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Robotic Versus Laparoscopic Low Anterior Resection of Rectal Cancer: Short-Term Outcome of a Prospective Comparative Study

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ABSTRACT

Background. The aim of this study is to compare the short-term results between robotic-assisted low anterior resection (R-LAR), using the da Vinci® Surgical System, and standard laparoscopic low anterior resection (L-LAR) in rectal cancer patients.

Methods. 113 patients were assigned to receive either R-LAR ($n = 56$) or L-LAR ($n = 57$) between April 2006 and September 2007. Patient characteristics, perioperative clinical results, complications, and pathologic details were compared between the groups. Moreover, macroscopic grading of the specimen was evaluated.

Results. Patient characteristics were not significantly different between the groups. The mean operation time was 190.1 ± 45.0 min in the R-LAR group and 191.1 ± 65.3 min in the L-LAR group ($P = 0.924$). The conversion rate was 0.0% in the R-LAR groups and 10.5% in the L-LAR group ($P = 0.013$). The serious complication rate was 5.4% in the R-LAR group and 19.3% in the L-LAR group ($P = 0.025$). The specimen quality was acceptable in both groups. However, the mesorectal grade was complete ($n = 52$) and nearly complete ($n = 4$) in the R-LAR group and complete ($n = 43$), nearly complete ($n = 12$), and incomplete ($n = 2$) in the L-LAR group ($P = 0.033$).

Conclusion. R-LAR was performed safely and effectively, using the da Vinci® Surgical System. The use of the system resulted in acceptable perioperative outcomes compared to L-LAR.

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Recently, laparoscopic colorectal resection has been popularized because it results in decreased postoperative pain, shorter length of hospitalization, and earlier return to normal functioning, and increasing demand for laparoscopic surgery from patients.[1–3] However, rectal cancer surgery is a more technically demanding procedure than colon cancer surgery because it is performed in the narrow pelvic cavity. Thus, the surgeon needs highly technical skills for the laparoscopic rectal resection.

Meanwhile, the da Vinci® Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) was developed to overcome the disadvantages of conventional laparoscopic surgery such as an assistant-dependent unstable camera platform, two-dimensional view, limited dexterity of instruments inside the patient, and fixed instrument tips.[4,5] Moreover, the robotic system provides excellent ergonomics, tremor elimination, ambidextrous capability, motion scaling, and instruments with multiple degrees of freedom. These advantages of the robotic system are even more beneficial when the operation field is narrow such as in prostatectomy. Thus, the robotic system's applications have expanded since it was first used in urology in June 2006.[6] We thought that the robotic system would have the same beneficial effect when used for rectal dissection such as prostatectomy in the urology area. These two kinds of surgeries have the same narrow operation field. Therefore, we have used the robotic system for rectal cancer surgery since 2006.[7] Robotic colorectal surgery was first performed in 2001.[8] However, experience with robotic rectal cancer surgery has been limited worldwide. Moreover, few previous studies have assessed its use for rectal cancer surgery compared with conventional laparoscopic surgery. Therefore, this study was designed to evaluate the difference of the short-term outcome after robotic or conventional laparoscopic surgery for low anterior resection in rectal cancer patients.

PATIENTS AND METHODS

One hundred twenty-three consecutive rectal cancer patients were treated by one surgeon (S.H.B.) between April 2006 and September 2007 at Severance Hospital, Yonsei University College of Medicine. Among these patients, 113 patients were either assigned to laparoscopic low anterior resection (L-LAR, $n = 57$) or robotic low anterior resection (R-LAR, $n = 56$). Based on preoperative workup, we excluded patients with clinical T4 stage ($n = 5$) or significant lateral pelvic nodes ($n = 3$), and tumor infiltration into the anal sphincter complex ($n = 2$). Patients were randomly assigned to robotic or standard laparoscopic techniques by computer-generated random sequence. However, eight patients who were assigned to R-LAR underwent standard L-LAR and six patients who were assigned to L-LAR underwent R-LAR according to patient decision. The current study began as a prospective randomized trial.[9] Thus, the original intention was evaluation of perioperative outcome as primary end-point and evaluation of pathologic outcome as secondary end-point. However, the authors thought that the ongoing present trial could not be a pure randomized trial because the cost of operation was different between the two arms, and patients were informed of the cost of operation and operation methods before the operation, even though patients were randomly assigned to undergo either robotic or laparoscopic low anterior resection. Thus, we abandoned the randomized approach and the present study was designed as a prospective comparative nonrandomized study.

