

Initial Experience in Rectal Cancer Surgery for the Next Generation of Robotic Surgeons Trained in a Dual Console System

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ABSTRACT

Background Robotic surgery for rectal cancer is used worldwide, with an increasing incidence of robotic surgeons. Therefore, the most appropriate educational system for next-generation robotic surgeons should be urgently established.

Methods We analyzed 39 patients who underwent robotic rectal surgery performed by a next-generation surgeon with limited experience in laparoscopic rectal cancer surgery. The dual console system was used in the initial 15 cases, and we assessed short-term outcomes and the learning curve on operative time using the cumulative sum method.

Results The patients were divided into two groups: 15 cases in the early phase, and 24 cases in the late phase. The operative time and surgeon console time were significantly shorter in the late phase than the early phase ($P < 0.001$). Postoperative complications were more frequently observed in the early phase ($P = 0.049$); however, the estimated blood loss and length of hospital stay were not significantly different. In the initial 15 cases that using the dual console, the average operative time changing to the expert surgeon was 82 minutes in the first 5 cases, 19 minutes on average in the next 5 cases, and no change occurred in the last 5 cases. The learning curve peaked after 14 cases, plateaued from case number 15 to 23, and decreased in a linear fashion until the final case.

Conclusion Education of a next generation surgeon using a dual console system for robotic rectal cancer surgery was performed safely.

Key words dual console; rectal cancer; robotic surgery

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Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; CUSUM, cumulative sum; OT, operative time

In recent decades, the field of general surgery has changed significantly. The use of laparoscopic surgery and minimum invasive surgery is common worldwide, and has been reported to be beneficial in terms of both short- and long-term outcomes for various malignancies.^{1–4} Furthermore, treatment of colorectal cancer, which is one of the most commonly diagnosed cancers worldwide, has been adapted to laparoscopic surgery; this has led to a reduction in the length of hospital stay following surgery and reduced intraoperative blood loss,^{5, 6} without increasing morbidity, and with comparable oncologic outcomes to open surgery.⁷ However, the relatively high open conversion rate in laparoscopic colorectal cancer surgery is an important problem, because unsuccessful laparoscopic surgery is associated with worse prognosis.⁸ Furthermore, there remain technical limitations of laparoscopic surgery due to the rigidity of the instrument, non-movable forceps, unstable camera work, and greater tremor when the operating organs are located deeper from the port.

Robotic surgery represents a further evolution of minimally invasive surgery. The robotic platform, the Da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA), has several advantages compared to laparoscopic surgery, including the motion scaling function, filtration of natural tremor, wide-range movable forceps, stable camera with high quality three-dimensional imaging, and improved ergonomics. These features are well suited for rectal cancer surgery involving total mesorectal excision, which requires precise movement within a narrow pelvis.^{9, 10} In Japan, robotic surgery for rectal cancer was newly added to insurance coverage in April 2018; as a result, the number of institutions that have introduced Da Vinci has increased, together with an increase in the number of surgeons who perform robotic surgery. In line with this increase in the use of robotic technology, the education of next-generation surgeons has become an important issue.

Another advantage of robotic surgery using the Da Vinci system is that it has a dual console, which several studies have reported is useful as an educational

tool for young surgeons.^{11–13} The dual consoles allow the mentor to instruct the appropriate dissection site with a pointer on the surgeon's monitor, and when the operation is difficult or safety is compromised, the operator can switch the surgeon to a supervising physician in any given moment using the swap mode, and without the need to change seats. Given these advantages, next-generation surgeons can start robotic surgery with increased safety and confidence, and as a result, the surgeons may acquire the necessary skills faster than the first generation surgeons, even if they are not proficient to laparoscopic rectal cancer surgery. Previous reports have revealed that the learning curve of robotic rectal surgery is 25–44 cases^{14–16}; however, these reports were almost all performed by first-generation surgeons who were highly skilled in conventional laparoscopic surgery.¹⁴

In the current study, we assessed the short-term outcomes and the learning curve of robotic rectal surgery performed by a next-generation surgeon, who had limited experienced in both laparoscopic and robotic rectal cancer surgery, with a dual console education system.

