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Original Article

Comparing Perioperative Outcomes between Robotic-assisted and Laparoscopic Surgery for Colon Cancer: A Retrospective Analysis

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Key Words
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Colon cancer;
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Introduction. Colorectal cancer (CRC) was the leading cancer in Taiwan for 15 years until 2020, with 16,880 new cases diagnosed in 2021. Surgical resection, including laparoscopic surgery (LSS), remains an effective treatment. Robotic-assisted surgery (RAS) offers increased precision, but its use in colon cancer remains debated due to higher costs and longer operating times. This study compares perioperative outcomes between RAS and LSS for stage 1-3 colon cancer resections.
Methods. This retrospective study analyzed patients undergoing curative colon cancer resection with either RAS (da Vinci Xi) or LSS between 2018 and 2024. Preoperative and postoperative indicators were evaluated. A total of 831 cases were included (RAS: 179, LSS: 652).
Results. RAS patients were older and had more sigmoid colon lesions. RAS resulted in longer operative times (mean: 284.4 vs. 211.9 minutes, $p < 0.001$), fewer conversions to open surgery (0.5% vs. 2.9%, $p = 0.061$), and reduced drainage tube placements. Postoperative recovery was faster in the RAS group, including earlier drinking, eating, and bowel movements, with shorter hospital stays (5.8 vs. 8.9 days, $p < 0.001$). RAS patients experienced fewer minor complications, including ileus (8.4% vs. 19.3%, $p = 0.001$) and chyle leakage (0% vs. 2.1%, $p = 0.049$). However, RAS had a higher readmission rate (10.6% vs. 5.8%, $p = 0.025$), mostly due to minor complications (83.3%).
Conclusions. Robotic-assisted surgery for colon cancer demonstrates faster recovery, fewer minor complications, and shorter hospital stays compared to laparoscopic surgery. Despite higher costs and longer surgery times, RAS is a valuable option for selected patients undergoing colon cancer resection.
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Colorectal cancer consistently topped the list of cancer incidence rates for 15 years until 2020. Based upon epidemiological data taken from the Taiwan Cancer Registry, there were 16,880 newly diagnosed cases of colorectal cancer in Taiwan in 2021, among which 10,347 were new cases of colon cancer.[1] With a 5-year relative mortality rate of 35.1%.[2] Early detection remains essential with surgical resection remaining as one of the most effective treatment methods. The advent of laparoscopic surgery (LSS) has ushered in the era of minimally invasive surgery for colon cancer patients. Compared to traditional open surgery,

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LSS is a minimally invasive method which offers a faster recovery period and non-inferior oncological outcomes.[3,4] Over its years of development, LSS outcomes have significantly improved, with a reduction in conversion to open surgery being seen as well as lower postoperative complication rates.[5,6]

In recent years, robotic-assisted surgery (RAS), with its flexible wrists and precise cameras, has allowed surgeons to better identify organ structures and ideally follow any necessary surgical plan, particularly when performing low rectal cancer resection.[7] In March of 2023, Taiwan's National Health Insurance Administration approved reimbursement for robotic-assisted low rectal resection surgery. However, there still remains little evidence regarding the use of RAS for colon surgery. Some medical personnel believe that colon cancer surgery is relatively simple, and that laparoscopic assistance can achieve equally good results. Being that robotic assistance surgery has its limitations, including higher costs and longer overall surgical time,[8] many physicians remain cautious about its use in colon cancer resection.

This study both analyzes and compares the perioperative outcomes of robotic-assisted versus laparoscopic surgery for stage 1-3 colon cancer curative resections at a single medical center, aiming to provide more evidence for the application of robotic-assisted surgery in the treatment of colon cancer.

Materials and Methods

This study retrospectively analyzed patients who underwent routine colon cancer resection with either robotic assistance (da Vinci Xi) or laparoscopic surgery at a medical center in Taiwan from January 1, 2018, to February 29, 2024. Preoperative characteristics and postoperative recovery indicators were each analyzed in order to determine whether robotic assistance offered better surgical outcomes and recovery when compared to traditional laparoscopic surgery in minimally invasive colon cancer surgery patients. Data analysis was conducted from April 1 to May 15, 2024. This study was approved by Taichung Veterans General Hospital's Institutional Review Board (IRB), code: CE24324B.

Inclusion criteria

Patients having a diagnosis of colon cancer, clinical stages 1-3, with an American Society of Anesthesiologists (ASA) score of three or below who underwent elective and curative colon resection involving either robotic-assisted or laparoscopic surgery were included in the study.

Exclusion criteria

Any patient with a tumor located in their rectal segment was excluded. The definition of a tumor located in the rectal segment is a tumor observed within 15 cm from the anal verge as seen during a colonoscopy, a tumor identified below the S3 level on images, or a tumor shown in specimen photographs as being located below the point where taeniae coli disappear, which itself is defined as the upper rectum segment above the peritoneal reflection.[9] Traditional open surgery, a non-colonic adenocarcinoma diagnosis, metastatic colorectal cancer, combined other organ resection (liver, bladder, ureter or uterus), emergency surgery and unclear medical records were also all considered exclusion criteria. Cases within the learning curve for the robotic system of each surgeon (first twenty cases) were also excluded according to results from the previous study.[10]

The following contents were all analyzed. The primary outcomes for this study were perioperative outcomes of RAS and LSS. The secondary outcomes were rate of complications and 30-day re-admission and compositions of these events.

