Comparison between robotic-assisted and laparoscopic sphincter-preserving operations for ultra-low rectal cancer: a single institutional retrospective study

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Abstract

Background

Sphincter-preserving operations for ultra-low rectal cancer include low anterior resection and intersphincteric resection. In low anterior resection, the distal rectum is divided by a transabdominal approach, which is technically demanding. In intersphincteric resection, a perineal approach is performed. We aimed to evaluate whether robotic-assisted surgery is technically superior to laparoscopic surgery for ultra-low rectal cancer. The frequency of conducting low anterior resection by a specific procedure can indicate the technical superiority of that procedure for ultra-low rectal cancer. Thus, we compared the frequency of low anterior resection between robotic-assisted and laparoscopic surgery in cases of sphincter-preserving operations.

Methods

We investigated 183 patients who underwent sphincter-preserving robotic-assisted or laparoscopic surgery for ultra-low rectal cancer (lower border within 5 cm of the anal verge) between April 2010 and March 2020. The frequency of low anterior resection was compared between laparoscopic and robotic-assisted surgeries. The clinicopathological factors associated with an increase in performing low anterior resection were analyzed by multivariate analyses.

Results

Overall, 41 (22.4%) and 142 (77.6%) patients underwent laparoscopic and robotic-assisted surgery, respectively. Patient characteristics were similar between the groups. Low anterior resection was performed significantly more frequently in robotic-assisted surgery (67.6%) than in laparoscopic surgery (48.8%) ($p = 0.04$). Multivariate analyses showed that tumor distance from the anal verge ($p < 0.01$) and robotic-assisted surgery ($p = 0.02$) were significantly associated with an increase in the performance of low anterior resection. The rate of postoperative complications or pathological results was similar between the groups.

Conclusions

Compared with laparoscopic surgery, robotic-assisted surgery significantly increased the frequency of low anterior resection in sphincter-preserving operations for ultra-low rectal cancer. Robotic-assisted surgery has technical superiority over laparoscopic surgery for ultra-low rectal cancer treatment.

Background

Surgical outcomes of robotic-assisted surgery (RS) for rectal cancer have recently been reported [1–3]. Several studies have shown excellent outcomes with RS in terms of urinary function, sexual function, defecatory function, and local recurrence rate for rectal cancer compared to those achieved by laparoscopic surgery (LS) or open surgery (OS) [4–9].

To date, differences in the types of RS and LS for low rectal cancer have not been fully investigated. The advanced technology of RS allows sphincter-preserving operations (SPOs) to be performed more often than LS or OS [10, 11]. Further, RS enables patients with low rectal cancer to avoid abdominoperineal resection (APR) and the creation of a permanent stoma, suggesting that RS would be technically superior. Nevertheless, the indications for SPOs are determined not only by technical factors but also by anorectal function and lifestyle. SPOs markedly influence postoperative defecatory function [12]. Consequently, preoperative anorectal functions and the patient's acceptance of postoperative bowel dysfunction must always be considered when contemplating an SPO. Therefore, to evaluate the technical superiority of RS for rectal cancer in terms of selecting the type of operation, investigating only the frequency of SPOs would be insufficient.

For a more detailed investigation of the technical superiority of RS with regard to the operation type, we focused on two SPOs, low anterior resection (LAR) and intersphincteric resection (ISR), performed for ultra-low rectal cancer. [13]. Generally, LAR is performed when the distal rectum can be divided using linear staplers via a transabdominal approach, and ISR is performed when this is not possible. Dividing the distal rectum via the transabdominal approach is technically demanding, and the type of SPO that can be performed depends mainly on technical factors. Therefore, the frequency of conducting LAR by a specific procedure can indicate the technical superiority of that procedure for ultra-low rectal cancer. Thus, in this study, we compared the frequency of LAR between RS and LS in patients who underwent SPOs for ultra-low rectal cancer to evaluate whether RS was technically superior to LS.