MATERIALS AND METHODS

Patients and clinical characteristics

This retrospective study enrolled 39 consecutive patients who underwent robotic surgery for rectal cancer at our hospital between June 2018 and April 2020. All surgeries were performed by a single surgeon (M.Y.) who had performed less than 15 laparoscopic low rectal resections and no robotic rectal surgeries. In this series, the first 15 cases were instructed by the expert robotic surgeon (K.A.) of our institute using the dual console system, and when the surgeon had difficulty in the surgical procedure, the operating authority was converted to the expert using the swap pedal. These first 11 cases were performed with the Da Vinci Si surgical system, and the remaining 28 cases were performed with the Da Vinci Xi system. The demographic data [age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) score, presence of neoadjuvant therapy], operative findings [operative time (OT), surgeon console time, docking time, volume of blood loss, complications, presence of conversion to open or laparoscopic surgery], distance of the tumor from the anal verge, surgical procedure, postoperative complications, and length of hospital stay were collected from the patients' medical records. The operation time was considered from the first incision to the skin closure or stoma construction. The docking time was defined as the time from the start of moving the patients' cart to

the start of the robotic operation. The console time was defined as the time from the start of moving the robotic instrument to the time of finally undocking the patient cart. Six trocars were placed when using the Da Vinci Si platform. In the intraabdominal phase, the inferior mesenteric artery and vein were ligated, the descending and sigmoid colon were moved, and undocking was performed. After the placement of the patient cart was corrected and re-docked, the intra-pelvic phase was started. The rectal resection was performed laparoscopically following completion of the robotic surgery. After switching to the Da Vinci Xi platform, five trocars were placed, and almost all surgeries were completed without undocking. Rectal resection was performed robotically or laparoscopically after undocking. The clinicopathologic findings were assessed according to the 9th edition of the Japanese Classification of Colorectal, Appendiceal and Anal Carcinoma.¹⁷ The short-term outcomes were compared between the initial 15 cases, which were instructed using the dual console system, and the subsequent 24 cases. This study was approved by the Institutional Review Board of Tottori University (approval number: 20A051).

CUSUM method

The CUSUM method was used to evaluate the learning curve.^{14, 18} The cases were arranged chronologically, and the following equation was applied to calculate the CUSUM value:

$$\text{CUSUM}_x = \text{CUSUM}_{x-1} + (\text{OT}_x - \text{OT}_{\text{mean}})$$

Where X represents the case number, and $\text{CUSUM}_{\text{OT1st}}$ is the difference between the first case and the mean operating time for all cases; $\text{CUSUM}_{\text{OT2nd}}$ is calculated as $\text{CUSUM}_{\text{OT1st}} + (\text{OT}_{2\text{nd}} - \text{OT}_{\text{mean}})$. Thus, the difference between the mean OT and the case of OT is added to the CUSUM value of the previous case. This method was repeated, the obtained CUSUM values were plotted, and the learning phase was evaluated according to the curve.

Statistical analysis

Categorical variables were compared among groups using Fisher's exact test, and continuous variables were assessed using Wilcoxon rank sum test. The accepted level of significance was $P < 0.05$. All statistical analyses were performed using SPSS software (SPSS for Windows Version 24, SPSS Inc., Chicago, IL).

RESULTS

The demographic and operative characteristics are shown in Table 1. The median age of the included patients was 72 years, and the participants comprised

Table 1. Demographic characteristics of 39 patients who underwent robotic rectal cancer surgery

Variable	Median (range) or number (%)
Age (years)	72 (40–85)
Sex (male)	25 (64.1)
BMI (kg/m ²)	23.8 (16.6–29.9)
ASA	
1	2 (5.1)
2	29 (74.4)
3	8 (20.5)
Neoadjuvant therapy	20 (51.3)
Chemotherapy	4 (10.3)
Chemoradiotherapy	16 (41.0)
Distance from anal verge (mm)	50 (15–100)
Surgical procedure	
LAR (including Hartmann) *	14 (35.9)
ISR †	5 (12.8)
APR ‡	20 (51.3)
Conversion	0 (0.0)
Total operative time (min)	436 (285–659)
Surgeon console time (min)	220 (81–319)
Docking time (min)	10 (5–18)
Total blood loss (ml)	30 (5–185)
Postoperative complication	3 (7.7)
Length of hospital stay (days)	14 (8–38)
pT §	
0 (complete response)	3 (7.7)
1	4 (10.3)
2	13 (33.3)
3	18 (46.2)
4	1 (2.6)
pN	
0	27 (69.2)
1	7 (17.9)
2	5 (12.8)
3	0 (0.0)
M	
0	35 (89.7)
1	4 (10.3)
R1¶	0 (0.0)

