ASTR

ORIGINAL ARTICLE
pISSN 2288-6575 • eISSN 2288-6796
https://doi.org/10.4174/astr.2018.95.1.37
Annals of Surgical Treatment and Research

Comparative analysis of robot-assisted *vs.* open abdominoperineal resection in terms of operative and initial oncological outcomes

Jin Cheon Kim, Jong Lyul Lee, Chan Wook Kim

Department of Surgery, Asan Medical Center, Institute of Innovative Cancer Research, University of Ulsan College of Medicine, Seoul, Korea

Purpose: The present study aimed to objectively evaluate robot-assisted abdominoperineal resection (APR) in comparison with open APR, in terms of operative elements and initial oncological outcomes.
Methods: A total of 118 patients with lower rectal adenocarcinoma who had undergone curative APR were consecutively enrolled between June 2010 and June 2016, i.e., robot-assisted group (n = 40) and open group (n = 78).
Results: Transabdominal extralevator muscle excision was more frequently performed in the robot-assisted group than in the open group (68% *vs*. 42%, P = 0.012). In the robot-assisted group, the pain score at one day after surgery was less than in the open group, and the resumption of bowel function was earlier (P = 0.043 and P = 0.002, respectively). The occurrence of circumferential resection margin involvement (CRM+) was more than 5 times greater in the open group than in the robot-assisted group, presenting a marginal significance (P = 0.057). Although important postoperative morbidity did not generally differ between the 2 groups, voiding difficulty and male sexual dysfunction appeared to be encountered more frequently in the open group than in the robot-assisted group.
Conclusion: The robot-assisted APR facilitated transabdominal extralevator excision and bowel recovery and demonstrated a trend towards reduced CRM+.
[Ann Surg Treat Res 2018;95(1):37-44]

Key Words: Rectal cancer, Robotics, Abdominoperineal resection

INTRODUCTION

Sphincter-saving operations are commonly employed for lower rectal cancer (LRC) treatment, and advancements in preoperative chemoradiotherapy (CRT), surgical technology, and stapling devices have combined to reduce rates of abdominoperineal resection (APR) [1]. However, a sizable number of LRC patients still receive APR. For example, one large-volume hospital reported that, from 1998 to 2004, the rate of APR in stages II–III patients who had received preoperative CRT was as high as 43% [2]. APR still remains an indispensable surgical tool for use in LRC patients with tumors very low down in the rectum, particularly in the case of sphincter invasion, large tumors, poor sphincter function, and patients with a deep or narrow pelvis.

In terms of oncologic and functional outcomes, APR sometimes appears to be considered as a less-satisfactory surgical technique. A systematic review involving 24 comparative

Received September 25, 2017, **Revised** November 7, 2017,
Accepted December 1, 2017

Corresponding Author: Jin Cheon Kim
Department of Surgery, Asan Medical Center, Institute of Innovative Cancer Research, University of Ulsan College of Medicine, 88 Olympic-ro 43-gil, Songpa-gu, Seoul 05505, Korea
Tel: +82-2-3010-3489, **Fax:** +82-2-474-9027
E-mail: jckim@amc.seoul.kr
ORCID code: https://orcid.org/0000-0003-4823-8619

studies concluded that APR had a higher local recurrence rate and poorer survival outcome than anterior resection [3]. However, in this review, the APR group included lower and more advanced tumors, which probably affected the oncological outcomes. The acceptability of permanent stoma appears to depend on individual tolerance. One study using a trade-off method reported that most patients preferred anterior resection above APR even if LAR involved a risk of fecal incontinence, while another study reported that approximately twice as many patients constantly opted for APR rather than anterior resection (46% *vs.* 22%) [4,5].

Although the laparoscopic approach provides a magnified view, it still has technical inconveniences due to the levering effect and the failure to maintain triangulation using long-shaft instruments. Recently, several investigations covering small case-series reported that robot-assisted APR presents technical efficiencies and has encouraging outcomes [6-8]. The present study aimed to objectively evaluate robot-assisted APR in comparison with open APR, in terms of operative elements and initial oncological outcomes.

METHODS

Patients

A total of 118 patients (≤75 years) with LRC who had undergone curative APR at the Asan Medical Center (Seoul, Korea) between June 2010 and June 2016 were recruited from the consecutively enrolled registry, and retrospectively analyzed. The choice of operative method using a robot-assisted or open approach (n = 40 and n = 78, respectively) was made by the patients, who were provided with full information about the 2 procedures. APR was primarily indicated when the distal tumor margin was ≤4 cm from the anal verge, combined with either suspicious levator/external anal sphincter (EAS) muscle invasion, or a large tumor within a restrictive pelvis. Preoperative CRT was indicated for all advanced LRC patients with T4 cancers (including low-lying or large T3) or clinical stage ≥ III, as evaluated by pelvic MRI and endorectal ultrasonography patients with preoperative CRT or those with pathological stage ≥ III received postoperative adjuvant chemotherapy. All patients submitted written informed consent, and the study protocol was approved by the Institutional Review Board of Asan Medical Center (approval number: 2016-0894), in accordance with the Declaration of Helsinki.

