Original Article

Outcomes of Laparoscopic versus Robotic Surgery for Sigmoid Colon and Rectal Cancer: A Single-Center Young Colorectal Surgeon' Initial Experience

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Key Words
Colorectal cancer;
Laparoscopy;
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Purpose. Minimally invasive surgery is becoming increasingly important in its management of colorectal cancer. Laparoscopy, the most common type of minimally invasive surgery for colorectal surgery, has produced similar results to open surgery but has some limitations. Robotic surgery has emerged as an alternative, with potential benefits over laparoscopy. However, it is unclear whether young surgeons transitioning to robotic surgery require prior laparoscopic experience.
Methods. This study sought to compare the perioperative and postoperative outcomes of laparoscopic colorectal resection and robotic colorectal resection performed by a single early-career surgeon. Patients with colorectal adenocarcinoma who underwent anterior resection or low anterior resection between December 2019 and December 2023 were eligible. Surgical procedures, patient characteristics, intraoperative results, and postoperative complications were evaluated.
Results. A total of 60 surgeries were reviewed, with 30 robotic colorectal resection and 30 laparoscopic colorectal resection cases found. Patient demographics revealed no significant differences between the groups. Intraoperative outcomes revealed that robotic colorectal resection had significantly longer operative times than laparoscopic colorectal resection, but no significant differences in other parameters. Postoperative outcomes, including complications and oncologic measures, showed no significant difference between the groups.
Conclusions. Robotic colorectal resection performed by a young colorectal surgeon in the early stages of his career produces comparable intraoperative, oncologic, and postoperative results to laparoscopic colorectal resection. The study suggests that young colorectal surgeons can learn laparoscopic and robotic surgery skills concurrently, which is both safe and feasible.
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Colorectal cancer (CRC) is the third most common cancer and the second leading cause of cancer-related death globally.[1] The surgical management of CRC has evolved over the last decade, with mini-

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mally invasive procedures dominating the field. Minimally invasive surgery (MIS) is distinguished by smaller incisions, videoscopic imaging, and advanced technology. This approach allows for shorter hospital stays, less postoperative pain, better cosmetic results, and a faster return to normal activities.[2-4] Faced with a growing demand for MIS from patients, young surgeons must receive training in MIS techniques.

Among MIS in colorectal surgery, laparoscopy is the most commonly used. The early adoption of laparoscopy in colorectal surgery was relatively slow due to the long learning curve and concerns about oncologic adequacy. Nevertheless, growing evidence suggests that laparoscopic colectomy is a safe and effective treatment option for cancer, with long-term oncologic outcomes comparable to open surgery.[5,6] Laparoscopic surgery, however, has several drawbacks, including the need for rigid and inflexible devices, uncomfortable ergonomic positions, and the fulcrum effect, which impairs hand–eye coordination.[7] To address these limitations, robotic surgical systems have been introduced, with key benefits including tremor filtering, a 3-dimensional high-definition imaging system, and motion scaling, which allow for meticulous dissection.[8] Despite these presumed advantages, there is no strong clinical evidence to support the superiority of the robotic approach over traditional laparoscopy.[9-11] The ROLARR trial, the first and largest RCT of robot-assisted versus laparoscopic rectal resection, found that the benefit of robotic surgery over laparoscopy was greater among surgeons with more robotic experience.[9] However, there is no conclusive evidence that young surgeons must have prior experience with laparoscopy surgery before moving on to robotic surgery.[12] This study sought to compare the perioperative and postoperative outcomes of laparoscopic colorectal resection (LCR) and robotic colorectal resection (RCR) performed by a single early-career surgeon.

Materials and Methods

Study design

Between December 2019 and December 2023, consecutive patients who underwent LCR or RCR at Tri-Service General Hospital, Taiwan, were evaluated. All procedures were performed by a single surgeon who at the time of the study, was in his first year as an attending doctor. All consecutive patients with a histological diagnosis of colorectal adenocarcinoma who required either anterior resection (AR) or low anterior resection (LAR), were included in this study. Exclusion criteria included right and left colectomy, nonselective or emergency procedures, nonprimary colorectal cancer, and synchronous, metastatic, or recurrent disease.