*LAR: low anterior resection. †ISR: intersphincteric resection. ‡APR: abdominoperineal resection. §T1: Tumor invasion of the lamina propria or submucosa, T2: Tumor invasion of the muscularis propria, T3: Tumor invasion of the subserosa or within the adventitia, T4: Tumor penetration of the serosa, or tumor invasion of adjacent organs. ||N0: No regional lymph node metastasis, N1: Metastasis in 1–3 pericolic, perirectal, or intermediate lymph nodes, N2: Metastasis in ≥ 4 pericolic, perirectal, or intermediate lymph nodes, N3: Metastasis in the main or lateral lymph nodes. ¶R1: No residual tumor, but tumor is suspected at the resection margin.

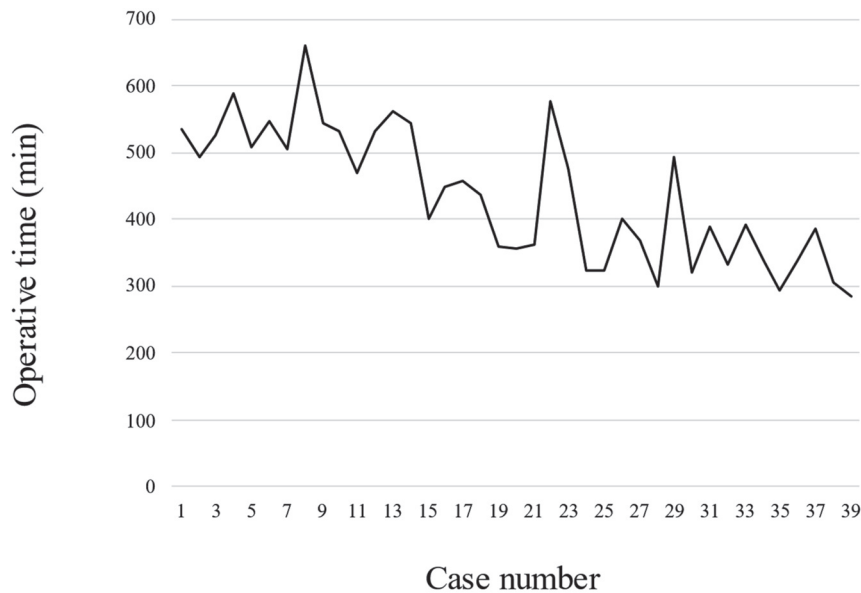


Fig. 1. Total operative time for all cases.

25 males and 14 females. The median BMI was 23.8, and almost half of the patients ($n = 20$, 51.3%) received preoperative chemotherapy ($n = 4$, 10.3%) or chemoradiotherapy ($n = 16$, 40.3%). The median distance of the tumor from the anal verge was 50 mm. A total of 14 patients underwent low anterior resection, 4 patients underwent intersphincteric resection, and 20 patients underwent abdominoperineal resection. There was no conversion to open or laparoscopic surgery in the current study. The median operative time was 436 minutes, and the median surgeon console time was 220, Figure 1 shows the operative time arranged chronologically from the first case. Postoperative complications (Clavien-Dindo classification Grade III or more) were observed in three patients: one patient underwent re-operation due to stoma necrosis, one patient had an intra-abdominal abscess that required percutaneous drainage, and the remaining patient had small bowel obstruction that were conservatively treated using an ileus tube.