Preoperative patient workup consisted of physical examination, complete blood count, electrolytes, liver function test, chest X-rays, and electrocardiogram. Colonoscopy was performed routinely to obtain tissue diagnosis and evaluate the entire colon. Abdominopelvic computed tomography was performed to assess distant metastasis and status of local disease infiltration. Pelvic magnetic resonance imaging was utilized to evaluate the degree of local infiltration and nodal metastasis. Tumor location was measured using rigid sigmoidoscopy. Patient demographics, American Society of Anesthesiologists (ASA) classification, history of previous abdominal surgeries, body mass index (BMI), operative procedure, perioperative clinical results, pathology results, and postoperative complications were recorded prospectively in the database. Perioperative clinical results included skin-to-skin operative time, hemoglobin (Hb) change between preoperative (1–2 weeks before operation) and postoperative time (1 day after operation), day to first passing flatus, length of stay, complications, and conversion. Criteria for discharge included no apparent complications, no abnormal findings on physical examination, no subjective complaints, and tolerance of soft diet. Pathology results included proximal and distal resection margins, number of harvested lymph nodes, and macroscopic integrity of the mesorectal fascia. Moreover, circumferential resection margin involvement (CRM) was also evaluated.

Quality of the mesorectum was scored using three grades (complete, nearly complete, and incomplete) by a pathologist who had no clinical information, as defined by the Dutch total mesorectal excision (TME) trial.[10]

Upon arrival at the laboratory, the macroscopic judgment of the resected specimen was evaluated by a pathologist using the definition as described above. Involvement of CRM was defined as CRM ≤ 1 mm. Distance of CRM was the shortest distance between the CRM and the tumor. The technical details were described in our previous study.[11] Informed consent was obtained from all patients.

Operative Techniques

Robotic Procedure In this study, we used the da Vinci® Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) for the robotic procedure. The da Vinci® Surgical System consists of three separate parts: the surgeon's console, an electronic tower holding video equipment, and the robotic arms. Figure 1 shows the robotic arms and the surgeon's console used in this study.

A standard mechanical bowel preparation was performed 24 h prior to operation and pneumatic compression stockings were fitted 1 h prior to the operation. The patient was placed supine with legs apart in 30° Trendelenburg position and 15° right down. For the first three cases, we used three robotic arms. After the third case, we changed the trocar locations to allow the use of four robotic arms.[12] One more 8-mm da Vinci® trocar was used on the left lateral to the previous left McBurney area da Vinci® trocar, and we removed the 12-mm trocar on the right lateral to the right da Vinci® trocar. A 10-mm trocar was placed in the right midabdomen lateral to the umbilicus in the midaxillary line to allow access for mobilization of the left colon and to allow the use of a 10-mm endo-clip. In combinations with these five trocar locations, one da Vinci® trocar in the right McBurney area was replaced with a 12-mm trocar to allow the use of an endoscopic stapler (Fig. 2).

Mobilization of the left colon was undertaken using standard laparoscopic instruments, after the inferior mesenteric artery (IMA) and vein were divided proximally using clips. Next, the robotic instrument was positioned between the legs. The rectum was suspended, using an atraumatic grasper through the left port, and rectal

FIG. 1 Operation theater with the da Vinci® Surgical System (**a**) and an operator at the master console (**b**)