Surgical procedures

Preoperative planning, surgical procedures, use of instruments, and postoperative care were all standardized. Preoperative evaluations for all patients included a physical examination, colonoscopy with tumor biopsy, contrast enhanced computed tomography scan of the chest and abdomen, and positron emission tomography scan. In laparoscopic-assisted AR and LAR, four trocar ports were placed as follows (Fig. 1): a 12-mm umbilical port with a 30° camera, one 12-mm port in the right lower quadrant (right hand working), and two 5-mm trocars in right upper quadrant (left hand working) and left upper quadrant (assistant hand working). Robotic-assisted anterior resection (AR) and low anterior resection (LAR) were performed with the robot docked on the left side of the patient, using the standard DaVinci HD Surgical System (Intuitive Surgical, Inc, Sunnyvale, CA, USA). Our hospital introduced the DaVinci Xi system in 2023; therefore, the first 19 cases were performed using the Si system, and the subsequent 11 cases used the Xi system. Three robotic working arms, as well as a camera, were utilized (Fig. 2). One assistant trocar port was used for further retraction.

In sigmoid and rectal resections, both laparoscopic and robotic operation were approached from medial to lateral. The left colon and sigmoid colon were mobilized by carefully dissecting the tissues and dividing the blood vessels supplying these areas. The inferior mesenteric artery and vein were typically ligated and divided. A trans-anal end-to-end mechanical anastomosis was used. The specimen was always extracted via the extended umbilicus incision (camera

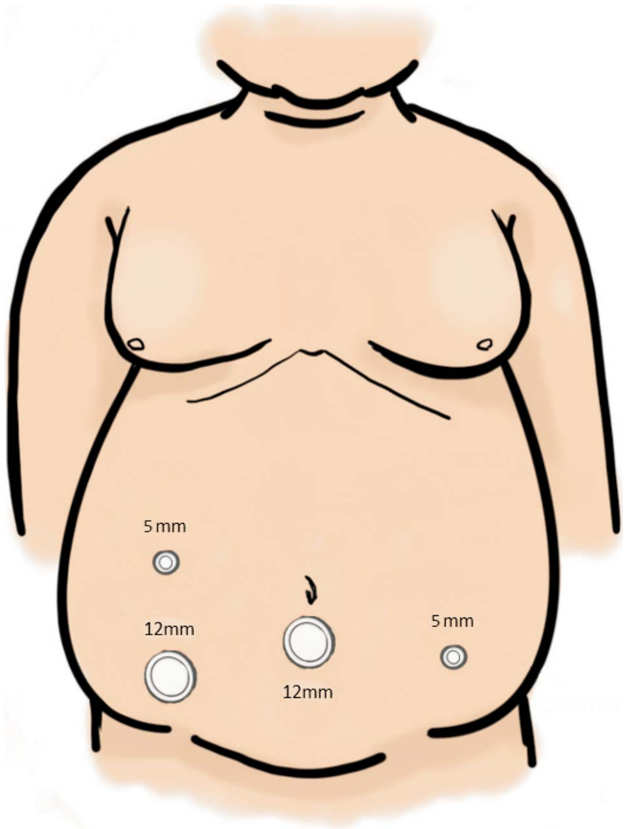

Fig. 1. Trocar placement in laparoscopic-assisted AR and LAR.

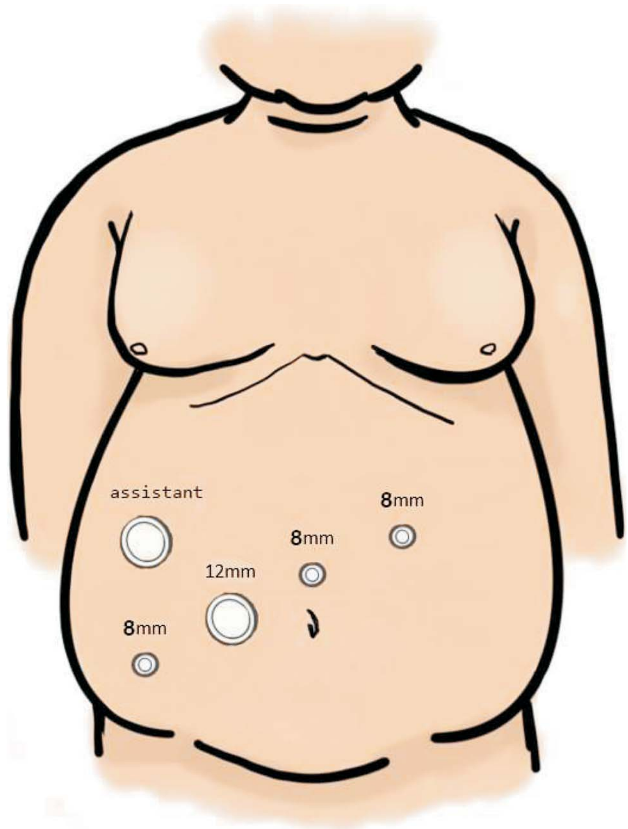

Fig. 2. Trocar placement in robotic-assisted AR and LAR.