Surgical procedures

The lithotomy position was used for the entire APR procedure in both groups of patients, including the perineal phase. The robot-assisted APR used one of three da Vinci surgical systems, S, Si, or Xi (Intuitive Surgical Inc., Sunnyvale, CA, USA). The patient was placed in a 15° tilted Trendelenburg and left-roll position. The port placement for the former 2 systems has been previously described [9], whereas, for the Xi system, five 8-mm ports were positioned in the using appropriate instruments after cart installation (Fig. 1). The robot-assisted transabdominal procedure consisted of the abdominopelvic phase and pelvic phase in order (Supplementary material). The abdominopelvic procedure started with excision of the inferior mesenteric vessels and left colon mobilization, followed by ordinary pelvic dissection to the level of the peritoneal reflections with strict

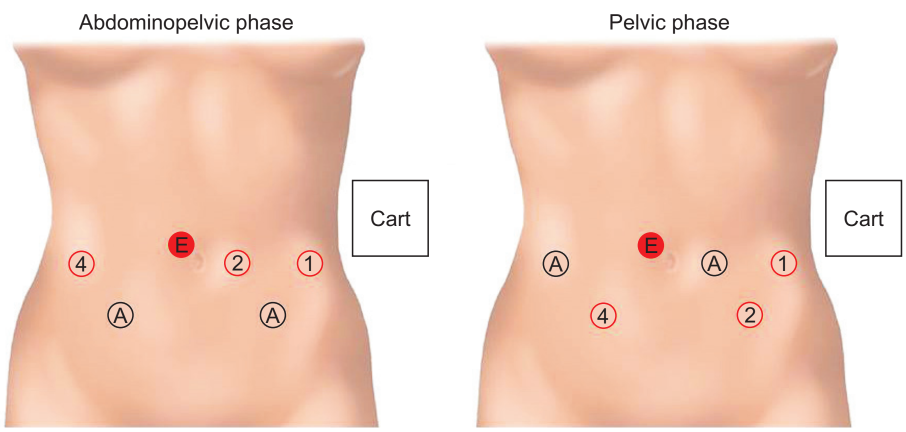

Fig. 1. Port positioning and instrument installation for the abdominopelvic phase and pelvic phase using a da Vinci Xi system (Intuitive Surgical Inc., Sunnyvale, CA, USA). All ports are 8 mm, except for the right lateral port used for the Smart stapler and Hem-o-lok (TeleFlex, Westmeath, Ireland). The 8-mm endoscope port is placed about 1 cm right and cephalad to the umbilicus. The remaining 3 horizontal ports are then placed on the umbilical line, i.e., 2 lateral ports 2 cm from the midclavicular line, and a left medial port 6–8 cm from the lateral port. Right and left quadrant ports are placed at the McBurney's point and counter-McBurney's point respectively. Instruments used are as follows: tip-up fenestrated grasper ①, Maryland bipolar grasper ②, and monopolar curved scissors ④ for the abdominopelvic phase; Maryland bipolar grasper ①, tip-up fenestrated grasper ②, monopolar curved scissors ④ for the pelvic phase. E, endoscope port; A, assistant port.