Analysis content

Preoperative Factors: Patient age, gender, Body Mass Index (BMI), ASA anesthetic risk, tumor location, clinical stage, bowel preparation, Patient-controlled analgesia (PCA) insertion, and enhanced recovery after surgery (ERAS) protocol applications.

Intraoperative Outcomes: Surgical procedure, surgery time, blood loss, blood transfusion events, placement of drainage tube, stoma creation, rate of conversion to open surgery, pathological staging, pathological circumferential resection margin (CRM) being positive (pCRM+), tumor edge to colon cut end distal margin, and the number of lymph nodes (LNs) harvested.

Postoperative Recovery: Time to first drink of water, liquid diet intake and defecation, as well as time to urinary catheter removal and intravenous therapy (IV) removal. Additionally, length of hospital stay was recorded. The proportion of textbook recovery (discharge within 5 days without complications) was calculated while considering Taiwan's National Health Insurance system, where patients often stay a few extra days for observation. IV discontinuation (DC) textbook outcome was recalculated based upon IV removal indicating readiness for discharge. Postoperative complications within 30 days were classified using Clavian-Dindo scores: Grade I minor where the patient requires symptomatic medication, IV support, bedside wound dressing, physical therapy, or nasogastric tube insertion; Grade II minor where the patient requires upgraded antibiotics, blood transfusion or total parenteral nutrition (TPN) support; Grade III where the patient requires radiologic or surgical intervention; Grade IV major where the patient experiences single or multiple organ failure and requires intensive care unit (ICU) treatment; and Grade V major where the patient had died due to any surgical factors within 30 days postoperatively. Common complications included ileus, wound infection, pneumonia, cardiovascular events, cardiopulmonary events, anastomotic leakage and chylous ascites, all of which were separately recorded. Readmission to the hospital within 30 days, and the reasons why, were also analyzed.[11]

Complication events were defined as: 1. Cardiovascular events: any incident related to the heart or blood vessels occurring after surgery which include myocardial infarction, non-ST-elevation myocardial infarction (NSTEMI), arrhythmia, deep vein thrombosis, or other cardiovascular disturbance; 2. Pneumonia: an infection or inflammation within the lungs which has induced fever, chills or difficulty in breathing, in turn requiring the patient to be supported by an oxygen supplement or ventilation machine; 3. Ileus: cessation of a normal bowel movement after surgery, which has induced abdominal distension, nausea and/or vomiting, while also creating the inability to pass gas or stool. Any evidence of such complications can be proved through a physical exam or an abdominal kidney, ureter or bladder radiography (KUB) exam; 4. Wound infection: an infection which occurs at the site of surgical incision, with signs including redness, swelling or pus discharge; 5. Leakage: the leakage of fluids such as bowel content or bile juice from an anastomosis, as proven by a physical exam, images and laboratory data; 6. Chyle: the accumulation of lymphatic fluid in the abdomen cavity, typically proved through laboratory data involving the enrichment of triglycerides or via images; 7. Urinary tract infection (UTI): an infection of the urinary tract system, as related to urine retention and subsequent fever which can be proved through laboratory data.[12,13]

Textbook outcome (TO) is a novel surgical quality assessment tool which combines structure, process and surgical outcome.[14,15] We defined TO as a hospital stay of less than 5 days (75th percentile), along with the absence of any 30-day complications, need for readmission, or mortality.[16]

Data were analyzed in order to compare the differences in surgical outcomes and recovery status between robotic-assisted and traditional laparoscopic-assisted surgeries in routine curative colon cancer resection.

Statistical analysis

Quantitative data are expressed as the mean ± SD. One-way analysis of variance (ANOVA) with a least significant difference (LSD) multiple comparison was used to analyze the quantitative differences between the two groups. Groups were compared using t tests, Mann-Whitney U tests, Chi-square tests and Fisher's exact tests as deemed appropriate. Statistical analyses were performed with IBM SPSS 20.0 software (SPSS Inc., Chicago, IL, USA). Significance was set at $p < 0.05$.

Results

During the period from January 1, 2018, to February 29, 2024, a total of 1,715 minimally invasive colorectal surgery patients were enrolled, with 461 having used robotic assistance and 1,254 laparoscopic surgery. Amongst the 461 robotic cases, the following were excluded: 180 cases which had a lesion located in the rectal segment, 40 which been diagnosed as non-colonic adenocarcinoma, 26 which were diagnosed as metastatic disease, 18 which were within the robotic system learning curve (first twenty cases) of each surgeon, 15 which had undergone surgery involving other organs, two total colectomy cases, and one double cancer case. Amongst the 1,254 cases which underwent laparoscopic surgery, the following were excluded: 240 cases involving non-colonic adenocarcinoma, 204 which had a lesion located in the rectal segment, 97 which were diagnosed as metastatic disease, 40 which involved surgery with other organs, twelve which were emergency situations, four which were classified as ASA score IV, three which were undergoing total colectomy, and two which involved re-operative surgery. Ultimately, a total of 179 cases which underwent robotic-assisted surgery and 652 cases of laparoscopic surgery for colon cancer were included (Fig. 1).