port). A diverting ileostomy is not routinely created; it is determined based on the surgical scenario, considering factors such as excessive adhesions or colorectal injuries sustained during the procedure. Notably, LAR was defined as a standard surgical procedure, including dissection and anastomosis conducted below the peritoneal reflection, for mid to low rectal cancer. The decision to use a laparoscopic or robotic approach was based on the patient's preference and the accessibility of the robotic platform.

Outcomes evaluated

We compared baseline preoperative characteristics of patients undergoing LCR and RCR, including age, sex, body mass index (BMI), ASA class, received neoadjuvant chemoradiotherapy, and Eastern Cooperative Oncology Group (ECOG) performance status. We evaluated intraoperative outcomes including tumor location (distance from anal verge, cm), blood loss, surgical margin, stage, number of lymph nodes harvested, unplanned conversion to open, diverting stoma, and operative time. Finally, we assessed the following postoperative outcomes: length of hospital stay, postoperative ileus, anastomotic leak, major morbidity, 30-day readmissions, and 30-day mortality.

Operative time was measured from skin incision to wound closure. For RCR, docking time was included in the total operative time. Postoperative major morbidity was defined as events that occurred during the hospital stay or within 90 days of resection, specifically those that exceeded a Clavien–Dindo grade of 2. Oncological outcomes included the surgical margin and the number of lymph nodes harvested. The surgical margin consisted of proximal, distal, and circumferential resection margins (CRMs).

Statistical analysis

Statistical software (SPSS 25.0; SPSS Inc., Chicago, IL, USA) was used for all analyses. Categorical variables were analyzed using Fisher's exact test. Data for continuous variables were presented as means ± standard deviation and compared with Student's t-test and Chi-square. Statistical significance was determined as $p < 0.05$.

Ethics statement

This study was approved by the Institutional Review Board of the Tri-Service General Hospital (TSGH IRB No. A202405016; Taipei, Taiwan).

Results

A total of 100 patients underwent LCR or RCR throughout the study period. Two of these patients did not have primary colorectal cancer, while 3 had distal metastasis. Right and left colectomy were excluded (n = 30). Accordingly, 60 eligible patients (LCR: 30 patients; RCR: 30 patients, 14.1%) were identified (Fig. 3). The patient demographics are summarized in Table 1. There was no discernible difference in age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) score, Eastern Cooperative Oncology Group (ECOG) score, history of abdominal surgery, and whether they received neoadjuvant concurrent chemoradiotherapy (CCRT).

Table 2 summarizes intraoperative outcomes. The average lesion distance from the anal verge is 14.97 centimeter (cm) in RCR group and 15.30 cm in LCR group. The sigmoid colon was the most common tumor location in both groups. Low anterior resections (LAR) accounted for 40% (12) of RCR cases, and 63.3% (19) of LCR cases ($p = 0.121$). Among the group of patients who underwent LCR, there were a total of 17 patients with RS-colon or rectum lesions. However, 19 patients underwent LAR. This discrepancy arose because two patients with sigmoid colon lesions ultimately underwent LAR during surgery due to considerations regarding safe margins and blood supply. The proportion of patients who received diverting stomas was 20% in the RCR group and 30% in the LCR group ($p = 0.551$). In the RCR cases, approximately 401 minutes elapsed from the time between the first incision and the abdominal closure. In comparison, LCR surgeries took an average of 272 minutes ($p < 0.001$). Aside from operative time, there was no significant difference in the rate of intraoperative outcomes between the two groups.

Regarding oncologic outcome (Table 3), the pathologic TNM stage were not statistically distinct between the groups. Although the RCR cases appeared to have more lymph nodes harvested, there was no significant difference. Finally, there was no statistical difference between the cohorts concerning the mean tumor size, metastatic lymph node count, and proximal, distal, and circumferential resection margins (CRM).

Table 4 summarizes the postoperative outcomes. RCR cases appeared to have a lower rate of postoperative ileus, but no significant difference. There was no significant difference between the two groups in terms of postoperative complication rate (Clavien–Dindo score; $p = 0.626$), length of postoperative hospital stay ($p = 0.913$), 30-day readmission, and 30-day mortality.