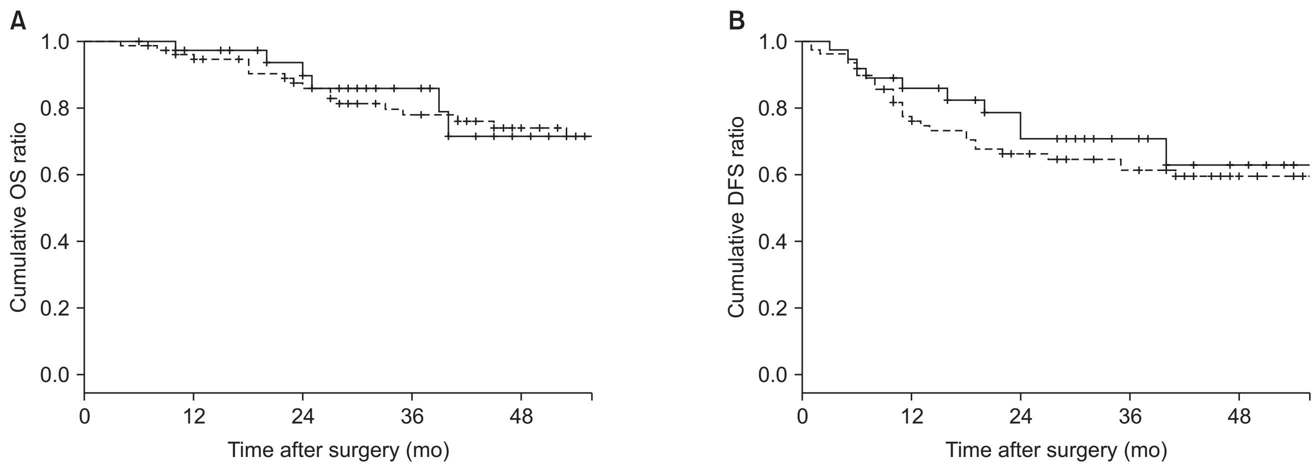

Fig. 2. The 2-year postoperative survival outcomes in 113 patients (robot-assisted APR group *vs*. open APR group, 36 *vs*. 77 patients) using the Kaplan-Meier method with the log-rank test. Robot-assisted APR group *vs*. open APR group: 2-year OS, 85.9% *vs*. 82.9%, P = 0.819; 2-year DFS, 70.7% *vs*. 67.6%, P = 0.487. APR, abdominoperineal resection; OS, overall survival; DFS, disease-free survival.

observance of total mesorectal excision (TME). The lengthened instruments of the Xi system enabled the abdominopelvic procedure to continue down to the bottom of the pelvis, where the mesorectum was connected to the levator muscles, or even to the level of the mesorectal end. The pelvic procedure mainly consisted of transabdominal extralevator (EL) excision, circumferentially from the rectourethralis to the anococcygeal ligament. The levator muscles underwent either partial or subtotal excision of the puborectalis-pubococcygeus muscles, securing a safe circumferential resection margin (CRM). The robot-assisted procedure usually enabled transabdominal excision up to the level of the EAS. An appropriate site of the proximal colon was then divided for the end-colostomy, after completion of the mesocolic division. Then, the anorectal stump was excised at the perineum including the transverse perineal and EAS remnants with ischiorectal fatty tissue after disengagement of the robot system. The main component of open APR was similar to that of the robot-assisted procedures, except for the level of transabdominal pelvic dissection at the mesorectal end. The EL excision was mostly performed during the perineal phase in the open APR. The perineal wound was primarily closed without using a mesh in all patients except for one, whose large perineal defect was reconstructed using a gluteus flap. All procedures were performed exclusively by a senior colorectal surgeon with over 30 years of experience and 4,000 rectal cancer operations, including 800 cases using the robot-assisted procedure.

Postoperative follow-up and evaluations

Surgical specimens were primarily examined in the operating zone by the operator and pathologist, for assessment of the presence of perforation, TME, and cylindrical excision. Serial sections were prepared at 3- to 5-mm intervals to identify involvement of the CRM (CRM+), which was defined as a distance of ≤1 mm between the deepest tumor cell and CRM. Patients received a regular follow-up examination every 6 months for the first 5 years, according to the guidelines of our institution [9]. Postoperative pain was recorded as the maximum value from 3-time assessments at one day after surgery using a visual analog scale (0–10). The operators' physical discomfort was similarly assessed by the surgeon using a visual analog scale (a modification of Lawson's: scales 0–5) immediately after the operation [9]. General surgical complications were evaluated during the 6-month postoperative period. Urinary dysfunction was determined as the patient requiring indwelling catheterization with supportive medication for more than 2 weeks (residual urine volume > 200 mL). Male sexual function (≤65 years) was assessed at 6–12 months postsurgery, with erectile firmness and ejaculatory frequency graded according to a visual analog scale, i.e., none–mild (0–1), moderate (2–3), and severe (4–5). Male sexual dysfunction was defined according to moderate and severe grades of either erectile or ejaculatory potency. The mean follow-up period was 36 months (interquartile range, 22–46 months). Recurrences and survival outcomes were examined in 100 patients undergoing more than 2 years of postoperative follow-up.

Statistical analysis

Clinicopathological variables were compared between the 2 groups with a contingency-table analysis and a Fisher exact test with 2-sided verification, a Pearson chi-square test, or an unpaired Student t-test. Significant variables were identified with a multivariate analysis using binary logistic regression. Survival outcomes were analyzed using the Kaplan-Meier method with a log-rank test. Statistical significance was defined as a P-value ≤ 0.05. All calculations were performed using IBM SPSS Statistics ver. 21.0 (IBM Co., Armonk, NY, USA).

RESULTS

Patient and tumor characteristics

The physical and tumor characteristics of the patients are presented in Table 1. The age difference was minimally adjusted by the inclusion of ≤75 years. However, the mean age was somwhat lower in the robot-assisted group than in the open group, possibly due to affording higher cost of the robot procedure in the former group. The mean body mass index in the 2 groups was 23.2 kg/m^2 (interquartile range, 21.4–25 kg/m^2). Preoperative CRT was administered in >90% of patients, and there was no difference in this incidence between the two groups. All patients received R0 resection for primary rectal cancer. In all patients except for one (the patient with groin and para-aortic lymph node metastases) in the robot-assisted group, R0 ablation for the synchronous metastasis was provided by resection, radiofrequency ablation, or stereotaxic radiotherapy, or a combination of these techniques. The mean tumor distance from the anal verge was 2 cm in the 2 groups. The direction and size of tumors did not differ between the 2 groups.