Preoperative factors

Compared to the traditional laparoscopic surgery patients, the robotic-assisted surgery patients were older [median age: 73.5 (63.7-80.6) vs. 65.1 (56.3-74.4), $p < 0.001$], and had a higher proportion of elderly (> 80 years) patients (26.3% vs. 14.6%, $p < 0.001$) when compared to the LSS patients. Case characteristics regarding gender ratio, BMI and ASA distribution were similar between the RAS and LSS groups. More patients in RAS were diagnosed with sigmoid colon lesions (62.0% vs. 51.5%, $p = 0.033$), while fewer RAS patients had right-sided lesions (31.3% vs. 41.9%, $p = 0.033$), indicating the lower prevalence of RAS application for right side colon surgery. Perioperative bowel preparation (94.4% vs. 95.1%, $p = 0.674$) and clinical stage was similar between each group. More robotic-assisted patients received PCA (91.1% vs. 34.2%, $p < 0.001$) and entered the ERAS protocol (91.1% vs. 13.4%, $p < 0.001$) (Table 1).

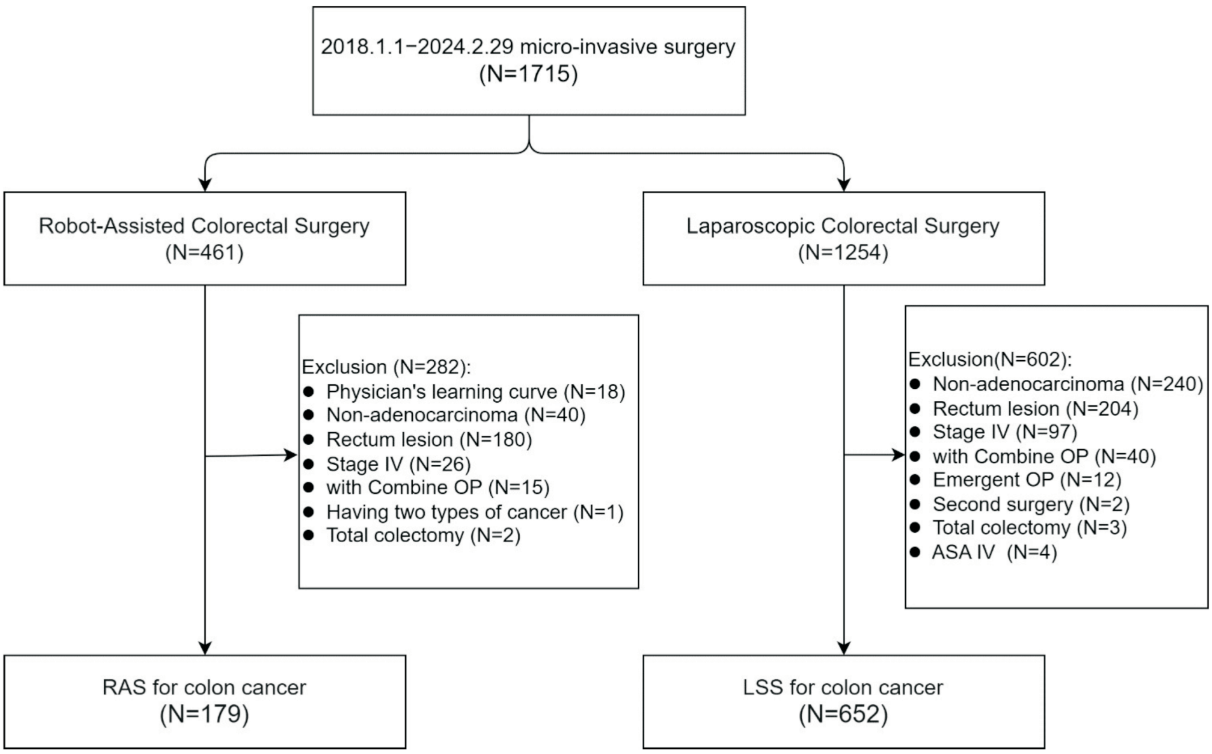

Fig. 1. Schematic illustration for study materials and methods.