The 39 patients were classified into two groups: Early phase group, including the initial 15 patients; and the late phase group with the subsequent 24 patients. Table 2 shows the patient demographics in the early and late phase groups. There were no significant differences between the two groups in terms of age, sex, BMI, ASA score, neoadjuvant therapy, and distance of the tumor from the anal verge. Table 3 shows the surgical findings of the two groups; the patients in the late phase group had a significantly shorter operation time ($P < 0.001$), surgeon console time ($P < 0.001$), and docking time ($P < 0.001$) compared to those in the early phase

group. There was no significant difference in blood loss between the early and late phase patients. Postoperative complications were observed in three patients of the early phase group, and no complications were observed in the late phase group ($P = 0.049$). The length of hospital stay was not significantly different between the two groups. In the 15 early phase cases that involved use of the dual console, the average operative time changing to the expert surgeon was 82 minutes in the first 5 cases, 19 minutes on average in the next 5 cases, and no change occurred in the last 5 cases (Fig. 2).

The $CUSUM_{OT}$ value was calculated as outlined above, and the learning curve is shown in Figure 3. The $CUSUM_{OT}$ curve peaked at approximately case number 14, and plateaued from case number 15 to 23, then decreased in a linear fashion until the final case.

DISCUSSION

In the current study, we clarified the short-term outcomes of initial surgical cases performed by a next-generation surgeon in robotic rectal cancer who had limited experience of both laparoscopic and robotic rectal cancer surgery. The surgeon was proctored in the first 15 cases using a dual console system, and the subsequent 24 operations were performed independently. Postoperative complications were observed in three patients (7.7%), and there were no conversions to open surgery or mortality. The dual console system allows even surgeons who are inexperienced in laparoscopic rectal cancer surgery to safely perform initial robotic surgery for rectal cancer.

Table 2. Difference in demographic and clinical variables between the early and late phases

Variable	Early phase (n = 15)	Late phase (n = 24)	P-value
Age (years)	71.9 ± 5.6	70.4 ± 12.5	0.662
Male sex (n)	11	14	0.496
BMI (kg/m ²)	23.5 ± 2.9	23.4 ± 3.5	0.975
ASA			0.307
1	0	2	
2	13	16	
3	2	6	
pStage			0.588
0 (Complete response)	1	1	
I	4	8	
II	4	7	
III	3	7	
IV	3	1	
Neoadjuvant therapy	9	11	0.389
Distance from anal verge (mm)	43 ± 1.8	55 ± 2.2	0.094

Table 3. Comparison of intraoperative and postoperative outcomes between early and late phases

Variable	Early phase (n = 15)	Late phase (n = 24)	P-value
Surgical procedure			0.570
LAR	5	9	
ISR	3	2	
APR	7	13	
Operative time (min)	530 ± 57	377 ± 73	< 0.001
Console time (min)	281 ± 35	188 ± 47	< 0.001
Blood loss (mL)	48 ± 48	43 ± 43	0.769
Postoperative complications	3	0	0.049
Length of hospital stay (days)	16.7 ± 7.3	14.4 ± 4.4	0.229

Previous study reported that the use of the dual console system significantly decreased the mean operative time and the incidence of intra- and post-operative complications compared to the single console system in robot-assisted radical prostatectomy.¹² With regards to gynecologic robotic surgery, a previous report demonstrated that surgery with a dual console was both safe and feasible, and represented a useful educational tool.¹⁹ Furthermore, *Bolger* reported that the dual console was a safe and effective platform for training junior surgeons in colorectal surgery, and suggested that the dual console system has the potential to alter surgical training pathways.¹³ However, these previous reports did not

indicate how many surgeries should be performed with the dual console system in order to instruct to junior surgeons. In our current series, the learning curve reached a plateau after 14 cases. In Japan, the licensing of robotic surgeons is limited to technically certified laparoscopic surgeons, and although the background of the surgeons differs from the above report, the results of this study suggest that the proctoring of 15 cases of new robotic surgeons with dual console is appropriate.