Operative elements and measures

The operative characteristics are presented in Table 2 (upper-half rows). Of 730 LRC patients who received curative primary tumor resection, 123 patients (16.4%) underwent APR, with a significantly greater incidence in the open group than in the robot-assisted group (27.5% *vs.* 9%, P < 0.001). The mean operative time was 43 minutes longer in the robot-assisted group than in the open group (P < 0.001), although the mean console time in the robot-assisted group was only 70 minutes. EL APR with TME, including excision of either one or both sides of the puborectalis and/or pubococcygeus muscles, was more frequently performed in the robot-assisted group than in the open group (P = 0.004). A complete specimen of cylindrical shape with intact TME, positively related to the EL excision (P = 0.007), was achieved in 79% of all the patients. Others were in the category of near complete specimen. Rates of intraoperative rectal perforation were similar in both groups (5%). Two cases of perforation occurred at the tumor necrosis in the robot-assisted group, whereas 2 cases occurred during perineal dissection of the rectourethralis muscle in the open APR group. No conversion to the open approach was experienced in the robot-assisted group. The operator's physical discomfort was significantly lower in the robot-assisted group than in the open group (P < 0.001). Total hospital charges were approximately 2-times greater in the robot-assisted APR than in the open APR (18,000 United States dollars [USD] *vs.* 9,500 USD, P < 0.001).

Postoperative courses and complications

Postoperative outcomes are summarized in Table 2 (lower-half rows). The pain score at one day after surgery was less, and

Table 1. Physical and tumor characteristics of the patients

Parameter	APR		P-value[a]
	Robot-assisted group (n = 40)	Open group (n = 78)	
Sex, male:female	27 (67):13 (33)	53 (68):25 (32)	>0.999
Age (yr)	54 ± 12	59 ± 9	0.016
ASA physical status, I–II:III	38 (95):2 (5)	77 (99):1 (1)	0.250
Prior abdominopelvic surgery	6 (15)	9 (12)	0.575
Body mass index (kg/m^2)	22.9 ± 3	23.4 ± 2.8	0.354
Interspinal distance (cm)	9.6 ± 8.7	9.2 ± 11.14	0.056
sagittal midpelvic diameter (cm)	9.8 ± 9.2	9.8 ± 13	0.877
Preoperative sCEA (ng/mL)	2.8 ± 3.2	3.3 ± 4.9	0.613
cStage[b], I:II:III:IV	2 (5):5 (12):32 (78):1 (5)	5 (7):5 (6):58 (75):10 (12)	0.224
cT-category, 1:2:3:4	2 (5):4 (10):20 (50)/14 (35)	3 (4):7 (9):40 (51):28 (36)	0.998
Preoperative CRT (%)	37 (93)	72 (92)	>0.999
Tumor distance of AV (cm)	1.5 ± 1	1.8 ± 1.1	0.104
Tumor long diameter (cm)	2.5 ± 2.2	2.5 ± 2.4	0.968
Tumor direction, A:P:C	10 (25):14 (35):16 (40)	28 (36):32 (41):18 (23)	0.146

Values are presented as number (%) or mean ± standard deviation.
APR, abdominoperineal resection; ASA, American Society of Anesthesiologists; sCEA, serum carcinoembryonic antigen; cStage/cT, clinical American Joint Committee on Cancer stage/T category; CRT, chemoradiotherapy; AV, anal verge; A:P:C, anterior:posterior: combined.
[a]All parameters were compared using Fisher exact test with 2-sided verification or Pearson chi-square test and an unpaired t-test. [b]Cancer staging according to the American Joint Committee on Cancer (8th ed., 2017). Preoperative clinical staging was determined by CT and MRI.

Table 2. Operative and postoperative outcomes

Parameter	APR		P-value[a]
	Robot-assisted group (n = 40)	Open group (n = 78)	
APR/all lower rectal cancer surgeries[b]	39/431 (9)	84/319 (27.5)	<0.001
Conversion to open surgery	0 (0)	NA	
Total operative time (min)	215 ± 56	172 ± 58	<0.001
Console time (min)	70 ± 20	NA	
Intraoperative rectal (tumor) perforation	2 (5)	4 (5)	>0.999
Extralevator muscle excision[c]	27 (68)	33 (42)	0.012
Cylindrical APR	34 (85)	59 (76)	0.341
Transfusion, >400 mL (%)	5 (13)	10 (13)	>0.999
Operator's physical discomfort[d]	1.5 ± 0.6	2.5 ± 0.6	<0.001
Pain score at 1 day after surgery[e]	4.6 ± 2.0	5.4 ± 2.2	0.043
Flatus passage (day)	2.3 ± 1	2.9 ± 1.0	0.002
Hospitalization (day)	8 ± 2.8	7.7 ± 4.7	0.724
General complications, ≤6-month postsurgery			
Perineal wound infection	4 (10)	15 (19)	0.290
Ileus	1 (3)	7 (9)	0.263
Voiding difficulty[f]	4 (10)	20 (26)[e]	0.055
Incisional hernia	0 (0)	3 (4)	0.550
Male sexual dysfunction/evaluable patients[g]	5/22 (23)	15/35 (43)	0.159
Mortality, ≤1 month of surgery	0 (0)	0 (0)	>0.999