Table 1. Patient characteristics for elective colon cancer resection using robot assisted surgery (RAS) and laparoscopic (LSS) surgery

	RAS (n = 179)	LSS (n = 652)	*p*
Gender			0.357
Female	82 (45.8%)	324 (49.7%)	
Male	97 (54.2%)	328 (50.3%)	
Age			
Mean (SD)	72.1 ± 11.6	65.0 ± 13.0	< 0.001**
Median (IQR)	73.5 (63.6-81.2)	65.1 (56.2-74.4)	< 0.001**
Age group			< 0.001**
21-40	0 (0.0%)	21 (3.2%)	
41-60	30 (16.8%)	205 (31.4%)	
61-80	102 (57.0%)	331 (50.8%)	
> 80	47 (26.3%)	95 (14.6%)	
BMI			
Mean	24.72 ± 4.00	24.32 ± 3.95	0.520
< 18	7 (3.9%)	21 (3.2%)	
18-25	100 (55.9%)	374 (57.4%)	0.871
> 25	72 (40.2%)	257 (39.4%)	
ASA			0.856
1	18 (10.1%)	74 (11.3%)	
2	106 (59.2%)	387 (59.4%)	
3	55 (30.7%)	191 (29.3%)	
Malignant disease			
Lesion site			0.033*
Rt	56 (31.3%)	273 (41.9%)	
Lt	12 (6.7%)	43 (6.6%)	
Sigmoid	111 (62.0%)	336 (51.5%)	
Clinical stage			0.247
0	6 (3.4%)	20 (3.1%)	
1	46 (25.7%)	188 (28.8%)	
2	51 (28.7%)	218 (33.4%)	
3	76 (42.7%)	226 (34.7%)	
Bowel preparation	169 (94.4%)	620 (95.1%)	0.714
PCA	163 (91.1%)	222 (34.0%)	< 0.001**
ERAS	163 (91.1%)	89 (13.7%)	< 0.001**

Chi-square test or independent t-test/Mann-Whitney U test. * $p < 0.05$.

Intraoperative outcomes

Robotic-assisted surgery (RAS) patients experienced more anterior resection (without opened peritoneum reflex) and fewer right-side hemicolectomies (RH) (27.9% vs. 39.1%, $p < 0.041$) than the LSS patients. RAS required significantly longer surgical times [median: 278.0 (234.0-323.0) vs. 197.0 (152.0 vs. 254.0), $p < 0.001$] [mean: 284.4 (±66.5) vs. 211.9 (±86.7), $p < 0.001$] when compared to LSS. Blood loss [52.9 (±111.5) vs. 50.8 (±96.0), $p = 0.801$) and transfusion events (2.8% vs. 3.6%, $p = 0.508$) were similar. The rate of transfer to open was with the trend which has shown it to be lower (0.6% vs. 3.1%, $p = 0.061$) in RAS. There were fewer drainage tube placements in the RAS (16.8% vs. 73.8%, $p < 0.001$) patients. The stoma creation rate (1.1% vs. 0.6%, $p = 1.000$), pathological staging distribution, and CRM positive rate (1.7 vs. 0.9%, $p = 0.414$) showed no differences. The distal margin in RAS was with the trend, showing to be fewer (4.3 ± 3.5 cm vs. 4.9 ± 5.0 cm, $p = 0.117$). The number of lymph nodes harvested showed a trend of being higher in the RAS group compared to the LSS group (27.4 ± 11.9 vs. 25.8 ± 10.6, $p = 0.091$) (Table 2). As for the protective ileostomy, it was performed in two cases in the RAS group and four cases

Table 2. Intra-operative outcomes for the robot assisted surgery (RAS) and laparoscopic (LSS) surgery patients

	RAS (n = 179) N (%)	LSS (n = 652) N (%)	*p*
Surgery			0.041*
RH	50 (27.9%)	255 (39.1%)	
LH	17 (9.5%)	53 (8.1%)	
AR	112 (62.6%)	342 (52.5%)	
T-colectomy	0 (0.0%)	2 (0.3%)	
Operation time, minutes			
Median (IQR)	278.0 (234.0-323.0)	197.0 (152.0-254.0)	< 0.001**
Mean	284.4 ± 66.5	211.9 ± 86.7	< 0.001**
Blood loss			
Median (IQR)	30.0 (30.0-30.0)	30.0 (30.0-30.0)	0.397
Mean	52.9 ± 111.5	50.8 ± 96.0	0.801
Blood transfusion			0.508
Yes	5 (2.8%)	25 (3.8%)	
Open rate	1 (0.6%)	20 (3.1%)	0.061
Drainage tube			< 0.001**
Yes	149 (83.2%)	171 (26.2%)	
No	30 (16.8%)	481 (73.8%)	
Stoma creation	2 (1.1%)	4 (0.6%)	1.000
Pathology stage			0.159
0	11 (6.1%)	29 (4.4%)	
1	39 (21.8%)	195 (29.9%)	
2	63 (35.2%)	200 (30.7%)	
3	66 (36.9%)	228 (35.0%)	
pCRM+	3 (1.7%)	6 (0.9%)	0.414
Distal margin	4.3 ± 3.5	4.9 ± 5.0	0.117
LN harvest	27.4 ± 11.9	25.8 ± 10.6	0.091

Chi-square test/Fisher's exact test or independent t-test/Mann-Whitney U test. * $p < 0.05$, ** $p < 0.01$.

in the LSS group. In three of these cases, patients had underlying conditions such as uremia or a history of coronary artery disease (CAD). Additionally, two cases involved patients with a partially obstructed colon, while the final case involving a locally advanced descending colon cancer underwent neoadjuvant radiotherapy, necessitating the ileostomy.