Methods

Patient Selection

Data were collected from the institutional database at Shizuoka Cancer Center and were analyzed retrospectively. Between April 2010 and March 2020, 287 patients with primary ultra-low rectal adenocarcinoma (lower edge of the tumor within 5 cm from the anal verge [AV]) underwent robotic-assisted or laparoscopic SPO with curative intent. SPOs included LAR and ISR, and all patients underwent transabdominal total mesorectal excision (TME) [14]. No patients underwent transanal TME (TaTME). During LAR, both TME and division of the distal rectum using a linear stapler were performed via a transabdominal approach. The coloanal anastomosis was performed using the double-stapling technique. ISR was defined as a surgical procedure that included both transabdominal and transanal approaches. In ISR, TME was performed using the transabdominal approach, followed by transanal resection. This involved surgical dissection of the intersphincteric space and en bloc resection of the rectum, together with the internal anal sphincter within the anatomical anal duct. After removal of the

specimen, a coloanal anastomosis was performed using transanal manual suturing in all patients [15, 16]. Patients in whom the intersphincteric space could be entered and in whom partial excision of the internal anal sphincter was performed via the transabdominal approach were included in the LAR group, as previously described [17].

We excluded patients with tumors that extended into the anal canal, those who received preoperative treatment, such as chemotherapy and/or radiotherapy, those with multi-visceral resection, and those with a history of colectomy other than appendectomy (Fig. 1). Consequently, 183 patients were enrolled in this study.

Preoperative assessment included digital rectal examination, colonoscopy, computed tomography, contrast enema, and magnetic resonance imaging. If necessary, positron-emission tomography-computed tomography was performed. Tumor staging was performed using the tumor node metastasis classification [18]. The indications for lateral lymph node dissection (LLD) were low rectal adenocarcinoma with cT3–4 or cT1–2 with metastasis to the lateral lymph nodes [19, 20]. However, LLD was not performed if the patients without lateral lymph node metastasis on preoperative images were 75 years or older, had severe comorbidities, or received preoperative chemoradiation [19]. Consistent with a previous report, we regarded lateral lymph nodes as regional lymph nodes [21].

At our institution, RS was introduced in December 2011. Until March 2018, the national public health insurance in Japan did not cover RS for rectal cancer. Thus, RS was an expensive procedure. The selection of RS, LS, or OS was based on the patient's preference and informed consent. Since April 2018, RS is covered by the national public health insurance. We, therefore, performed RS for most patients.

The study was approved by the institutional review board of Shizuoka Cancer Center (Approval Code: J2020-37-2020-1-3).

Indications for SPO

SPO was indicated only for patients with the following characteristics: a clear resection margin, acceptable postoperative anal function, and absence of invasion into the levator ani muscles and external anal sphincter. The standard operative rule was total TME with autonomic nerve preservation [14]. Japanese D2 or D3 lymph node dissection was performed [12, 15]. LAR was indicated for patients in whom the transabdominal approach could divide the distal rectum using linear staplers. ISR was performed when the distal rectum could not be divided via the transabdominal approach, either because of technical difficulties or to ensure a sufficient distal resection margin. ISR was excluded for patients with poorly differentiated adenocarcinoma or with decreased anal sphincter tonus. APR was performed when (1) the tumor invaded the external anal sphincter or levator ani muscles, (2) the tumor was the diffuse infiltrative spreading type based on macroscopic appearance, (3) fecal continence was impaired preoperatively, or (4) patients could not tolerate postoperative defecatory dysfunction. All treatment strategies were approved in a multidisciplinary team conference.

Surgical Procedure

The institutional standard surgical procedure has been described elsewhere [22–24]. The surgical procedure was almost the same in both LAR and ISR up to dividing the rectum. In brief, the inferior mesenteric artery and vein ligations and colon mobilization were performed via a medial-to-lateral approach. The rectum was mobilized down to the pelvic floor as for TME. During LAR, the distal rectum was divided using linear staplers via the transabdominal approach. In RS, robotic-assisted or a conventional laparoscopic linear stapler was used. In LS, only a conventional laparoscopic linear stapler was used. The specimen was extracted through a mini-laparotomy at the umbilical site. The standard double-stapling technique was utilized for end-to-end anastomosis. A diverting stoma was constructed if necessary. In patients who underwent ISR, intersphincteric dissection and specimen extraction were performed via the transanal approach [24]. The coloanal anastomosis was hand-sewn. A diverting stoma was constructed in all patients who underwent ISR. During the transanal part of the surgery, the surgical procedure was the same in both RS and LS [20].