Values are presented as number (%) or mean ± standard deviation.
APR, abdominoperineal resection; NA, not applicable.
[a]All parameters were compared using Fisher exact test with 2-sided verification and an unpaired t-test. [b]The number of lower rectal adenocarcinoma patients (tumor located ≤6 cm from the anal verge) with R0 resections during the study period. [c]APR with *en bloc* excision of more than either one or both side(s) of the puborectalis and/or pubococcygeus muscles. [d]Assessed by the surgeon using a visual analog scale (a modification of Lawson's: scales 0–5) immediately after the operation [15]. [e]According to the patient's subjective evaluation of pain on a visual analogue scale , 0 (none) to 10 (agonizing). [f]All patients recovered by supportive management within 3 months of surgery, except for one patient in each group who needed intermittent catheterization. [g]Assessed regarding erectile firmness and ejaculatory frequency, presented by grades using a visual analog scale, i.e., none–mild (0–1), moderate (2–3), and severe (4–5). Male sexual dysfunction: ≤65-year-old patients with moderate and severe grades of either erectile or ejaculatory potency.

the resumption of bowel function was somewhat earlier, in the robot-assisted group compared with the open group (P = 0.043 and P = 0.002, respectively). Although important postoperative morbidity did not generally differ between the 2 groups, voiding difficulty and male sexual dysfunction appeared to be encountered more frequently in the open group than in the robot-assisted group (2.6 and 1.9 fold, respectively; P = 0.055 and 0.159). Perineal wound complication (requiring drainage and antibiotics) occurred in 15% of all patients. Incisional hernia was found exclusively in the open group (4%). There were no operative mortalities (defined as within 1 month of surgery) in either group.

Pathological features related with oncological outcome

The pathological features are summarized in Table 3. Complete tumor regression was identified in 17 of the 109 patients (14.4%) who received preoperative CRT, with no significant difference found between the 2 groups. Overall pathological down-staging was achieved in a little more than half (63 of 109) of the patients. The number of retrieved lymph nodes and metastatic lymph nodes did not differ between the 2 groups. CRM+ occurrence was approximately 5 fold greater in the open group than in the robot-assisted group; however, the difference in incidence between the 2 groups was only marginally significant (P = 0.042 in 1-sided verification). The multivariate analysis showed that CRM+ was significantly associated with the parameters for perineural invasion and pT4 (P = 0.012 and P = 0.013, respectively, Table 4).

Recurrences and survival outcomes

During the mean follow-up period of 36 months (1–71 months), a local recurrence did not occur in the robot-assisted group, whereas 2 patients (3%) incurred local recurrence in the open group. Systemic recurrence occurred in 18% of the robot-assisted group and 28% of the open group during the same period; however, there were no differences in these incidences regarding local and systemic recurrences (P = 0.548 and P = 0.261, respectively). The 2-year overall survival (OS) and disease-free survival (DFS) rates in patients with stages 0–III did not

Table 3. Pathological features

Parameter	APR		P-value[a)]
	Robot-assisted group (n = 40)	Open group (n = 78)	
TRG[b)], I:II:III:IV:V	6 (16):1 (29):16 (42):4 (11):1 (3)	11 (13):14 (20):29 (42):18 (25):0 (0)	0.278
pAJCC stage[c)], 0:I:II:III:IV	7 (18):7 (18): 11 (28):13 (33):2 (5)	12 (15):15 (19):22 (28):19 (24):10 (13)	0.670
pT-category, 0:Tis:1:2:3:4	6 (15):5 (13):7 (18):19 (48):2 (5):1 (3)	11 (12):5 (5):15 (8):33 (23):10 (41):4 (12)	0.639
Growth, expanding:infiltrative	8 (2):32 (80)	7 (9):71 (91)	0.142
Differentiation, WD:MD:PD	7 (18):31 (78):2 (5)	11 (14):59 (76):8 (10)	0.584
Lymphovascular invasion +	5 (13)	10 (13)	>0.999
Perineural invasion +	8 (20)	22 (26)	0.506
No. of retrieved lymph nodes	17 ± 7	15 ± 5	0.134
No. of metastatic lymph nodes	1 ± 1	1 ± 3	0.151
CRM involvement, ≤1 mm (%)	1 (3)	11 (14)	0.057[d)]

Values are presented as number (%) or mean ± standard deviation.
APR, abdominoperineal resection; TRG, tumor regression grade; pStage/pT, pathological American Joint Committee on Cancer (AJCC) stage/T category; WD:MD:PD, well:moderately:poorly differentiated; CRM, circumferential resection margin.
[a)]All parameters were compared using Fisher exact test with 2-sided verification or Pearson chi-square test and an unpaired t-test. [b)]TRG 1, 2, 3, 4, and 5 defined as complete, near total, moderate, minimal and no responses, respectively. [c)]Cancer staging according to the American Joint Committee on Cancer (8th ed., 2017). [d)]P = 0.042 in 1-sided verification.