Postoperative recovery

Robotic-assisted surgery patients experienced significantly earlier times to their first drink of water (0.5 (±0.8) vs. 2.2 (±1.7) days, $p < 0.001$), first consumption of a liquid diet (0.8 (±0.8) vs. 2.7 (±1.9) days, $p < 0.001$), first defecation (1.8 (±1.7) vs. 3.8 (±2.5) days), urinary catheter removal (2.2 (±2.9) vs. 4.5 (±5.3) days, $p < 0.001$), and IV removal (4.4 (±5.0) vs. 8.0 (±6.3) days, $p < 0.001$) when compared to the LSS patients, along with shorter hospital stays as well (5.8 (±4.9) vs. 8.9 (±6.8 days), $p < 0.001$). There was a significantly higher proportion of textbook outcomes (50.3% vs. 14.7%, $p < 0.001$) and TO based on IV removal (83.2% vs. 25.8%, $p < 0.001$) in the RAS cases. Additionally, the RAS cases experienced significantly lower postoperative complication rates (23.5% vs. 32.5%, $p = 0.020$), as well as significantly fewer mild complications (20.1% vs. 28.1%, $p = 0.032$). Major complications (4.5% vs. 4.6%, $p = 0.940$) and mortality (0.6% vs. 0.8%, $p = 1.000$) were similar between the two groups (Table 3).

Complications compositions

A detailed examination revealed the top seven complications as being ileus, any cardiovascular event, pneumonia, UTI, chyle ascites, wound infection and

Table 3. Post operative outcomes for the robot assisted surgery (RAS) and laparoscopic surgery (LSS) patients

	RAS (n = 179) N (SD)	LSS (n = 652) N (SD)	p
Water intake (days)	0.5 (±0.8)	2.2 (±1.7)	< 0.001**
Liquid diet intake (days)	0.8 (±0.8)	2.7 (±1.9)	< 0.001**
Defecation (days)	1.8 (±1.7)	3.8 (±2.5)	< 0.001**
Foley removal (days)	2.2 (±2.9)	4.5 (±5.3)	< 0.001**
Days to DC IV	4.4 (±5.0)	8.0 (±6.3)	< 0.001**
Days to discharge	5.8 (±4.9)	8.9 (±6.8)	< 0.001**
	n (%)	n (%)	
Textbook outcomes	90 (50.3%)	96 (14.7%)	< 0.001**
DC IV textbook outcomes	149 (83.2%)	168 (25.8%)	< 0.001**
Any grade complications	42 (23.5%)	212 (32.5%)	0.020*
Minor complications			0.032*
All	36 (20.1%)	183 (28.1%)	
1	19 (55.9%)	103 (56.3%)	0.965
2	15 (44.1%)	80 (43.7%)	
Major complications			0.940
All	8 (4.5%)	30 (4.6%)	
3	5 (62.5%)	17 (58.6%)	0.949
4	2 (25.0%)	7 (24.1%)	
Mortality			
5	1 (12.5%)	5 (17.2%)	

Chi-square test/Fisher's exact test or independent t-test. * $p < 0.05$, ** $p < 0.01$.

anastomotic leakage. Robotic-assisted surgery showed significantly lower ileus rates (8.4% vs. 19.3%, p = 0.001) and lower chyle leak rates (0% vs. 2.1%, p = 0.049). There was also a lower rate, but without any significance, in cardiovascular events (0.0% vs. 1.5%, p = 0.130), pneumonia (3.4% vs. 4.6%, p = 0.467), and UTIs (1.1% vs. 1,8%, p = 0.746). The wound infection rate (3.9% vs. 3.5%, p = 0.808) and anastomosis leakage rate (2.2% vs. 2.0%, p = 0.771) were similar between RAS and LSS, while the 30-day readmission rate was significantly higher in the RAS group (10.6% vs. 5.8%, p = 0.025). Readmission causes were mostly due to minor complications in both RAS and LSS patients (83.3% vs. 86.8%, p = 0.703) (Table 4).

Discussion

Robotic-assisted surgery has been widely advocated in the field of rectal surgery, particularly for its advantages in low rectal resection.[7] The flexibility of the robotic arms and cameras helps surgeons preserve both nerves and blood vessels while ensuring complete tumor removal and anus preservation. However, the results seen regarding the use of RAS for rectal cancer surgery in the ROLLAR study[6] did not show a significant decrease in the open rate nor in other surgical outcomes. This may be possibly due to RAS being performed by surgeons with varying experience in the technique. In this study, we excluded the first twenty cases handled by each surgeon in order to eliminate this bias. The open rate showed a lower trend in RAS than in LSS (0.6% vs. 3.1%, p = 0.061). In contrast, there has been less emphasis on the use of RAS in general colon surgeries, including this study, where robotic-assisted surgeries were less frequently used for right-sided colorectal cancers, but more commonly for both left-sided sigmoid colon cancers and older patients. Our retrospective study results show that RAS brings a significantly faster recovery time as well as shorter hospital stays for colon cancer resection patients when compared to LSS. These findings suggest that robotic-assisted surgery has significant