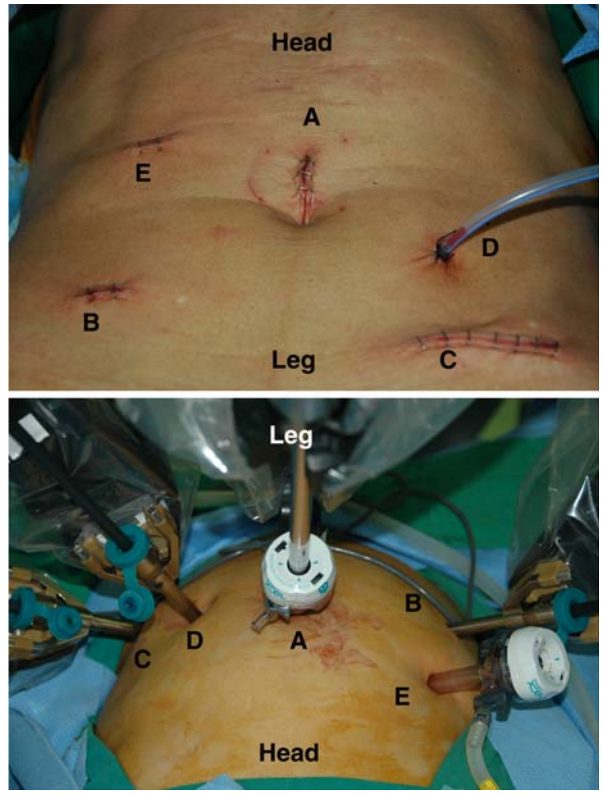

FIG. 2 Position of the working port for robotic low anterior resection. A: 12-mm camera port, B: 8-mm robot port. This port was exchanged with a 12-mm trocar to allow use of an Endo-GIA, C: 8-mm robot port, used for specimen delivery, D: 8-mm robot port, E: 11-mm port for assistance

dissection in the mesorectal plane proceeded using a cautery hook in accordance with tumor-specific mesorectal excision (TSME) principles (Fig. 2).[13]

The mesorectum was divided precisely beyond the tumor using both robotic arms. The rectum itself was divided using an Endo-GIA. The robotic instrument was then disengaged. The specimen was extracted though the left lower trocar incision, which was enlarged to approximately 3–4 cm, after protection with a polyurethane retrieval bag. An end-to-end anastomosis (EEA) anvil was then inserted in the proximal colon and secured with a purse-string suture. The colon was placed back into the abdomen and the port site was closed. Pneumoperitoneum was restored, and an EEA stapler was used to create an end-to-end anastomosis. The anastomosis was tested with air instillation. When Endo-GIA application was not possible due to very low tumor level, handsewn coloanal anastomosis was performed.

Laparoscopic Procedure Bowel preparation, pneumatic compression stockings fitting, and patient position were the same as for the robotic procedures. A 10-mm trocar was placed through an incision just above the umbilicus after achieving pneumoperitoneum, and then a 30° standard laparoscope was inserted through the 10-mm trocar. The other four trocars were used in the left McBurney's area, right McBurney's area, and the left and right midabdomen lateral to the umbilicus along the midaxillary line. A 12-mm trocar was used on the left McBurney's area to facilitate use of an Endo-GIA. Left colon mobilization was performed in a medial to lateral fashion. The IMA was divided at the root of the IMA using an endo-clip, and rectal dissection in the mesorectal plane proceeded using conventional laparoscopic instruments in accordance with TSME principles.[13] The mesorectum was divided precisely beyond the tumor with an ultrasonic device and then the rectum itself was divided with an Endo-GIA. Specimen extraction and reconstruction were the same as in the robotic procedure.

Statistical Analysis

Data were analyzed using SPSS (Statistical Product and Service Solutions 11.5 for Windows, SPSS Inc., Chicago, IL). The chi-squared test for categorical variables and Student's *t*-test for continuous variables were used for statistical comparisons of patient characteristics, perioperative clinical results, and pathologic details between robotic cases and laparoscopic cases. P values ≤0.05 were considered to be statistically significant.

RESULTS

Patient Characteristics

Patient characteristics were analyzed, comparing the robotic low anterior (R-LAR) cases and conventional laparoscopic low anterior resection (L-LAR) cases (Table 1). The R-LAR and L-LAR groups contained 56 cases and 57 cases, respectively. Sex ratio and distribution of the tumor–node–metastasis (TNM) stage in the two groups were the same. Mean age, height, weight, BMI, and ASA scores were not significantly different between the groups. Tumor distance from anal verge was not significantly different between the groups.

One R-LAR patient had history of previous open radical subtotal gastrectomy, and five patients in L-LAR group had history of previous abdominal surgeries (one appendectomy, two total abdominal hysterectomies, and two open radical subtotal gastrectomies). Five patients in the R-LAR group underwent neoadjuvant chemoradiotherapy and seven patients in the L-LAR group underwent neoadjuvant chemoradiotherapy.

Perioperative Clinical Results Between Groups

Mean operating time was 190 ± 45.0 min in the R-LAR group and 191.1 ± 65.3 min in the L-LAR group, which was not significantly different between the groups ($P = 0.924$). The Hb change was not significantly different between the groups ($P = 0.905$). Mean days to first passing flatus was 1.9 ± 1.0 days in the R-LAR group and 2.1 ± 1.2 days in the L-LAR group, but these means were not significantly different ($P = 0.492$). Mean days to soft diet was 4.7 ± 1.1 days in the R-LAR group and 5.5 ± 1.5 days in the L-LAR group ($P = 0.008$). Mean length of stay was 5.7 ± 1.1 days in the R-LAR group and 7.6 ± 3.0 days in the L-LAR group ($P = 0.001$) (Table 2).