Table 4. Parameters associated with positivity of the circumferential resection margin

Parameter	No (%)	P-value[a)]	OR	95% CI	P-value[b)]
Robot-assisted *vs.* open group	1/40 (2) *vs.* 11/78 (14)	0.057	2.989	0.31–28.826	0.344
TRG[c)], 1–2 *vs.* 3–5	1/40 (2.4) *vs.* 10/71 (13.3)	0.094	1.752	0.165–18.617	0.642
Preoperative sCEA level, ≤6 ng/mL *vs.* >6 ng/mL	9/103 (9) *vs.* 3/15 (20)	0.18	0.582	0.059–5.753	0.643
Cylindrical-shaped specimen, no *vs.* yes	5/25 (20) *vs.* 7/93 (8)	0.127	0.249	0.041–1.513	0.131
pT[d)], 0–3 *vs.* 4	5/101 (5) *vs.* 7/17 (41)	<0.001	9.837	1.611–60.052	0.013
Lymphovascular invasion, – *vs.* +	9/103 (9) *vs.* 3/15 (20)	0.18	0.671	0.086–5.244	0.704
Perineural invasion, – *vs.* +	4/89 *vs.* 8/29 (4 *vs.* 28)	0.001	9.692	1.633–57.505	0.012

OR, odds ratio; CI, confidence interval; TRG, tumor regression grade after preoperative chemoradiotherapy; sCEA, serum carcinoembryonic antigen; pT, pathological American Joint Committee on Cancer T category.
[a)]Parameters were compared using Fisher exact test with 2-sided verification. [b)]Potential variables were verified by multivariate analysis using binary logistic regression. [c)]TRG 1, 2, 3, 4, and 5 defined as complete, near total, moderate, minimal and no responses, respectively. [d)]Cancer staging according to the American Joint Committee on Cancer (8th ed., 2017).

differ between the 2 groups (robot-assisted group *vs.* open group: 2-year OS, 85.9% *vs.* 82.9%, P = 0.819; 2-year DFS, 70.7% *vs.* 67.6%, P = 0.487) (Fig. 2).

DISCUSSION

The transabdominal procedure of the robot-assisted APR allowed most of the EL excision to be accomplished, further down to the level of the EAS. The clearly magnified view into the pelvis enabled definitive identification of levator muscles from their origin to insertion. This single abdominal approach at the mesorectal end therefore has the advantage of a cylindrical excision without waist formation. However, in the 750 LRC patients operated on during the study period, the APR rate was significantly reduced in the robot-assisted group in comparison with the open group (9% *vs.* 27.5%), as it was replaced with intersphincteric resection. Our operative time in the robot-assisted group was shorter than in other reports, as the lithotomy position and primary closure of the wound saved time [6,8]. We did not experience any conversion to open APR. A recent comparative study using the US nation-wide database also presented a significantly lower conversion rate for robot-assisted APR compared with laparoscopy-assisted APR (5.7% *vs.* 13.4%) [10]. The operator's physical discomfort was significantly lower in the robot-assisted group than in the open group. The physical burden may be reduced in the robot procedure because of reductions to 3 common ergonomic errors in the posture of surgeons, namely, a forward head position, improper shoulder elevation, and pelvic girdle asymmetry [11]. The hospital stay in the 2 groups appears to be a little longer, concurrently without any differences between the 2 groups, raising an introduction of the "Enhanced Recovery After Surgery" protocol [12].

Similarly to previous reports, the pain sensation on the day of surgery was less in the robot-assisted group, and functional recovery of bowel was earlier in comparison with the open group. These were probably due to the reduced invasiveness of the robot-assisted procedure [6,9,13-15]. In the present study, urinary and male sexual functions appeared to be better preserved in the robot-assisted group than in the open group (90% *vs.* 74%, and 77% *vs.* 57%, respectively), with a similar trend also being identified in our previous study concerned with sphincter-saving operations [14]. The reported rates of voiding difficulty and male sexual dysfunction after rectal cancer surgery vary from 0%–35% to 5%–65% respectively [16]. The robot-assisted APR provided clear visualization and fine dissection, enabling preservation of the pelvic autonomic nerves along the entire course, particularly at the inferior hypogastric plexus and their vesiculoprostatic branches. However, some injury to the pelvic nerves may be unavoidable during division of the levator muscles, transverse perineal muscles, and presacral parietal fascia [17]. External beam radiation therapy to the penile cavernous bodies has also been suggested as a cause of erectile dysfunction, as it may result in increased fibrosis and decreased smooth muscle content [18]. Perineal wound complications requiring drainage and antibiotics occurred in 10% of our robot-assisted group, a similar rate to that in a recent report on robot-assisted APR [6]. We used primary closure of the perineal wound without an omental flap, biomesh, or myocutaneous flap, except for one patient in the open group where a gluteus flap was used. Although a wider excision accompanied by EL excision and radiotherapy have been suggested as risk factors [19,20], primary closure was conveniently accomplished without severe tension or any occurrence of necrosis in the present study.