Outcome Variables

We collected data on patient characteristics as well as perioperative outcomes, including the frequency of LAR, postoperative complications, and pathological results. Postoperative complications within 30 days were categorized according to the Clavien–Dindo classification system [25]. The association between clinicopathological factors and SPO type was analyzed. The radicality of each surgical procedure was defined as R0 (macroscopic complete resection with no microscopic residual tumor), R1 (macroscopic complete resection with microscopic residual tumor at the resection margin), or R2 (macroscopic residual tumor).

Statistical Analyses

Parametric variables are expressed as median values. The Fisher's exact test, the chi-squared test, and the Mann–Whitney U test were used, as appropriate, to assess the significance of between-group differences. Univariate and multivariate logistic regression analyses were performed to identify factors associated with the performance of LAR. A p-value of < 0.05 was considered significant. All statistical analyses were performed using R software version 3.5.2 (The R Foundation for Statistical Computing, Vienna, Austria).

Results

A total of 183 consecutive patients who underwent SPOs for ultra-low rectal cancer were analyzed. The characteristics of the 41 (22.4%) patients who underwent LS and 142 (77.6%) patients who underwent RS are summarized in Table 1. Although the clinical stage in the RS group tended to be more advanced than that in the LS group, the difference was not statistically significant.

Table 1
Patient characteristics

	LS	RS	
	<i>(n = 41)</i>	<i>(n = 142)</i>	<i>p</i>
Age (years)	65 (29–83)	64 (29–84)	0.61
Sex			0.19
Male	24 (58.5%)	100 (70.4%)	
Female	17 (41.5%)	42 (29.6%)	
BMI (kg/m ²)	23.0 (12.8–37.6)	23.1 (15.7–32.5)	0.74
ASA–PS			0.12
1	11 (26.8%)	33 (23.2%)	
2	26 (63.4%)	105 (73.9%)	
3	4 (9.8%)	4 (2.8%)	
Tumor distance from the AV (cm)	5.0 (3.0–5.0)	5.0 (2.0–5.0)	0.38
Tumor size (mm)	33 (2–122)	36 (2–121)	0.85
Clinical T stage			0.44
T1	15 (36.6%)	41 (28.9%)	
T2	9 (22.0%)	25 (17.6%)	
T3	15 (36.6%)	71 (50.0%)	
T4	2 (4.9%)	5 (3.5%)	
Clinical N stage			0.19
N0	31 (75.6%)	84 (59.2%)	
N1	7 (17.1%)	37 (26.1%)	
N2	3 (7.3%)	21 (14.8%)	
Clinical stage			0.18
I	21 (51.2%)	55 (38.7%)	

Values are expressed as the number (percentage) or median value (range).

LS: laparoscopic surgery, RS: robotic-assisted surgery, BMI: body mass index, ASA–PS: American Society of Anesthesiologists–Physical Status, AV: anal verge

	<i>LS</i>	<i>RS</i>
II	10 (24.4%)	28 (19.7%)
III	10 (24.4%)	51 (35.9%)
IV	0 (0.0%)	8 (5.6%)
Values are expressed as the number (percentage) or median value (range).		
LS: laparoscopic surgery, RS: robotic-assisted surgery, BMI: body mass index, ASA–PS: American Society of Anesthesiologists–Physical Status, AV: anal verge		

Table 2 summarizes the perioperative outcomes. Compared to the LS group, LLD was performed significantly more frequently in the RS group. Operative times were significantly longer in the RS group than in the LS group. However, when the patients who underwent LLD were excluded, operative times in the RS group tended to be shorter than those in the LS group (Supplementary Table 1). The frequency of LAR was significantly higher, blood loss was significantly less, and the length of postoperative hospital stay was significantly shorter in the RS group than in the LS group.