Six open conversions were noted in the L-LAR group. Open conversion occurred because of severely narrow pelvis for rectal dissection in four patients, bleeding in the pelvic wall in one patient, and rectal perforation in one patient. These six patients have no previous surgery histories. Thus, previous surgery history did not affect open

TABLE 1 Patient demographics

	R-LAR ($n = 56$)	L-LAR ($n = 57$)	P
Age [mean ± SD, median (range)] (years)	60.3 ± 8.3, 60.0 (38.0–78.0)	63.2 ± 10.4, 64.0 (35.0–81.0)	0.101
Height [mean ± SD, median (range)] (cm)	164.3 ± 9.3, 167.0 (144.0 – 185.0)	161.4 ± 8.3, 162.0 (145.0 – 177.0)	0.176
Weight [mean ± SD, median (range)] (kg)	63.0 ± 7.9, 62.0 (51.8–83.0)	60.7 ± 9.7, 59.0 (43.0–85.0)	0.305
BMI [mean ± SD, median (range)] (kg/m^2)	23.4 ± 3.0, 23.4 (18.0–33.0)	23.2 ± 2.7, 23.0 (18.6–29.4)	0.805
Sex (%)			0.480
Male	37 (66.1)	34 (59.6)	
Female	19 (33.9)	23 (40.4)	
ASA score (%)			0.161
1	41 (73.2)	31 (54.4)	
2	14 (25.0)	22 (38.6)	
3	1 (1.8)	3 (5.3)	
4	0 (0.0)	1 (1.8)	
TNM staging			0.237
I	22 (39.3)	14 (24.6)	
II	16 (28.6)	19 (33.3)	
III	18 (32.1)	24 (42.1)	
Distance from anal verge [mean ± SD, median (range)] (cm)	9.6 ± 3.4, 10.0 (3.0–15.0)	9.5 ± 3.4, 10.0 (3.0–15.0)	0.845
Previous abdominal surgery (%)	1 (1.8)	5 (8.8)	0.084
Appendectomy	0	1	
Total abdominal hysterectomy	0	2	
Open radical subtotal gastrectomy	1	2	
Neoadjuvant chemoradiotherapy(%)	5 (8.9)	7(12.3)	0.563

SD standard deviation, *BMI* Body mass index, *ASA* American Society of Anesthesiologists, *R-LAR* robotic low anterior resection, *L-LAR* laparoscopic low anterior resection

TABLE 2 Comparison of operative clinical results between groups

	R-LAR ($n = 56$) [mean ± SD, median (range)]	L-LAR ($n = 51$)[a] [mean ± SD, median (range)]	*P*
Operative time (min)	190.1 ± 45.0, 178 (120.0–315.0)	191.1 ± 65.3, 179 (100–360.0)	0.924
Hb change (g/dl)	0.99 ± 1.0, 0.8 (0–2.8)	0.97 ± 0.81, 0.8 (0–3.4)	0.905
Days to first passing flatus	1.9 ± 1.0, 2.0 (1–5)	2.1 ± 1.2, 2.0 (1–6)	0.492
Days to soft diet	4.7 ± 1.1, 4.0 (4–9)	5.5 ± 1.5, 5.0 (3–10)	0.008
Length of stay (days)	5.7 ± 1.1, 5.0 (5–10)	7.6 ± 3.0, 6.0 (4–16)	0.001
Conversion [no. (%)]	0 (0.0)	6 (10.5)	0.013

SD standard deviation, *R-LAR* Robotic low anterior resection, *L-LAR* laparoscopic low anterior resection

[a] Number of patients without conversion cases

conversion in the present study. Meanwhile, there were no open conversion cases in the R-LAR group. These results showed statistical significance ($P = 0.013$).

The overall complication rate was 10.7% in the R-LAR group and 19.3% in the L-LAR group. However, the serious complication rate was significantly lower in the R-LAR group (5.4%) than in the L-LAR group (19.3%) ($P = 0.025$) (Table 3).

