration, than did

Table 6. Subgroup analysis results

	Robotic (n = 28)	Laparoscopic (n = 20)	*p*
Lesion location (AAV, cm)	6.0 ± 2.9	6.8 ± 3.2	0.402
Operation time (min)	345.3 ± 79.3	291.3 ± 74.4	0.021*
Conversion to open			1
Y	0	0	
N	28 (100)	20 (100)	
Blood loss (mL)			0.048*
< 10	13 (46.4)	15 (75)	
10-500	15 (53.6)	5 (25)	
> 500	0	0	
Blood transfusion			0.729
Y	1 (3.6)	0	
N	27 (96.4)	20 (100)	
Ostomy creation			0.241
Y	20 (71.4)	11 (55)	
N	8 (28.6)	9 (45)	
Drain			0.329
Y	28 (100)	18 (90)	
N	0	2 (10)	
Immediate ICU transfer			0.329
Y	0	2 (10)	
N	28 (100)	18 (90)	
Postoperative LOS (days)			
Mean ± SD	11.5 ± 8.8	9.0 ± 6.0	0.270077
Median [IQR]	8 [7-10.75]	8 [6-9.25]	
Time to Foley catheter removal (POD)	3.8 ± 2.8	2.0 ± 2.1	0.023*
Time to mobilization (POD)	1.5 ± 0.9	2.3 ± 1.7	0.059
Time to diet (POD)	1.5 ± 0.8	1.3 ± 0.8	0.359
Time to drain remove (POD)	8.8 ± 6.4	11.1 ± 10.2	0.183
PPN/TPN use			< 0.001***
Y	20 (71.4)	4 (20)	
N	8 (28.6)	16 (80)	
PPN/TPN days	5.6 ± 4.9	8.3 ± 6.3	0.18582
PONV			0.499
Y	8 (28.6)	4 (20)	
N	20 (71.4)	16 (80)	
Postoperative ileus			0.377
Y	1 (3.6)	3 (15)	
N	27 (96.4)	17 (85)	
Anastomosis leakage			0.499
Y	3 (10.7)	1 (5)	
N	25 (89.3)	19 (95)	
Infection			0.729
Y	1 (3.6)	0	
N	27 (96.4)	20 (100)	
Bleeding			1
Y	0	0	
N	28 (100)	20 (100)	
Reoperation			0.625
Y	1 (3.6)	1 (5)	
N	27 (96.4)	19 (95)	

Table 6. Continued

	Robotic (n = 28)	Laparoscopic (n = 20)	*p*
Postoperative complications by C-D classification			0.816
I	5 (17.9)	3 (15)	
II	2 (7.1)	2 (10)	
III	1 (3.6)	1 (5)	
IV	1 (3.6)	0	
14-day ER visit			0.864
Y	0	0	
N	28 (100)	20 (100)	
30-day mortality			1
Y	0	0	
N	28 (100)	20 (100)	

Note. The categorical data is presented with number (percentage). Numerical data is presented with mean ± standard deviation.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Y = yes; N = no; SD = standard deviation; IQR = interquartile range; AAV = above the anal verge; ICU = intensive care unit; POD = postoperative day; PPN/TPN = peripheral/total parenteral nutrition; LOS = length of stay; C-D = Clavien-Dindo.

the laparoscopic surgery group. Morbidity, mortality, and pathologic outcomes did not significantly differ between the groups. Subgroup analysis, excluding patients with upper rectal cancer, yielded results consistent with those of the main analysis.

ERAS protocols have been widely adopted worldwide, prompting numerous studies to evaluate their effects on robotic surgery. Recent literature has reported conflicting findings regarding the benefits of robotic surgery. In a 2018 cohort study, Asklid et al. compared the short-term outcomes of robotic and laparoscopic rectal surgery under an ERAS program.[22] Their findings revealed a 4-day shorter hospital stay, lower conversion rate, and fewer complications associated with robotic rectal surgery. Since 2016, ERAS has been fully integrated into the clinical practice of our hospital, with our previous reports demonstrating significant improvements in postoperative recovery among colorectal surgery patients, most of whom underwent laparoscopic surgery.[11] Our current study focused on patients with rectal cancer and revealed no significant difference in postoperative recovery time between robotic and laparoscopic surgery under our modified ERAS protocol (11.4 ± 8.5 vs. 9.8 ± 6.3 days, $p = 0.421$). However, the postoperative LOS in the current study was longer than that reported previously at our hospital (post-ERAS: 7.8 ± 3.6 days).[11] This might be because our previous study enrolled patients with CRC, whereas the present study enrolled patients with rectal cancer. Moreover, although the mean postoperative LOS was longer in the robotic surgery group, the median LOS was identical between the robotic and laparoscopic surgery groups (8 [7-10.75] and 8 [7-10] days, respectively), suggesting that a few extreme values influenced the mean data. Despite these differences, robotic rectal surgery appeared to achieve ERAS performance outcomes similar to those of laparoscopic rectal surgery, further supporting the applicability of ERAS protocols across surgical modalities.