Table 2
Perioperative outcomes

	<i>LS</i>	<i>RS</i>	
	(<i>n</i> = 41)	(<i>n</i> = 142)	<i>p</i>
Operative time (minutes)	305 (153–528)	322 (138–625)	0.02
Blood loss (mL)	29 (0–385)	13 (0–215)	0.02
Type of operation			0.04
ISR	21 (51.2%)	46 (32.4%)	
LAR	20 (48.8%)	96 (67.6%)	
Lateral lymph node dissection	8 (19.5%)	70 (49.3%)	< 0.01
Diverting stoma	25 (61.0%)	85 (59.9%)	1.00
Conversion	0 (0.0%)	0 (0.0%)	1.00
Length of postoperative hospital stay (days)	8 (6–28)	7 (6–22)	0.01
Values are expressed as the number (percentage) or median value (range).			
LS: laparoscopic surgery, RS: robotic-assisted surgery, ISR: intersphincteric resection, LAR: low anterior resection			

The associations between clinicopathological factors and the type of SPO are shown in Table 3. Univariate analyses indicated that tumor distance from the AV and RS were significantly associated with

an increase in the frequency of LAR for ultra-low rectal cancer. Multivariate analyses revealed that tumor distance from the AV and RS was significantly associated with an increased LAR frequency.

Table 3
Univariate and multivariate analyses of factors linked to LAR performance frequency

	<i>ISR</i>	<i>LAR</i>	<i>Univariate</i>			<i>Multivariate</i>		
	(<i>n</i> = 67)	(<i>n</i> = 116)	<i>Odds ratio</i>	<i>95% CI</i>	<i>p</i>	<i>Odds ratio</i>	<i>95% CI</i>	<i>p</i>
Age (years)	63 (29–79)	65 (29–84)	1.01	0.98–1.04	0.46	1.01	0.98–1.05	0.54
Sex			0.96	0.50–1.82	0.90	1.03	0.46–2.33	0.94
Male	45 (36.3%)	79 (63.7%)						
Female	22 (37.3%)	37 (62.7%)						
BMI (kg/m ²)	23.1 (12.8–32.3)	23.0 (15.7–37.6)	0.99	0.91–1.07	0.76	1.03	0.93–1.14	0.58
Tumor distance from the AV (cm)	4.0 (2.0–5.0)	5.0 (3.0–5.0)	3.40	2.06–5.61	< 0.01	3.52	1.93–6.40	< 0.01
Tumor size (mm)	33 (2–121)	38 (2–122)	1.01	0.99–1.02	0.20	1.01	0.99–1.03	0.48
Clinical T stage			1.33	0.73–2.44	0.35	0.99	0.39–2.49	0.98
T1–2	36 (40.0%)	54 (60.0%)						
T3–4	31 (33.3%)	62 (66.7%)						
Clinical N stage			1.09	0.59–2.04	0.78	0.83	0.36–1.91	0.66
N0	43 (37.4%)	72 (62.6%)						
N1–2	24 (35.3%)	44 (64.7%)						

Values are expressed as the number (percentage) or median value (range).

ISR: intersphincteric resection, LAR: low anterior resection, LS: laparoscopic surgery, RS: robotic-assisted surgery, CI: confidence interval, BMI: body mass index, AV: anal verge

	<i>ISR</i>	<i>LAR</i>	<i>Univariate</i>		<i>Multivariate</i>		
Surgical approach			2.19	1.08–4.44	0.03	2.93	1.22–7.03
LS	21 (51.2%)	20 (48.8%)					
RS	46 (32.4%)	96 (67.6%)					
Values are expressed as the number (percentage) or median value (range).							
ISR: intersphincteric resection, LAR: low anterior resection, LS: laparoscopic surgery, RS: robotic-assisted surgery, CI: confidence interval, BMI: body mass index, AV: anal verge							

Table 4 summarizes the postoperative complications. The rate of postoperative complications ($\geq$ Clavien–Dindo grade II) was similar between the groups. Postoperative mortality did not occur in either group.