The postoperative complications of robotic surgery for rectal cancer were associated with male sex, previous abdominal surgery, and short distance of the tumor from the anal verge.²⁰ In this study, the median distance

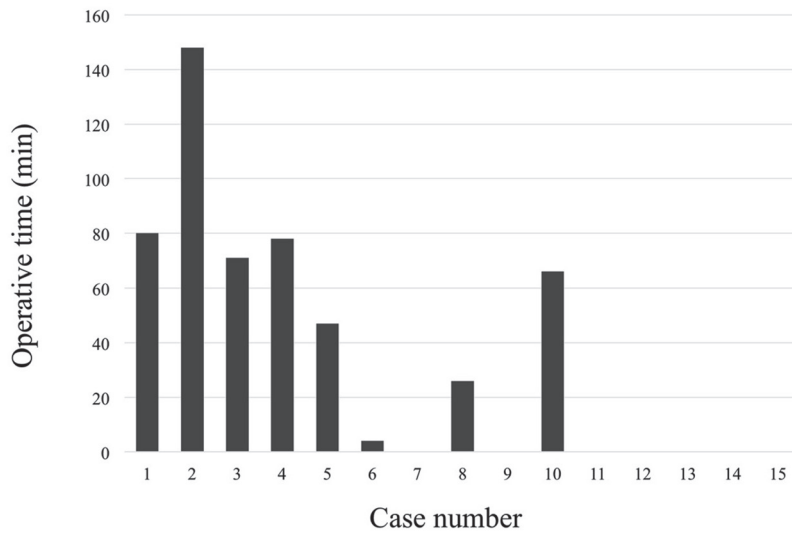


Fig. 2. Total operative time that the expert surgeon operated in first 15 cases.

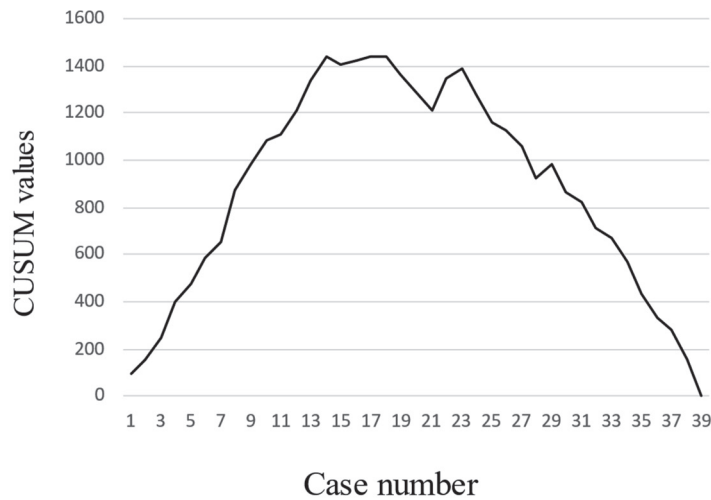


Fig. 3. Graph representing the learning curve with the CUSUM values plotted in chronological order.

of the tumor from the anal verge in the early phase group was 43 mm, which is shorter than that reported for the initial cases of robotic rectal surgery in previous studies.²¹⁻²³ Consequently, the operative time in the initial cases in this study was longer than in previous reports. However, there was less blood loss, and the post-operative complication rate was similar to that reported in previous studies. In the initial 15 cases using the dual console, the operator was instantly switched to the mentor when required, and guidance of the appropriate dissection layer was also given with a pointer throughout the surgery. We believe that these advantages of the dual console system contributed to the feasible and safe outcomes of surgery with a new robotic surgeon.

In the current study, the CUSUM method was

used to evaluate the learning curve in robotic rectal surgery.^{14, 18, 21, 22} In previous reports, the learning curve was divided into three phases: The initial learning phase, the stabilization phase, and the experienced phase; this was in agreement with the results of our study. A unique feature of the CUSUM method is that it is calculated based on the mean operative time, and is therefore not a reflection of the actual operative time. Thus, this learning curve is not for comparison with other surgeons, and is instead used to compare the proficiency of individual surgeons. The graphs plotting the CUSUM values are generally linear in shape, which makes it easy to visually identify the level of proficiency.