Both groups in our study achieved comparable ERAS-related outcomes. However, the laparoscopic surgery group had a shorter time to foley catheter removal than did the robotic surgery group (2.3 ± 2.8 vs. 3.8 ± 2.8 days, $p = 0.038$). Notably, two patients in the laparoscopic surgery group required foley reinsertion due to acute urinary retention; no such reinsertion or urinary tract infections were observed in the robotic surgery group. According to the ERAS guidelines, foley catheter removal within 1-3 days after colorectal surgery is considered acceptable, with risk factors for urinary retention, such as male sex, epidural analgesia, and pelvic surgery, requiring consideration. In their 2022 meta-analysis, McIntosh et al. examined time to foley catheter removal after colorectal surgery[23] and noted higher urinary retention rates in the early removal group and increased infection rates in the late removal group. The authors concluded that foley catheter removal on postoperative day 3 or 4 achieves

the best balance between retention and infection risks. These findings support the current results that robotic surgery patients, despite having slightly later time to foley catheter removal, experienced no urinary retention or infection events. This underscores the feasibility of adhering to the ERAS guidelines across both surgical modalities while minimizing complications associated with foley catheter use.

The original ERAS guidelines emphasize early resumption of oral intake because any delay in returning to a normal oral diet after major surgery increases the rates of infectious complications and delayed recovery.[12] In the current study, both the robotic and laparoscopic surgery groups demonstrated similar timing for oral intake resumption, in adherence to the ERAS principles.

The ERAS guidelines do not address parenteral nutrition specifically; in our institution, its use is based on the surgeon's clinical assessment. Patients who are elderly, are preoperatively malnourished, or undergo prolonged surgical procedures are more likely to receive postoperative parenteral nutrition. Given the longer operative time and more complex cancer locations typically encountered in robotic surgical procedures, patients in the robotic surgery group were more likely to require parenteral nutrition. Despite this increased need, parenteral nutrition was discontinued earlier in the robotic surgery group, suggesting a trend toward faster recovery; however, this difference was nonsignificant.

In our institution, robotic surgery is typically recommended for tumors located in the lower rectum because of the enhanced dexterity provided by multijointed instruments, which enable precise dissection within the deep, narrow pelvic cavity. To account for differences in tumor location between the robotic and laparoscopic surgery groups, we performed subgroup analysis after the exclusion of patients with upper rectal cancer. Before exclusion, the robotic surgery group demonstrated significantly lower tumor locations than did the laparoscopic surgery group (6.4 ± 3.2 vs. 9.3 ± 4.5 cm above the anal verge, $p = 0.006$), which also contributed to a higher ostomy creation rate (70.0% vs. 43.3%, $p = 0.037$). After exclusion, tumor location or ostomy creation rates did not differ significantly between the groups. The postexclusion reduction in the differences in ostomy creation rates may be attributable to the protective role of ostomy in rectal surgery, particularly in patients undergoing low anterior resection. A 2014 meta-analysis reported that ostomy creation reduces anastomotic leakage risk in these patients.[24] Despite the original ERAS guideline recommending against routine drainage tube placement, most patients in both our groups received surgical drainage tubes (100% vs. 90%, $p = 0.329$) to facilitate early detection of anastomotic leakage in the subgroup analysis. The anastomotic leakage rates were 10.7% and 5.6% in the robotic and laparoscopic surgery groups, respectively, with no leakage-related reoperations or mortality reported in either group.

This study has several limitations warranting further research. First, the retrospective design used here introduced an inherent selection bias. To ensure accurate postoperative care tracking and better comparability, we individually selected patients whose care the researchers were directly involved in and matched the two groups at a 1:1 ratio. However, this approach led to more increased selection bias and a relatively small sample size, limiting the generalizability of our findings. Second, although ERAS has been integrated into clinical practice, individual surgeons at our hospital adjusted perioperative care on the basis of patient conditions. As a result, strict adherence to the ERAS protocol was not consistently maintained, potentially influencing the outcomes. Future studies should include larger samples with a multicenter design and more stringent inclusion criteria, such as specifically including patients who fully adhere to standardized ERAS protocols, to validate these findings.