Table 4
Postoperative complications

	<i>LS</i>	<i>RS</i>	
	(<i>n</i> = 41)	(<i>n</i> = 142)	<i>p</i>
$\geq$ Grade II (Clavien–Dindo)	11 (26.8%)	35 (24.6%)	0.84
Ileus	3 (7.3%)	4 (2.8%)	0.19
Anastomotic leakage	2 (4.9%)	8 (5.6%)	1.00
Enteritis	2 (4.9%)	2 (1.4%)	0.22
Urinary tract infection	1 (2.4%)	7 (4.9%)	0.69
Urinary retention	1 (2.4%)	6 (4.2%)	1.00
Wound infection	1 (2.4%)	3 (2.1%)	1.00
Pneumonia	1 (2.4%)	2 (1.4%)	0.54
Abdominal abscess	1 (2.4%)	1 (0.7%)	0.40
Intra-abdominal bleeding	0 (0.0%)	3 (2.1%)	1.00
Others	1 (2.4%)	3 (2.1%)	1.00
Mortality	0 (0.0%)	0 (0.0%)	1.00
Values are expressed as the number (percentage) or median value (range).			
LS: laparoscopic surgery, RS: robotic-assisted surgery			

Table 5 shows the pathological results. Complete local resection (R0) rates and distal resection margins were similar between the LS and RS groups.

Table 5
Pathological outcomes

	<i>LS</i>	<i>RS</i>	
	<i>(n = 41)</i>	<i>(n = 142)</i>	<i>p</i>
Pathological T stage			0.34
T1	16 (39.0%)	43 (30.3%)	
T2	15 (36.6%)	45 (31.7%)	
T3	8 (19.5%)	48 (38.8%)	
T4	2 (4.9%)	6 (4.2%)	
Pathological N stage			0.86
N0	28 (68.3%)	97 (68.3%)	
N1	9 (22.0%)	27 (19.0%)	
N2	4 (9.8%)	18 (12.7%)	
Pathological stage			0.15
I	25 (61.0%)	73 (51.4%)	
II	2 (4.9%)	25 (17.6%)	
III	13 (31.7%)	36 (25.4%)	
IV	1 (2.4%)	8 (5.6%)	
Local resection margin			1.00
R0	41 (100%)	140 (98.6%)	
R1	0 (0.0%)	2 (1.4%)	
R2	0 (0.0%)	0 (0.0%)	
Distal resection margin (mm)	14.5 (0.5–35.0)	16.0 (0.5–50.0)	0.60
Values are expressed as the number (percentage) or median value (range).			
LS: laparoscopic surgery, RS: robotic-assisted surgery			

Discussion

In this study, we evaluated whether RS has technical superiority over LS for ultra-low rectal cancer by comparing LAR frequency in patients who underwent SPOs. Compared to LS, RS was significantly associated with an increased frequency of LAR in SPOs for ultra-low rectal cancer. Our findings support the argument that RS has technical superiority over LS for ultra-low rectal cancer treatment.

Minimally invasive surgery for low rectal cancer requires highly advanced surgical skills. The lower the tumor is located in the deep and narrow pelvis, the more technically challenging the procedure becomes. Previously, APR was the standard procedure for low rectal cancers within 5 cm of the AV [16, 26, 27]. However, ISR is now widely recognized as an acceptable SPO procedure [28]. Moreover, recent advances in surgical techniques have made it possible to perform LAR, including partial excision of the internal anal sphincter, via a transabdominal approach for ultra-low rectal cancer [17, 29].