EL excision was primarily intended in cases of ≥T3 lesions in our study, and it was more frequently performed in the robot-assisted group than in the open group. A previous morphometrical study stated that cylindrical EL APR removed more tissue around the tumor, leading to a reduction in CRM+ and intraoperative rectal perforation [21]. This study also reported an anterior perforation rate of 81.8%. In the present study, rectal perforation occurred mostly at the necrotic portion of the tumors, except for 2 cases in the open group, where it occurred during anterior dissection. It appears hard to achieve an intact specimen without injury at the tumor necrosis, but operative injury near the tumor must be avoided. The levering effect during anterior pelvic dissection may result in an iatrogenic injury, regardless of the abdominal or perineal procedure, while the articulated fine instruments used in the robot-assisted APR enable transabdominal pelvic dissection at the levator muscles without any motion barrier.

CRM+ occurrences were up to 5 times greater in the open group than in the robot-assisted group, but this difference was only marginally significant, which was probably due to the low incidence in our limited cohort. Nevertheless, CRM involvement is a strong predictor for local recurrence and decreased OS after any type of rectal cancer surgery [22,23]. The multivariate analysis identified CRM+ as being closely correlated with pT4 and perineural invasion. A study that included 5,017 patients also presented the same relationship between CRM+ and pT4 [24]. Perineural invasion (PNI+) has been reported as a strong predictor for CRM+ [24,25]. The present study did not show remarkable correlations between CRM+ and either EL or cylindrical excision. One study that included 176 EL APRs by 11 European surgeons presented less CRM+ than in standard APR, whereas another review did not find any evidence of reduced CRM+ in EL APR [19,26]. These contradictory findings may be partly due to inconsistent definitions of the extent of excision of EL APR. Nevertheless, a sufficient resection margin should be obtained to reduce CRM+, particularly at and adjacent to the tumor.

Since the introduction of laparoscopic APR, it has shown our findings should be interpreted with consideration of several study limitations. Firstly, this was a retrospective study involving consecutive cases experienced by a single surgeon. Secondly, a limited period and sample size mean that the findings do not necessarily indicate reliable oncological outcomes. We did not include the laparoscopy group due to limited number of cases during the study period, although laparoscopy-assisted APR has been reported to exhibit lower morbidity risks compared with open APR [10,27]. Despite these limitations, the robot-assisted APR facilitated a trend towards reduced CRM+ in transabdominal EL excision, and improved functional recovery. Further studies including randomized controlled trials are needed to complement and establish the evidence for the oncological superiority of robot-assisted APR.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGEMENTS

This study was supported by the grants from the Korea Research Foundation (2016R1E1A1A02919844), Ministry of Science, ICT, and Future Planning, Republic of Korea.

SUPPLEMENTARY MATERIAL

Supplementary material can be found via https://www.astr.or.kr/src/sm/astr-95-37-001.mp4.