Table 4. The seven most common complications and 30-day re-admission reasons for the robot assisted surgery (RAS) and laparoscopic (LSS) surgery patients

	RAS (n = 179) N (%)	LSS (n = 652) N (%)	*p*
Ileus	15 (8.4%)	126 (19.3%)	0.001**
Cardiovascular	0 (0.0%)	10 (1.5%)	0.130
Pneumonia	6 (3.4%)	30 (4.6%)	0.467
UTI	2 (1.1%)	12 (1.8%)	0.746
Chyle	0 (0.0%)	14 (2.1%)	0.049*
Wound inf.	7 (3.9%)	23 (3.5%)	0.808
Leakage	4 (2.2%)	13 (2.0%)	0.771
30-day re-admission	19 (10.6%)	38 (5.8%)	0.025*
Minor/major			0.703
Re-admission due minor	15 (83.3%)	33 (86.8%)	
Re-admission due major	3 (16.7%)	5 (13.2%)	

Chi-square test/Fisher's exact test or independent t-test. * $p < 0.05$, ** $p < 0.01$.

advantages in improving patient recovery time, while also reducing certain complications in colon cancer treatment. RAS patients experienced quicker times to drinking water, eating and bowel movements after surgery. Additionally, the lower incidence of postoperative ileus contributed to faster recoveries and shorter hospital stays. This can be attributed to the technique's advantage in offering precise movements, which reduces damage and improves recovery. We analyzed patient pain scores on the day of surgery (Fig. 2) and discovered that patients undergoing RAS reported significantly lower pain, thus facilitating earlier mobilization, which in turn stimulates bowel motility and significantly reduces ileus (8.4% vs. 19.3%, $p = 0.001$). There is also the lower trend of cardiovascular (0.0% vs. 1.5%, $p = 0.130$) and pneumonia complications (3.4% vs. 4.6%, $p = 0.467$) which results from the use of RAS. The chyle rate was also significantly lower in RAS patients (0.0% vs. 2.1%, $p = 0.049$). This occurs because the robotic-assisted system possesses bipolar coagulation capabilities on both arms, allowing the surgeon to easily coagulate the lymphatic vessels, and thus reducing the likelihood of postoperative chyle leakage. Consequently, the overall complication rates were lower. A high proportion of patients in RAS groups potentiate to achieve textbook recovery times (IV DC textbook outcome: 84.2%). Although it comes with higher costs and longer surgical times, robotic-assisted surgery is still worth considering in specific cases. Future research should help towards further optimizing robotic-assisted surgery's cost-effectiveness, while also expanding its application in colorectal cancer treatment.

	Robot (n = 179)	LSS (n = 652)	*p* value
POD0 VAS	3 (2-3)	5 (3-7)	< 0.001**

Mann-Whitney U test. * $p < 0.05$, ** $p < 0.01$.

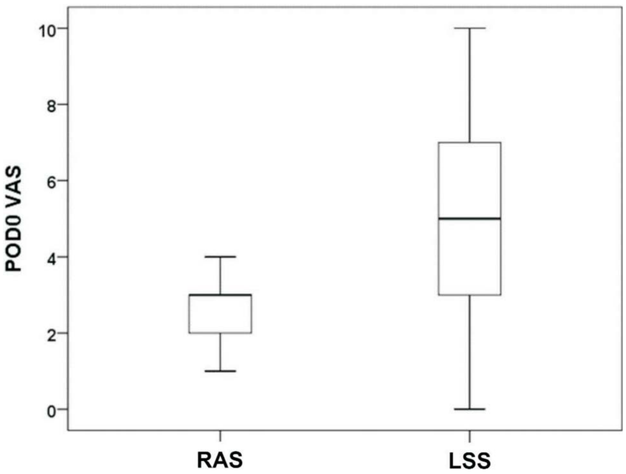

Fig. 2. Severity of pain on post operative Day 1, scaled using pain score grading.

Additionally, RAS delegated dissection potentially harvested more lymph nodes than LSS (27.4 (±11.9) vs. 25.8 (±10.6), $p = 0.091$) in this study. However, the limited surgical field in RAS may have influenced the adequacy of the distal margin (4.3 (±3.5) vs. 4.9 (±5.0), $p = 0.117$) when compared to LSS, which needs to be overcome through repeated practice. Our results are also coherent with another study[8] in regards to right-sided colon cancer.

A recent large-scale data analysis performed by Farah et al.[16] using a large database taken from ACS-NSQIP during the period from 2015 to 2020 showed a similar result with our study. For rectal cancer resection, there were no significant advantages seen in robotic-assisted surgery. Apart from similar lymph node harvest numbers and slightly shorter hospital stays, there were higher rates of ileus, leakage, major complications and readmission. In contrast, RAS in colon cancer resection provided more lymph node retrieval, a lower conversion to open surgery rates, shorter hospital stays, and fewer instances of ileus, with the only downside being longer surgical times.