The learning curve in laparoscopic rectal cancer

surgery has been reported in around 60–80 cases,²⁴ and it was found to be longer compared to that for robotic surgery. This can be explained by the fact that laparoscopic surgery might be technically difficult, especially in the narrow pelvic space; in contrast, robotic surgery has advantages over laparoscopic surgery, such as 3-D imaging, free movable forceps, and image stabilization.¹⁴ Therefore, robotic surgery may shorten the learning curve compared to laparoscopic surgery. *Odermatt et al.* compared the learning curves of robotic rectal surgery for surgeons with more and less experience in laparoscopic rectal surgery, and reported that prior experience in laparoscopic rectal surgery shortened the learning curve of robotic rectal surgery.²⁵ In our study, the next-generation surgeon had experience of less than 15 cases of laparoscopic middle and low rectal cancer surgery; however, he experienced about 150 cases of laparoscopic colon cancer surgery including that of upper rectal cancer. *Foo et al.* also reported the learning curve of robotic-assisted low rectal resection in a novice rectal surgeon, and demonstrated that prior experience of laparoscopic surgery is necessary to initiate robotic surgery.²² In contrast, one previous study reported two plateaus in the learning curves of robot-assisted rectal cancer surgery using the CUSUM method; the first plateau was noted after 33 cases, and the second plateau was noted after 72 cases.²⁶ Another report showed that approximately 75 cases would be required to establish a robotic colorectal cancer program, although this study also included some colon cancer cases.²³ Moreover, the ROLARR randomized trial examined open conversion rates in laparoscopic and robotic rectal cancer surgery, and showed no significant difference in open conversion rates between two groups.²⁷ In this study, registered robotic surgeons had experienced a median of 50 robotic surgeries. Open conversion from robotic surgery was found to be decreased in cases performed by surgeons with experience of more than 68 robotic surgeries, whereas the number of experienced laparoscopic surgical cases did not significantly affect the conversion rate from laparoscopic to open surgery.²⁸ In our series, a total of 39 cases were enrolled, which is a small number of cases; therefore, new plateaus may be discovered as following greater accumulation of cases in the future.

The importance of surgical skill acquisition and the associated educational system has long been debated. Indeed, a previous study reported on the expert consensus of train-the-trainer curricula in robotic colorectal surgery, and demonstrated that a train-the-trainer course was beneficial and necessary to provide a higher standard of training.²⁹ In another recent report, the author surveyed the robotic surgery training curricula in

general surgery, and reported difficulty in quantifying resident experience and assessing competence for safe robotic surgery practices since there has not yet been sufficient adoption of a standardized program.³⁰ Due to the characteristics of its modalities, robotic surgery requires attention to its unique disadvantage, in which losing sight of the instrument or the lack of tactile feedback could easily result in damage to other organs. Furthermore, when surgeons experienced difficult-to-control bleeding, it was difficult to convert from robotic to open surgery. Consequently, it is recommended that the robotic surgeons and their teams should routinely simulate a variety of potential problems. It is likely that the field and use of robotic surgery will continue to grow rapidly, and consequently, it is expected that there will be more opportunities for young surgeons to perform robotic surgery in the future. In order to safely introduce this new state-of-the-art technology, we believe that a more practical education and assessment system that is both unified and standardized, should be urgently established.

There were several limitations in this study. First, as described above, the study was initially conducted with 39 cases, but the sample size may be too small to examine the actual learning curve. However, robotic surgery is already widely used, and surgical techniques are being established and teams are maturing; therefore, next-generation surgeons may learn the technique in fewer cases than before. Second, the Da Vinci's platform changed from Si to Xi in the 12th case, and there was no uniformity in the surgical techniques throughout all cases, including the number of trocars and the method of rectal resection. Third, almost half of the patients underwent abdominoperineal resection, and the low number of anastomoses may be one reason for the low rate of postoperative complications. Fourth, the operative time in the current study includes the change-over time to the proctor, which may not be an accurate learning curve. Fifth, the learning curve in this study is not a comparison between using and not using the dual console, therefore, it is not clear whether the use of the dual console systems leads to a shorter learning curve or not.

In the present study, we have examined the short-term outcomes and the learning curve of the initiation of robotic surgery performed by an inexperienced surgeon with a dual console system. The next-generation surgeon was able to safely initiate robotic surgery in this cohort; therefore, the dual-console system may contribute to the education of next-generation robotic surgeons in rectal cancer surgery.

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The authors declare no conflict of interest.

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