In conclusion, robotic surgery was an alternative to meet the current trend of rectal cancer treatment with fair short-term outcomes under modified ERAS protocol. Patients with middle to low rectal cancer undergoing robotic surgery could achieve comparable outcomes with those undergoing standard laparoscopic surgery.

Declaration of Competing Interests

The authors have no competing interests to declare.

References

1. Bray F, Laversanne M, Sung H, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin* 2024;74(3):229-63. doi:10.3322/caac.21834
2. Cancer Registry Annual Report, Taiwan, 2021 (2023).
3. Bonjer HJ, Deijen CL, Abis GA, et al. A randomized trial of laparoscopic versus open surgery for rectal cancer. *N Engl J Med* 2015;372(14):1324-32. doi:10.1056/NEJMoa1414882
4. Guillou PJ, Quirke P, Thorpe H, et al. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. *Lancet* 2005;365(9472):1718-26. doi:10.1016/S0140-6736(05)66545-2
5. Jeong SY, Park JW, Nam BH, et al. Open versus laparoscopic surgery for mid-rectal or low-rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): survival outcomes of an open-label, non-inferiority, randomised controlled trial. *Lancet Oncol* 2014;15(7):767-74. doi:10.1016/S1470-2045(14)70205-0
6. Kang SB, Park JW, Jeong SY, et al. Open versus laparoscopic surgery for mid or low rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): short-term outcomes of an open-label randomised controlled trial. *Lancet Oncol* 2010;11(7):637-45. doi:10.1016/S1470-2045(10)70131-5
7. Trastulli S, Cirocchi R, Listorti C, et al. Laparoscopic vs open resection for rectal cancer: a meta-analysis of randomized clinical trials. *Colorectal Disease* 2012;14(6):e277-96. doi:10.1111/j.1463-1318.2012.02985.x
8. Weeks JC. Short-term quality-of-life outcomes following laparoscopic-assisted colectomy vs open colectomy for colon cancer: a randomized trial. *JAMA* 2002;287(3):321. doi:10.1001/jama.287.3.321
9. Ljungqvist O, Scott M, Fearon KC. Enhanced recovery after surgery: a review. *JAMA Surg* 2017;152(3):292-8. doi:10.1001/jamasurg.2016.4952
10. Shida D, Tagawa K, Inada K, et al. Modified enhanced recovery after surgery (ERAS) protocols for patients with obstructive colorectal cancer. *BMC Surgery* 2017;17(1). doi:10.1186/s12893-017-0213-2
11. Wang WL, Huang YJ, Lu YJ, Lin EK, Chen CC, Tong YS, Kuo LJ, Chen CH, Wei PL. Implementation of modified early recovery after surgery in minimally invasive colorectal surgery at a single community hospital. *J Soc Colon Rectal Surgeon (Taiwan)* 2020;31(1):32-40. doi:10.6312/SCRSTW.202003_31(1).10822
12. Gustafsson UO, Scott MJ, Hubner M, et al. Guidelines for perioperative care in elective colorectal surgery: Enhanced Recovery After Surgery (ERAS((R))) Society recommendations: 2018. *World J Surg* 2019;43(3):659-95. doi:10.1007/s00268-018-4844-y
13. Vlug MS, Wind J, Hollmann MW, et al. Laparoscopy in combination with fast track multimodal management is the best perioperative strategy in patients undergoing colonic surgery: a randomized clinical trial (LAFA-study). *Ann Surg* 2011;254(6):868-75. doi:10.1097/SLA.0b013e31821fd1ce
14. Asmat MLV, Caballero-Alvarado J, Lozano-Peralta K, Mariñas HV, Zavaleta-Corvera C. Robotic versus laparoscopic approaches for rectal cancer: a systematic review and meta-analysis of postoperative complications, anastomotic leak, and mortality. *Langenbeck's Archives of Surgery* 2024;409(1). doi:10.1007/s00423-024-03545-z
15. Jayne D, Pigazzi A, Marshall H, et al. Effect of robotic-assisted vs conventional laparoscopic surgery on risk of conversion to open laparotomy among patients undergoing resection for rectal cancer: the ROLARR randomized clinical trial. *JAMA* 2017;318(16):1569-80. doi:10.1001/jama.2017.7219
16. Kim CW, Kim CH, Baik SH. Outcomes of robotic-assisted colorectal surgery compared with laparoscopic and open surgery: a systematic review. *J Gastrointest Surg* 2014;18(4):816-30. doi:10.1007/s11605-014-2469-5
17. Park JS, Lee SM, Choi GS, et al. Comparison of laparoscopic versus robot-assisted surgery for rectal cancers: the COLRAR randomized controlled trial. *Ann Surg* 2023;278(1):31-8. doi:10.1097/SLA.0000000000005788
18. Trastulli S, Farinella E, Cirocchi R, et al. Robotic resection compared with laparoscopic rectal resection for cancer: systematic review and meta-analysis of short-term outcome. *Colorectal Dis* 2012;14(4):e134-56. doi:10.1111/j.1463-1318.2011.02907.x
19. Tyler JA, Fox JP, Desai MM, Perry WB, Glasgow SC. Outcomes and costs associated with robotic colectomy in the minimally invasive era. *Dis Colon Rectum* 2013;56(4):458-66. doi:10.1097/DCR.0b013e31827085ec
20. Qingyang Feng WY, Li TY, Tang B, Jia BQ, Zhou YB, Zhang W, Zhao R, Zhang C, Cheng LW, Zhang XQ, Liang F, He GD, Wei Y, Xu JM; REAL Study Group. Robotic versus laparoscopic surgery for middle and low rectal cancer (REAL): short-term outcomes of a multicentre randomised controlled trial. *Lancet Gastroenterol Hepatol* 2022;7(11):991-1004. doi:10.1016/S2468-1253(22)00248-5
21. Asklid D, Ljungqvist O, Xu Y, Gustafsson UO. Short-term outcome in robotic vs laparoscopic and open rectal tumor surgery within an ERAS protocol: a retrospective cohort study from the Swedish ERAS database. *Surgical Endoscopy* 2022;36(3):2006-17. doi:10.1007/s00464-021-08486-y
22. Asklid D, Gerjy R, Hjern F, Pekkari K, Gustafsson UO. Robotic vs laparoscopic rectal tumour surgery: a cohort study. *Colorectal Dis* 2019;21(2):191-9. doi:10.1111/codi.14475
23. McIntosh S, Hunter R, Scrimgeour D, Bekheit M, Stevenson L, Ramsay G. Timing of urinary catheter removal after colorectal surgery with pelvic dissection: a systematic review and meta-analysis. *Ann Med Surg (Lond)* 2022;73:103148. doi:10.1016/j.amsu.2021.103148
24. Wu SW, Ma CC, Yang Y. Role of protective stoma in low anterior resection for rectal cancer: a meta-analysis. *World J Gastroenterol* 2014;20(47):18031-7. doi:10.3748/wjg.v20.i47.18031