Discussion

In this study, we conducted a direct comparison of LCR and RCR for sigmoid and rectal cancer, both conducted by a single young colorectal surgeon. This surgeon, who is still in the early stages of his career, has

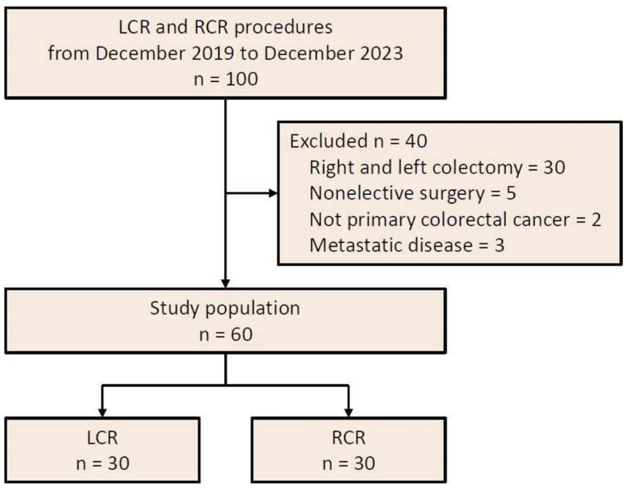

Fig. 3. Flowchart of the patient selection.

Table 1. Patient demographics

Patient characteristic	RCR (n = 30)	LCR (n = 30)	*p* value
Age, mean (SD)	62.60 (11.31)	65.47 (13.01)	0.366
Sex, No. (%)			0.796
F	13 (43.3)	15 (50.0)	
M	17 (56.7)	15 (50.0)	
BMI	23.66 (3.51)	23.79 (3.18)	0.879
Height, cm (SD)	161.82 (7.70)	159.91 (7.65)	0.339
Weight, cm (SD)	62.16 (11.04)	61.14 (11.13)	0.723
ASA score			0.444
1	18 (60.0)	13 (43.3)	
2	9 (30.0)	13 (43.3)	
3	3 (10.0)	4 (13.3)	
ECOG score			0.169
0	27 (90.0)	23 (76.7)	
1	3 (10.0)	3 (10.0)	
2	0 (0)	4 (13.3)	
Previous abdomen surgery			1.000
N	24 (80.0)	25 (83.3)	
Y	6 (20.0)	5 (16.7)	
Neoadjuvant CCRT			0.778
N	22 (73.3)	20 (66.7)	
Y	8 (26.7)	10 (33.3)	
Clinical T stage			0.960
cT1	5 (16.7)	4 (12.9)	
cT2	13 (43.3)	13 (41.9)	
cT3	9 (30.0)	11 (35.5)	
cT4	3 (10.0)	3 (9.7)	
Clinical N stage			0.822
cN0	17 (50.7)	15 (50.0)	
cN1	10 (33.3)	10 (33.3)	
cN2	3 (10.0)	5 (16.7)	
Clinical M stage			0.706
cM0	27 (90.0)	25 (83.3)	
cM1	3 (10.0)	5 (16.7)	

Unless otherwise indicated, values are presented as number (percentage).
ASA, American Society of Anesthesiologists; BMI, body mass index; ECOG, Eastern Cooperative Oncology Group; CCRT, concurrent chemoradiotherapy.
* $p < 0.05$ was considered statistically significant.

Table 2. Intraoperative outcomes

Outcome measure	RCR (n = 30)	LCR (n = 30)	*p* value
Mean lesion distance from anal verge, cm (SD)	14.97 (6.87)	15.30 (9.56)	0.877
Tumor location			0.491
S colon	17 (56.7)	13 (43.3)	
RS-colon	6 (20.0)	6 (20.0)	
Rectum	7 (23.3)	11 (36.7)	
Procedure			0.121
AR	18 (60.0)	11 (36.7)	
LAR	12 (40.0)	19 (63.3)	
Diverting stoma			0.551
No	24 (80.0)	21 (70.0)	
Yes	6 (20.0)	9 (30.0)	
Operative time	401.40 (129.96)	272.87 (112.35)	< 0.001
Blood loss, ml	185.33 (365.96)	210.00 (240.11)	0.759
Bleeding needed transfusion	0	0	NA
Conversion to open	0	0	NA

Unless otherwise indicated, values are presented as number (percentage).
AR, anterior resection; LAR, low anterior resection.
* $p < 0.05$ was considered statistically significant.