That said, LAR for ultra-low rectal cancer requires mobilization of the rectum, even in the anal canal, by the transabdominal approach, which still requires highly advanced surgical techniques. Therefore, the technical superiority of RS over LS could be evaluated by comparing the frequency of LAR between these two types of SPOs for ultra-low rectal cancer. To the best of our knowledge, no previous study has attempted to compare the types of SPOs between LS and RS for ultra-low rectal cancer. In contrast to previous reports, we excluded APR, the indications of which are determined by the tumor and technical and non-technical factors, such as preoperative anorectal dysfunction and tolerance of postoperative defecatory dysfunction. As such, the types of SPOs utilized for the patients herein were determined largely based on technical factors, which is also a strong point of our study.

In this study, LAR frequency was significantly higher in the RS group (67.6%) than in the LS group (48.8%), and multivariate analyses showed that RS and the tumor distance from the AV were significantly associated with an increased frequency of LAR for ultra-low rectal cancer. Furthermore, there were no significant differences in the postoperative complications or the pathological results between the RS and LS groups. Although the operation time was longer in the RS group, this was attributed to the higher proportion of patients who underwent LLD in the RS group. Hence, compared to LS, RS allows transection of the distal rectum for ultra-low rectal cancer via the transabdominal approach, without compromising surgical and pathological outcomes. These findings suggest that RS has technical superiority over LS for ultra-low rectal cancer. This superiority can be attributed to the technology involved in RS, such as digital suppression of hand tremors, free-moving multi-joint forceps, and high-quality three-dimensional visualization. Furthermore, the robotic stapler may be advantageous during stapling owing to its good maneuverability [30, 31].

In addition to the transabdominal approach, TaTME has been used for rectal cancer [32]. It has been reported that the transanal approach could enhance access to the distal part of the rectum and enable better visualization making a more accurate oncological dissection possible [33, 34]. However, early adopters of TaTME underscored its technical difficulty. Several studies examining TaTME registry data have revealed that patients sustained visceral injuries during perineal dissection [35, 36]. Additionally, Wasmuth et al [37]. demonstrated that the oncological outcomes after TaTME were inferior to the

national results. Further investigation is required to evaluate the long-term oncological results of TaTME. In contrast, RS makes it possible to perform surgery safely and precisely, even for ultra-low rectal cancer via the transabdominal approach, which is commonly used for TME. Since RS is performed in a familiar transabdominal field-of-view, it is easy to recognize the anatomy and the surgery can be performed safely even in the deep pelvis. Furthermore, several studies have indicated good long-term results [2, 11, 38].

This study has several limitations. First, this was a retrospective study performed at a single institution. Second, long-term outcomes were not investigated. Randomized controlled trials are necessary to validate our findings. Third, although this study focused on the technical aspects, it was unclear whether LAR or ISR is better in terms of postoperative anorectal function. Previous studies have reported that patients who have undergone ISR have a higher risk of fecal incontinence and bowel dysfunction than those who have undergone LAR [39, 40]. However, the characteristics of patients in previous studies were different from those in this study, and these results could not be extrapolated to the present study. Further studies are necessary to clarify the effects on postoperative anal function.

Conclusion

The findings of the present study revealed that RS significantly increased the frequency of transection of the rectum by the transabdominal approach in SPOs, supporting that RS has technical superiority over LS for the treatment of ultra-low rectal cancer.

Abbreviations

RS: Robotic-assisted surgery; LS: Laparoscopic surgery; OS: Open surgery; SPOs: Sphincter-preserving operations; APR: Abdominoperineal resection; LAR: Low anterior resection; ISR: Intersphincteric resection; AV: Anal verge; TME: Total mesorectal excision; TaTME: Transabdominal total mesorectal excision; LLD: Lateral lymph node dissection; BMI: Body mass index; ASA–PS: American Society of Anesthesiologists–Physical Status; CI: Confidence interval

Declarations

Ethics approval and consent to participate

The study was approved by the institutional review board of Shizuoka Cancer Center (Approval Code: J2020-37-2020-1-3) and it conforms to the provisions of the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

TK and HH drafted the paper. HH designed this study. AS, HK, YY, SM, MH, and SK obtained and analyzed data. All authors critically revised the report, commented on drafts of the manuscript, and approved the final report.

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Figures

Figure 1

Flowchart of patient selection

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