原　著

術後加速康復 (ERAS) 方案在直腸癌患者手術預後中的影響：單中心經驗分析

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目的　術後加速康復 (Enhanced Recovery After Surgery, ERAS) 計畫旨在減少手術應激反應並促進術後恢復。儘管 ERAS 已被廣泛應用，但針對其在機器人直腸手術中的相關臨床效果，研究仍較為有限。因此，本研究比較了接受機器人手術與腹腔鏡手術的直腸癌患者，在應用 ERAS 計畫後的臨床結果。

材料與方法　我們回顧性收集接受修改版術後加速康復 (ERAS) 方案下選擇性腹腔鏡或機器人直腸癌手術患者的臨床數據。主要研究指標為術後住院時間 (LOS)，次要研究指標包括 ERAS 相關結果、併發症、術後 14 天內急診就診率及 30 天死亡率。

結果　本研究共納入本機構於 2022 年 1 月至 2024 年 4 月期間接受結直腸癌手術的 304 名患者。其中，30 名患者符合納入分析的標準，並分為機器人手術組與腹腔鏡手術組。結果顯示，機器人手術組的術後住院時間 (LOS) 略長於腹腔鏡手術組，但差異無統計學意義 (平均：11.4 ± 8.5 天 vs. 9.8 ± 6.3 天，中位數：8 [7-10.75] 天 vs. 8 [7-10] 天，p = 0.421)。腹腔鏡手術組較早拔除導尿管 (3.8 ± 2.8 天 vs. 2.3 ± 2.8 天，p = 0.038)。此外，機器人手術組的患者較常接受靜脈營養 (73.3% vs. 26.7%, p < 0.001)，但靜脈營養的使用時間較短 (4.86 ± 4.09 天 vs. 7.13 ± 5.11 天，p = 0.22)。兩組在併發症發生率、術後 14 天內急診就診率、30 天死亡率及病理學結果方面均無顯著差異。進一步的次群分析結果與主要分析結果相似。

結論　機器人直腸手術在修改版術後加速康復 (ERAS) 方案下，其短期療效不劣於其他治療方式，對於直腸癌患者來說可作為一種替代選擇。中低位直腸癌患者也可能適合採用此種替代方案。

關鍵詞　機器手臂手術、直腸癌、術後加速康復 (ERAS)。