Table 3. Oncologic outcomes

Outcome measure	RCR (n = 30)	LCR (n = 30)	*p* value
Pathologic T stage			0.636
T1	6 (20.0)	3 (10.0)	
T2	8 (26.7)	8 (26.7)	
T3	15 (50.0)	16 (53.3)	
T4	1 (3.3)	3 (10.0)	
Pathologic N stage			0.806
N0	16 (53.3)	17 (56.7)	
N1	7 (23.3)	5 (16.7)	
N2	7 (23.3)	8 (26.7)	
Pathologic M stage			0.702
M0	27 (90.0)	25 (83.3)	
M1	3 (10.0)	4 (13.3)	
M2	0 (0)	1 (3.3)	
Stage			0.883
1	8 (26.7)	8 (26.7)	
2	7 (23.3)	7 (23.3)	
3	13 (43.3)	11 (36.7)	
4	2 (6.7)	4 (13.3)	
Surgical margin free**	30 (100)	30 (100)	NA
Mean number of metastatic lymph node (SD)	2.07 (2.99)	1.50 (3.20)	0.482
Mean number of lymph nodes harvested (SD)	15.27 (5.58)	13.53 (6.13)	0.257
Mean tumor size, cm (SD)	3.18 (1.81)	2.78 (1.55)	0.354
Surgical margins (P)	6.65 (3.45)	6.35 (3.95)	0.758
Surgical margins (D)	3.72 (1.98)	4.44 (3.68)	0.345
Surgical margins (CRM)	0.52 (0.30)	0.58 (0.58)	0.638

Unless otherwise indicated, values are presented as number (percentage).
Surgical margin P, proximal; D, distal; CRM, circumferential resection margin.
* $p < 0.05$ was considered statistically significant.
** The surgical margin consisted of proximal, and distal, circumferential resection margins.

Table 4. Postperative outcomes

Outcome measure	RCR (n = 30)	LCR (n = 30)	*p* value
Postoperative ileus			0.353
No	29 (96.7)	26 (86.7)	
Yes	1 (3.3)	4 (13.3)	
Anastomotic leak			1.000
No	30 (100.0)	29 (96.7)	
Yes	0 (0)	1 (3.3)	
Clavien-Dindo grade			0.626
0-1	26 (86.7)	23 (76.7)	
2	3 (10.0)	4 (13.3)	
3	1 (3.3)	3 (10.0)	
Length of postoperative hospital stay	9.50 (6.82)	9.67 (4.74)	0.913
30-day readmission	0	0	NA
30-day mortality	0	0	NA

Unless otherwise indicated, values are presented as number (percentage).
* $p < 0.05$ was considered statistically significant.

used laparoscopic and robotic surgery to treat colorectal cancer. There is a limited body of literature comparing the learning curves of LCR and RCR. Bokhari et al. reported that after a learning curve phase of 15-25 cases, the surgeon may achieve a higher level of competence in robotic surgery.[13] However, another study suggested that a larger number of cases might be needed.[14] Comparing the two techniques is difficult because most surgeons typically have prior experience with laparoscopy before attempting robotic surgery, which may have both direct and indirect effects on their robotic skills. Only one study directly compared laparoscopy to robotic rectal surgery, concluding that the simultaneous development of laparoscopy and robotic surgery results in acceptable perioperative outcomes. Furthermore, the study found that robotics has a faster learning curve.[14] A previous study found that to train junior attending surgeons in robotic skills, prior experience in open or laparoscopic colorectal surgery may not be required.[15] We believe that robotic instruments have greater dexterity and provide a more stable view of the operating field within the constrained pelvic cavity when compared to laparoscopic instruments. This feature can be especially beneficial for inexperienced surgeons. This is also why we decided to compare the AR and LAR procedures in LCR and RCR.

The outcome of RCR remains controversial in the existing literature. The ROLARR trial found that robotic surgery, when performed by surgeons of varying experience, does not provide an advantage in rectal cancer resection.[9] Farah et al. discovered no significant improvement in outcome with robotic LAR, instead noting an increased risk of serious complications.[16] However, many studies have found that RCR is associated with shorter hospital stays, less intraoperative blood loss, and even postoperative ileus.[17-20] Our study revealed no significant differences in postoperative outcomes between the RCR and LCR groups, including postoperative ileus, anastomotic leak, and major morbidity. Furthermore, no significant differences were found in oncological outcomes, such as margin status and total number of harvested lymph nodes. Therefore, for young attending surgeons, the simultaneous development of robotic surgery and laparoscopic surgery is deemed safe and viable.