In the present study, median follow-up period was 14.3 months (range 7–27 months). Two systemic recurrences occurred in the L-LAR group. The first recurrence case was a 40-year-old male patient with pathologic TNM stage III (T3N2M0) and recurrence-free survival of 12 months. The second recurrence case was a 54-year-old female patient with pathologic TNM stage III (T2N1M0) and recurrence-free survival of 13 months. In the R-LAR group, also, two systemic recurrences occurred. The first recurrence patient was a 58-year-old female with pathologic TNM stage III (T3N2M0) and recurrence-free survival of 12 months. The second patient was a 70-year-old male patient with pathologic TNM stage III (T3N2M0) and recurrence-free survival of 8 months.

Pathologic Results Between Groups

Mean number of harvested lymph nodes was 18.4 ± 9.2 in the R-LAR group and 18.7 ± 12.0 in the L-LAR group ($P = 0.825$). Mean proximal resection margin in the R-LAR and L-LAR groups was 10.9 ± 4.0 cm and 10.8 ± 4.3 cm, respectively ($P = 0.971$), and mean distal resection margin was 4.0 ± 1.6 cm and 3.6 ± 1.7 cm, respectively ($P = 0.497$). Macroscopic grading of the specimen in the R-LAR group was complete in 52 cases and nearly complete in 4 cases. In the L-LAR group, grading was complete in 43 cases, nearly complete in 12 patients, and incomplete in 2 cases. These results showed statistical significance between the groups ($P = 0.033$). However, circumferential resection margin involvement was not statistically different between the groups ($P = 0.749$) (Table 4).

DISCUSSION

The advantages of the da Vinci® Surgical System are a three-dimensional surgical view using a stable camera

TABLE 3 Comparison of postoperative complications between groups

Complications	R-LAR ($n = 56$)	L-LAR ($n = 57$)	*P*
Serious complications			
Intraluminal bleeding	1	0	
Intra-abdominal bleeding	0	1	
Bladder injury	0	1	
Anastomotic leakage	1	4	
Myocardial infarction	0	1	
Pleural effusion	0	1	
Ileus	1	3	
Complication rate (%)	5.4	19.3	0.025
Light complications			
Back pain	2	0	
Scrotal swelling	1	0	
Overall complication rate (%)	10.7	19.3	0.202

R-LAR Robotic low anterior resection, *L-LAR* laparoscopic low anterior resection

TABLE 4 Comparison of pathologic results between groups

	R-LAR ($n = 56$) [mean ± SD, median (range)]	L-LAR ($n = 57$) [mean ± SD, median (range)]	*P*
Lymph node harvested (no.)	18.4 ± 9.2, 17.5 (4.0–43.0)	18.7 ± 12, 17.0 (4.0–53.0)	0.831
Proximal resection margin (cm)	10.9 ± 4.0, 10.0 (6.0–25.0)	10.8 ± 4.3, 9.8 (6.0–23.0)	0.971
Distal resection margin (cm)	4.0 ± 1.6, 4.0 (1.0–7.0)	3.6 ± 1.7, 3.0 (1.0–9.0)	0.497
Macroscopic judgment of the specimen			
Complete	52	43 (2)[a]	0.033
Nearly complete	4	12 (3)[a]	
Incomplete	0	2 (1)[a]	
Circumferential resection margin			0.749
Noninvolved (>1 mm)	52	52(6)[a]	
Involved (≤1 mm)	4	5	

R-LAR robotic low anterior resection, *L-LAR* laparoscopic low anterior resection

[a] Conversion cases

platform, and the fine and free movements of the robotic arm in the surgical fields. The fine movement of the robotic arm results from the functions of the da Vinci® Surgical System such as tremor elimination, motion scaling, dexterity, and ambidextrous capability.[14–16] We feel that these advantages might be more beneficial when the surgical field is narrow and limited, such as in rectal cancer surgery.

In this study, days to soft diet and length of stay of the robotic group were shorter than for the laparoscopic group. Minimal-invasive characteristics and the technological advantages of the robotic system may influence these outcomes and may be related to lower postoperative complication rates. This study showed lower serious complication rates in the robotic group than in the laparoscopic group, even though the overall complication rate, which included back pain and scrotal swelling, was not statistically different between the groups. The lower serious complication rate in the robotic group may be related to the shorter time to day of soft diet and length of stay.

Conversion did not occur in the robotic group whereas six conversions occurred in the laparoscopic group. The reasons for conversion in the laparoscopic group were severe hemorrhage from the lateral pelvic wall, severe narrow pelvic cavity, and rectal perforation. One of the most important technological advantages of the robotic system is the ability for fine dissection in a narrow surgical field. We feel that this technological advantage may influence these results.