Regarding major complications in our study, robotic-assisted surgery and traditional laparoscopic surgery had similar results (4.5% vs. 4.6%, $p = 0.940$). The most concerning postoperative complication in colon surgery, anastomotic leakage, showed no difference in occurrence between the two groups (2.2% vs. 2.0%, $p = 0.771$). This indicates that robotic-assisted surgery does not reduce the likelihood of anastomotic leakage,[6,16,17] suggesting that other patient factors such as nutritional status, smoking history, vascular health, diabetes and renal disease may all influence anastomotic healing.

There were seven major complication cases seen in the RAS group, with four cases being due to anastomosis leakage, two due to pneumonia, one for fascia dehiscence, and a final one due to small bowel injury. Notably, the trocar sites for RAS were far apart. If the instruments are not carefully kept under the abdominal wall when docking, and instead go deeper into the mesentery, they may damage the small bowel. This is a challenge that the entire surgical team needs to be aware of and ultimately overcome during the procedure's learning curve.[18] Scheduling robotic surgeries to start in the morning and performing only simple cases like typical anterior resection can help reduce the risk of complications caused by medical personnel fatigue.[19] Therefore, having a dedicated room strictly for robotic system surgeries is necessary. Robotic-assisted surgery showed a higher 30-day readmission rate (10.2% vs. 6.7%, $p = 0.025$), but this was mainly due to minor complications (85.0%) resulting from both ileus (35%) and wound infections (20%). These complications were likely not observed during the initial hospital stay due to patients being given an earlier discharge, as opposed to being due to any major complications.

Robotic arms are becoming increasingly more suitable for complex surgeries involving multiple organs.[20] In cases of rectal cancer with liver metastasis, when compared to open surgery, RAS helps reduce complication rates (31.4% vs. 57.6%, $p = 0.014$), improves bowel movement (63.7 hours vs. 93.8 hours, $p < 0.001$) and shows no difference in 3-year disease free survival rates (39.5% vs. 35.5%, $p = 0.739$).[21] Robotic-assisted surgery (RAS) also offers greater precision, which is beneficial in delicate procedures. Recent studies also show that RAS patients experience a lower inflammatory response, leading to faster recovery times.[22] This makes robotic arms a valuable tool in modern surgical practices, particularly in complex cases.

This study has some limitations. There were inherent differences between patients undergoing robotic-assisted surgery and those undergoing laparoscopic surgery, such as patient age and tumor location, which affected the population distribution. The differences in interventions like PCA and ERAS protocol adherence impacted both the surgical outcomes and pain score objectivity. The ERAS (Enhanced Recovery After Surgery) protocol,[23,24] which includes preoperative education, precise intraoperative anesthesia and fluid management, and early postoperative feeding and rehabilitation, has been widely promoted by surgical societies worldwide in recent years. Many concepts involving preoperative education and early postoperative feeding and activity have been integrated into laparoscopic surgeries. In the Ripollés-Melchor, J., et al. study,[25] even the non-ERAS group experienced a 59.1% ERAS implementation rate, as compared to 72.7% in the ERAS group, indicating that the gap between ERAS and non-ERAS groups is narrowing. Current patients, regardless of ERAS protocol inclusion, are influenced by ERAS principles in their perioperative care. This difference warrants future prospective studies which will allow for a more objective and detailed comparison of the outcomes seen in each of the two surgical methods.

Conclusions

Robotic-assisted surgery for colon cancer patients demonstrates significant benefits in terms of faster recovery, a reduction in minor complications, and shorter hospital stays when compared to laparoscopic surgery. Despite the challenges seen in regards to its higher costs and longer operative times, the improved outcomes associated with RAS suggest it is a valuable option for colon cancer resection surgery.