The conversion rate to open surgery is one of the most frequently discussed parameters for assessing the benefits of RCR. In our surgical experience, situations requiring conversion include massive bleeding, severe adhesion, visible anastomotic leak, and stapler complication. A meta-analysis found that switching from laparoscopic to open surgery was associated with a higher risk of anastomotic leakage, overall morbidity, and wound abscess.[21] Furthermore, multiple studies have found that converting to open surgery is associated with poorer long-term outcomes in rectal cancer surgery.[22,23] Previous large-scale studies and meta-analysis found that RCR was associated with fewer conversion rates than LCR.[17,18,20] The statistical difference is most likely due to improved visualization using the Da Vinci's 3D camera and increased maneuverability provided by its instruments. In our study, none of the 30 cases of RCR required conversion to open surgery. Given that the surgeon is still in the stage of gaining experience, we try to avoid selecting patients who have had previous surgeries with potential adhesion risks or who are in clinical stage T4 for surgery.

Our results for operative time were significantly longer in the RCR group, which is consistent with previous literature.[17,19] In our study, the average operative time for RCR was 1-2 hours longer than that of LCR. Our operative time includes both docking and undocking time, and during the study, we switched between the Si and Xi robotic systems. As well as the lack of familiarity of the surgeon and staff with this new technology may be the source of this time loss. A previous study found that using a robotic approach increased operative time by only 20.3 minutes on average.[17] In this regard, we still have room to improve. In the last five RCR we performed, the operative time was comparable to LCR, and even faster when docking time was excluded. This lends supports to the theory that the learning curve is the primary cause of the difference in operative time.

This study had several limitations. First, its retrospective nature resulted in inherent selection bias. Second, the small number of completed robotic cases at our institution to date is a limitation. Moreover, because all surgeries were performed by the same surgeon, there may be cumulative or synergistic learning effects transferring between laparoscopy and robotic surgery that cannot be assessed. Furthermore, while we evaluated various postoperative and oncological outcomes, life quality parameters related to colorectal surgery, such as urine retention and sexual function, were not measured. Existing evidence suggests that robotic-assisted prostate surgery produces better functional outcomes in terms of the recovery of continence and sexual function than laparoscopic surgery.[24] The improved visualization and access provided by the robotic approach may aid in the preservation of nerve function following rectal cancer surgery, as demonstrated in urologic procedures. Long-term studies will necessitate assessing this critical functional outcome.

Conclusion

To summarize, performing RCR by a young colorectal surgeon in his early career produces comparable intraoperative, oncologic, and postoperative outcomes to LCR. As experience grows, operative time gradually decreases. These findings indicate that simultaneously developing laparoscopic and robotic surgery skills is safe and feasible for young colorectal surgeons.

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Conflicts of Interest Statement

The authors have no conflicts of interest to declare.

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腹腔鏡手術與機器人手術治療大腸直腸癌的結果：一位單中心年輕大腸直腸外科醫生的初步經驗

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目的 微創手術在大腸直腸癌的治療上變得越來越重要。腹腔鏡手術是結直腸手術最常見的微創手術類型,其效果與開腹手術相似，但也有一些限制。機器人手術已成為一種替代方案,比腹腔鏡手術具有潛在的優勢。然而，目前尚不清楚年輕完訓的大腸直腸外科醫生過渡到機器人手術是否需要腹腔鏡手術經驗。

方法 本研究旨在比較由一位早期職業外科醫生進行的腹腔鏡結直腸切除術和機器人結直腸切除術的圍手術期和術後結果。此醫師無先前腹腔鏡手術經驗。2019 年 12 月至 2023 年 12 月接受前切除或低位前切除的結直腸腺癌患者符合資格。評估手術過程、病患特徵、術中結果和術後併發症。

結果 共回顧手術 60 例，其中機器人結直腸切除術 30 例，腹腔鏡結直腸切除術 30 例。患者人口統計顯示各組之間沒有顯著差異。術中結果顯示，機器人結直腸切除術比腹腔鏡結直腸切除術的手術時間更長，但其他參數無顯著差異。術後結果，包括併發症和腫瘤學指標，兩組之間沒有顯著差異。

結論 年輕外科醫生在其職業生涯的早期階段進行的機器人結直腸切除術所產生的術中、腫瘤學和術後結果與腹腔鏡結直腸切除術相當。研究表明，年輕完訓的大腸直腸外科醫生可以同時學習腹腔鏡和機器人手術技能，既安全又可行。

關鍵詞 大腸直腸癌、腹腔鏡手術、機器手臂手術。