In rectal cancer surgery, the quality of the resected specimen is very important because it is related to oncologic outcomes.[10] Proper lymph node dissection and macroscopic completeness of resected rectal specimen are two main factors that show the quality of the resected specimen. In rectal cancer surgery, total mesorectal excision (TME) has become the surgical treatment of choice.[17] The principle underlying TME is secure dissection of an avascular plane between the presacral fascia and the fascia propria of the rectum without injuring the fascia propria of the rectum.[17–19] Thus, TME is a technically demanding procedure because the surgical field of TME is a narrow pelvis and the macroscopic completeness of a resected rectal specimen is variable according to patient anatomic factors and the quality of surgical procedures. In this study, macroscopic grading in the robotic group was better than that in the laparoscopic group. We postulate that these pathologic results account for the technological advantage of the robotic system and that it improves long-term survival, even though there is, as of yet, no study about long-term survival in robotic rectal cancer surgery. Moreover, it will facilitate the preservation of the pelvic autonomic nerve, which is associated with postoperative sexual and voiding functions.

Involvement rate of circumferential resection margin (CRM) was not statistically different between groups. The advantage of the robotic system for secure dissection may be a beneficial effect of a safe CRM, like the macroscopic grading of the resected specimen. However, this study did not show the advantages of the robotic system for a safe CRM. Involvement of CRM is influenced by two factors. The first is tumor location from the fascia propria of the rectum and the second is quality of surgery. We thought that the involvement rate of CRM in the robotic group was not lower than in the conventional laparoscopic group because of the above reason. However, the macroscopic completeness of the resected specimen is influenced by only one factor: the quality of dissection. The macroscopic grading was better in the robotic group than in the conventional laparoscopic group.

The major drawbacks of the robotic system are lack of both tactile sensation and tensile feedback to the surgeon. Therefore, the robotic arms should not be moved out of surgical view because the force of the robotic arm is powerful and the surgeon cannot detect tissue damage by the robotic arm if it moves out of the surgical view. In contrast, the surgeon can operate and stop the laparoscopic instrument immediately after feeling resistance from the laparoscopic instrument tips even if the instrument is out of the surgical view. This disadvantage is more problematic during colon resection because the surgical field of colon surgery is much larger than that of rectal surgery. The second drawback is that prompt open conversion is impossible during the robotic procedure because removing the robotic system is a time-consuming procedure. Prompt open conversion is sometimes necessary for immediate control of serious bleeding. The third drawback is the high cost of using the robotic system. The price of one robotic system is more than US $2,000,000. Moreover, the usual cost of disposable instruments is more than US $2,000 from our experiences. These high costs are considerable issues and may be debated for cost effectiveness.

The da Vinci® Surgical System is a slave robotic system. The movement of the robotic arm is totally regulated by the surgeon's hand and finger movements. Thus, the surgeon's experience and ability are closely related to perioperative outcomes. We can postulate that the perioperative outcomes will be better in the robotic group when the operations are performed by the same surgeon according to the present study results. However, we guess that experienced surgeon can overcome the disadvantages of the standard laparoscopic instruments compared with the robotic system. Thus, if we were to compare our results in robotic low anterior resection group with results in standard laparoscopic low anterior resection groups which were performed by other experienced laparoscopic surgeons, we cannot predict the results.

This study has several limitations. The first is that this study is based on a single surgeon's experience. The surgeon's personal experiences and subjective demand could be biased. However, the study design of a single surgeon series avoids intersurgeon or intercenter variability of a multicenter trial. The second limitation is that this study is not double-blinded; the surgeon and the patient knew the operation methods. This information may positively influence the results in the robotic low anterior resection group. The third limitation is that all cases were not assigned randomly. This could be the cause of statistical bias, even if the patient characteristics between the two groups were not statistically different.

CONCLUSIONS

The current study demonstrated that low anterior resection in rectal cancer patients can be performed safely and effectively using the robotic system. Lower serious complication rates and better mesorectal grade were noted in the robotic low anterior resection group compared with the standard laparoscopic group. However, our data is limited in that this study was not double-blinded and had statistical limitation. Moreover, the high cost of the robotic system is a considerable problem for its use in rectal cancer surgery. Future larger studies are necessary for evaluation of long-term oncologic and functional outcomes.

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