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References

1. 110 癌症登記報告. 2023-11-10; Available from: https://www.hpa.gov.tw/Pages/List.aspx?nodeid=269.
2. 台灣 10 大癌症 106-110 年新發個案存活率 (追蹤至 111) . 2024; Available from: https://twcr.tw/.
3. Nelson H, et al. A comparison of laparoscopically assisted and open colectomy for colon cancer. *N Engl J Med* 2004; 350(20):2050-9.
4. Veldkamp R, et al. Laparoscopic surgery versus open surgery for colon cancer: short-term outcomes of a randomised trial. *Lancet Oncol* 2005;6(7):477-84.
5. Falk PM, et al. Laparoscopic colectomy: a critical appraisal. *Dis Colon Rectum* 1993;36(1):28-34.
6. Jayne D, 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.
7. Kim NK, Kim YW, Cho MS. Total mesorectal excision for rectal cancer with emphasis on pelvic autonomic nerve preservation: expert technical tips for robotic surgery. *Surg Oncol* 2015;24(3):172-80.
8. Meyer J, et al. Robotic versus laparoscopic right hemicolectomy: a systematic review of the evidence. *J Robot Surg* 2024;18(1):116.
9. Steele SR, T.L.H., Hyman N, Maykel JA, Read TE, Whitlow CB. The ASCRS Textbook of Colon and Rectal Surgery Textbook, Fourth Edition. 2022.
10. Lin CY, et al. Learning curve and surgical outcome of robotic assisted colorectal surgery with ERAS program. *Sci Rep* 2022;12(1):20566.
11. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 2004; 240(2):205-13.
12. Kirchhoff P, Clavien PA, Hahnloser D, Complications in colorectal surgery: risk factors and preventive strategies. *Patient Saf Surg* 2010;4(1):5.
13. Scarborough JE, et al. Associations of specific postoperative complications with outcomes after elective colon resection: a procedure-targeted approach toward surgical quality improvement. *JAMA Surgery* 2017;152(2):e164681.
14. Yang CC, et al. The association between the composite quality measure "textbook outcome" and long term survival in operated colon cancer. *Medicine (Baltimore)* 2020;99:e22447.
15. Kolfschoten NE, et al. Focusing on desired outcomes of care after colon cancer resections; hospital variations in 'textbook outcome'. *European Journal of Surgical Oncology (EJSO)* 2013;39:156-63.
16. Farah E, et al. Perioperative outcomes of robotic and laparoscopic surgery for colorectal cancer: a propensity score-matched analysis. *World Journal of Surgical Oncology* 2023; 21(1):272.
17. Gebhardt JM, et al. Robotic-assisted versus laparoscopic surgery for rectal cancer: an analysis of clinical and financial outcomes from a tertiary referral center. *J Clin Med* 2024; 13(6).
18. Guend H, et al. Developing a robotic colorectal cancer surgery program: understanding institutional and individual learning curves. *Surg Endosc* 2017;31(7):2820-8.
19. Müller C, et al. Surgical complexity and outcome during the implementation phase of a robotic colorectal surgery program-a retrospective Cohort study. *Front Oncol* 2020;10: 603216.
20. DiBrito SR, et al. Perioperative and oncological outcomes following robotic en bloc multivisceral resection for colorectal cancer. *Colorectal Dis* 2024.
21. Chang W, et al. Robotic versus open surgery for simultaneous resection of rectal cancer and liver metastases: a randomized controlled trial. *International Journal of Surgery* 2023;109(11).
22. Cuk P, et al. Surgical stress response in robot-assisted versus laparoscopic surgery for colon cancer (SIRIRALS): a randomized clinical trial. *Br J Surg* 2024;111(3).

23. Hung CY, et al. Developing a robotic surgical platform is beneficial to the implementation of the ERAS program for colorectal surgery: an outcome and learning curve analysis. *J Clin Med* 2023;12(7).
24. Lassen K, et al. Consensus review of optimal perioperative care in colorectal surgery: Enhanced Recovery After Surgery (ERAS) Group recommendations. *Arch Surg* 2009;144(10):961-9.
25. Ripollés-Melchor J, et al. Association between use of enhanced recovery after surgery protocol and postoperative complications in colorectal surgery: the postoperative outcomes within enhanced recovery after surgery protocol (POWER) study. *JAMA Surg* 2019;154(8):725-36.

原　著

機械手臂輔助與腹腔鏡手術於大腸癌切除手術前後結果比較分析：單一醫學中心回溯性研究

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引言　大腸癌在台灣自 2005 年起，連續 15 年位居癌症發病率之首，直到 2020 年。在 2021 年，台灣新增大腸癌病例達 16,880 例。外科手術切除，包括腹腔鏡手術 LSS，仍是治療大腸癌的有效方式。機器人輔助手術 RAS 由於能提供更高的精確度逐漸受到矚目，但在大腸癌中的應用仍具爭議，主要因為其較高的成本與較長的手術時間。本研究旨在比較 RAS 與 LSS 在第一至第三期大腸癌根治性切除手術中的圍手術期結果。

方法　本回溯性研究分析了 2018 年至 2024 年間，於台灣接受 RAS 或 LSS 進行大腸癌根治性切除的患者，並評估術前及術後指標。共納入 831 例患者 (RAS：179 例，LSS：652 例) 進行分析。

結果　RAS 組患者年齡較大，且有較多乙狀結腸病變。RAS 手術時間較長 (平均：284.4 分鐘 vs. 211.9 分鐘，$p < 0.001$)，但轉為開腹手術的比例較低 (0.5% vs. 2.9%, $p = 0.061$)，且使用引流管的比例較少。RAS 組患者術後恢復速度較快，包括更早飲水、進食及排便，且住院天數較短 (平均 5.8 天 vs. 8.9 天，$p < 0.001$)。此外，RAS 組輕微併發症的發生率較低，如腸阻塞 (8.4% vs. 19.3%, $p = 0.001$) 及乳糜漏 (0% vs. 2.1%, $p = 0.049$)。然而，RAS 組的再入院率較高 (10.6% vs. 5.8%, $p = 0.025$)，主要由輕微併發症 (83.3%) 引起。

結論　相較於腹腔鏡手術，機器人輔助手術在大腸癌患者中的術後恢復速度較快，輕微併發症較少，且住院天數較短。儘管其成本較高且手術時間較長，但 RAS 在大腸癌切除手術中具明顯優勢，適合特定患者群體選擇使用。

關鍵詞　機械手臂手術、腹腔鏡手術、大腸癌、手術前後恢復結果。