REFERENCES

1. Chau A, Maggiori L, Debove C, Kanso F, Hennequin C, Panis Y. Toward the end of abdominoperineal resection for rectal cancer? An 8-year experience in 189 consecutive patients with low rectal cancer. Ann Surg 2014;260:801-5.
2. Weiser MR, Quah HM, Shia J, Guillem JG, Paty PB, Temple LK, et al. Sphincter preservation in low rectal cancer is facilitated by preoperative chemoradiation and intersphincteric dissection. Ann Surg 2009;249:236-42.
3. How P, Shihab O, Tekkis P, Brown G, Quirke P, Heald R, et al. A systematic review of cancer related patient outcomes after anterior resection and abdominoperineal excision for rectal cancer in the total mesorectal excision era. Surg Oncol 2011;20:e149-55.
4. Bossema E, Stiggelbout A, Baas-Thijssen M, van de Velde C, Marijnen C. Patients' preferences for low rectal cancer surgery. Eur J Surg Oncol 2008;34:42-8.
5. Zolciak A, Bujko K, Kepka L, Oledzki J, Rutkowski A, Nowacki MP. Abdominoperineal resection or anterior resection for rectal cancer: patient preferences before and after treatment. Colorectal Dis 2006;8:575-80.
6. Eftaiha SM, Pai A, Sulo S, Park JJ, Prasad LM, Marecik SJ. Robot-assisted abdominoperineal resection: clinical, pathologic, and oncologic outcomes. Dis Colon Rectum 2016;59:607-14.
7. Kim JC, Kwak JY, Yoon YS, Park IJ, Kim CW. A comparison of the technical and oncologic validity between robot-assisted and conventional open abdominoperineal resection. Int J Colorectal Dis 2014;29:961-9.
8. Sieffert M, Ouellette J, Johnson M, Hicks T, Hellan M. Novel technique of robotic extralevator abdominoperineal resection with gracilis flap closure. Int J Med Robot 2017;13(3). https://doi.org/10.1002/rcs.1764.
9. Kim JC, Yang SS, Jang TY, Kwak JY, Yun MJ, Lim SB. Open versus robot-assisted sphincter-saving operations in rectal cancer patients: techniques and comparison of outcomes between groups of 100 matched patients. Int J Med Robot 2012;8:468-75.
10. Moghadamyeghaneh Z, Phelan M, Smith BR, Stamos MJ. Outcomes of open, laparoscopic, and robotic abdominoperineal resections in patients with rectal cancer. Dis Colon Rectum 2015;58:1123-9.
11. Rosenblatt PL, McKinney J, Adams SR. Ergonomics in the operating room: protecting the surgeon. J Minim Invasive Gynecol 2013;20:744.
12. Ljungqvist O, Scott M, Fearon KC. Enhanced recovery after surgery: a review. JAMA Surg 2017;152:292-8.
13. Park JS, Choi GS, Lim KH, Jang YS, Jun SH. S052: a comparison of robot-assisted, laparoscopic, and open surgery in the treatment of rectal cancer. Surg Endosc 2011;25:240-8.
14. Kim JC, Lim SB, Yoon YS, Park IJ, Kim CW, Kim CN. Completely abdominal intersphincteric resection for lower rectal cancer: feasibility and comparison of robot-assisted and open surgery. Surg Endosc 2014;28:2734-44.
15. Lee SH, Lim S, Kim JH, Lee KY. Robotic versus conventional laparoscopic surgery for rectal cancer: systematic review and meta-analysis. Ann Surg Treat Res 2015; 89:190-201.
16. Kasparek MS, Hassan I, Cima RR, Larson DR, Gullerud RE, Wolff BG. Long-term quality of life and sexual and urinary function after abdominoperineal resection for distal rectal cancer. Dis Colon Rectum 2012;55:147-54.
17. Enker WE, Havenga K, Polyak T, Thaler H, Cranor M. Abdominoperineal resection via total mesorectal excision and autonomic nerve preservation for low rectal cancer. World J Surg 1997;21:715-20.
18. Lange MM, van de Velde CJ. Urinary and sexual dysfunction after rectal cancer treatment. Nat Rev Urol 2011;8:51-7.
19. West NP, Anderin C, Smith KJ, Holm T, Quirke P; European Extralevator Abdominoperineal Excision Study Group. Multicentre experience with extralevator abdominoperineal excision for low rectal cancer. Br J Surg 2010;97:588-99.
20. Butt HZ, Salem MK, Vijaynagar B, Chaudhri S, Singh B. Perineal reconstruction after extra-levator abdominoperineal excision (eLAPE): a systematic review. Int J Colorectal Dis 2013;28:1459-68.
21. West NP, Finan PJ, Anderin C, Lindholm J, Holm T, Quirke P. Evidence of the oncologic superiority of cylindrical abdominoperineal excision for low rectal cancer. J Clin Oncol 2008;26:3517-22.
22. Adam IJ, Mohamdee MO, Martin IG, Scott N, Finan PJ, Johnston D, et al. Role of circumferential margin involvement in the local recurrence of rectal cancer. Lancet 1994;344:707-11.
23. Kennelly RP, Rogers AC, Winter DC; Abdominoperineal Excision Study Group. Multicentre study of circumferential margin positivity and outcomes following abdominoperineal excision for rectal cancer. Br J Surg 2013;100:160-6.
24. van Leersum N, Martijnse I, den Dulk M, Kolfschoten N, Le Cessie S, van de Velde C, et al. Differences in circumferential resection margin involvement after abdominoperineal excision and low anterior resection no longer significant. Ann Surg 2014;259:1150-5.
25. Rickles AS, Dietz DW, Chang GJ, Wexner SD, Berho ME, Remzi FH, et al. High rate of positive circumferential resection margins following rectal cancer surgery: a call to action. Ann Surg 2015;262:891-8.
26. Krishna A, Rickard MJ, Keshava A, Dent OF, Chapuis PH. A comparison of published rates of resection margin involvement and intra-operative perforation between standard and 'cylindrical' abdominoperineal excision for low rectal cancer. Colorectal Dis 2013;15:57-65.
27. Ahmad NZ, Racheva G, Elmusharaf H. A systematic review and meta-analysis of randomized and non-randomized studies comparing laparoscopic and open abdominoperineal resection for rectal cancer. Colorectal Dis 2013;15:269-77.