Seung Yoon Yang (Orcid ID: 0000-0001-8129-7712)

Outcomes of Robotic Partial Excision of the Levator Ani Muscle for Locally Advanced Low Rectal Cancer Invading the Ipsilateral Pelvic Floor at the Anorectal Ring Level

Seung Yoon Yang, M.D., Min Soo Cho, M.D., and Nam Kyu Kim, M.D., Ph.D.

Department of Surgery, Severance Hospital, Yonsei University College of Medicine, Seoul, Korea

Article type: Original

Corresponding author: Nam Kyu Kim, M.D., Ph.D., FACS, FRCS, FASCRS (Hon)
Division of Colon and Rectal Surgery, Department of Surgery
Severance Hospital, Yonsei University College of Medicine
50-1 Yonsei-ro, Seodaemun-gu, Seoul, Korea
Zip code: 03722
Tel.: 82-2-2228-2100
Fax: 82-2-313-8289
E-mail: namkyuk@yuhs.ac

Declarations

Funding: The authors did not receive support from any organization for the submitted work.

Conflicts of interest: The authors have no relevant financial or non-financial interests to disclose.

Ethics approval: The institutional review board of Severance Hospital, Yonsei University Health System, approved this study.

Consent to participate: The institutional review board of Severance Hospital, Yonsei University Health System, waived the requirement for informed consent because of the study design.

Consent for publication: All authors consent to submission of this manuscript for consideration for publication.

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/rcs.2310.

Availability of data and material: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability: Not applicable.

Authors' contributions: All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Seung Yoon Yang, Min Soo Cho and Nam Kyu Kim. The first draft of the manuscript was written by Seung Yoon Yang and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Character (type) count (abstract and main text): 19,810

Acknowledgement

The authors would like to thank Dong-Su Jang, MFA, (medical illustrator) for his help with the illustrations.

Introduction

Recent advances in surgical techniques and multidisciplinary treatments have led to the possibility of sphincter preservation for patients with low rectal cancer; however, abdominoperineal resection (APR) is recommended for tumors extending beyond the intersphincteric plane (1). Intersphincteric resection (ISR) has been proposed as a way to preserve sphincter function when used in combination with neoadjuvant chemoradiotherapy (nCRT), which has resulted in significant downstaging and downsizing of tumors (2). Furthermore, nCRT has modified the concept of decision-making for sphincter-preserving surgery (SPS) by shortening the distal resection margin while maintaining oncologic safety (3,4).

Minimally invasive surgery for rectal cancer allows structures in the deep pelvis to be visualised more clearly and at greater magnification than conventional surgery (5). However, laparoscopic surgery for patients with low rectal cancer following nCRT is technically challenging (6). Robotic rectal cancer surgery is favoured over laparoscopic surgery because of its wristed instruments (providing enhanced dexterity in the narrow deep pelvis), better magnification, and three-dimensional view of the attachment of the levator ani muscle (LAM) to the rectum(7). Additionally, the sphincter complex can be seen more clearly with an abdominal approach.

With advances in pelvic magnetic resonance imaging (MRI), the concept of the distal rule has been replaced by the concept of circumferential resection margin (CRM) (8). CRM involvement is a well-known risk factor for local recurrence and poor oncologic outcomes, which occur more frequently with low rectal cancer than with mid- and upper rectal cancers (9-11). These poor outcomes have led to inconsistent decision-making regarding the choice of ISR versus APR, resulting in varying rates of SPS for low rectal cancer between hospitals (12). Recent advances in diagnostic modalities have resulted in efforts to use MRI assessment of tumor–intersphincteric plane relationships to classify low rectal cancer and standardise the most appropriate surgical techniques. It has been suggested that invasion of the intersphincteric plane by tumor is an absolute contraindication to SPS (13,14). However, when tumor invades the ipsilateral LAM at the level of the anorectal ring, we speculated that sphincter-preserving en bloc resection of the rectum with the involved LAM could be a good alternative to APR if it maintains anorectal function without negatively affecting oncologic outcomes. Based on the results of our anatomic studies, we therefore proposed partial excision of LAM (PELM) as a new surgical option for low rectal cancer (15).

In this study, we examined perioperative, short-term functional, and oncologic outcomes of robotic PELM to evaluate the PELM is a new surgical alternative to APR of ELAPR for low rectal cancer invading the ipsilateral LAM at the level of the anorectal ring. We used robotic surgery to facilitate precise division of the involved part of LAM and achieve a negative CRM while preserving the uninvolved anal sphincter complex.

Materials & Methods

Patients

Medical records of 23 consecutive patients who underwent robotic PELM by a single surgeon (NK Kim) from January 2011 to March 2019 were retrieved from a prospectively collected database and reviewed for eligibility. All patients had a pathologically confirmed low rectal adenocarcinoma located at the level of the anorectal ring and invading or abutting the ipsilateral LAM (Figure 1). The institutional review board of Severance Hospital, Yonsei University Health System, approved this retrospective study and waived the requirement for informed consent because of the study design.

The inclusion criteria were age 20 to 74 years; pathologic diagnosis of adenocarcinoma of the rectum; tumor invading or abutting the ipsilateral LAM at the level of the anorectal ring, according to the pretreatment MRI; tumor occupying less than half of the bowel lumen, according to preoperative colonoscopy; and general health considered adequate for curative surgery. The exclusion criteria were poor anal function; preoperative imaging results showing distant metastasis; tumor extending across the mid-line, beyond the ipsilateral LAM at the level of the anorectal ring and directly invades or adheres to adjacent organs or structure, according to the pretreatment MRI; or tumor occupying more than half of the bowel lumen on preoperative colonoscopy.

Preoperative staging investigations included the following: colonoscopy with biopsy; serum carcinoembryonic antigen (CEA) level; computed tomography (CT) of the chest, abdomen, and pelvis; and rectal MRI. nCRT was administered to all patients using a standard, long-course, neoadjuvant regimen of 5-fluorouracil (5FU)-based chemotherapy and a total dose of 50.4 Gy external-beam radiation. The chemotherapy regimens were either 5-FU/leucovorin or capecitabine. Surgical resection was performed 6 to 8 weeks after completing nCRT. All patients underwent traditional total mesorectal excision (TME) with lymph node (LN) dissection. Adjuvant chemotherapy was administered based on the surgical pathology results and National Comprehensive Cancer Network guidelines (16).

Patients were followed at 3-month intervals for the first 3 years after surgery, at 6-month intervals for the next 2 years, and annually thereafter. The follow-up assessments included a physical examination, endoscopy, chest radiography, serum CEA, abdominopelvic CT, and toxicity evaluations. When recurrence was suspected, histologic confirmation, MRI, or 18F-fluorodeoxyglucose-positron-emission tomography was obtained. Disease recurrence was diagnosed according to imaging results or, when possible, histologic findings.

Surgical technique

All patients underwent standard bowel preparation using 4 L of Colyte the day before surgery and received antibiotic prophylaxis before skin incision. The surgery was performed under general anaesthesia, with the patient placed in the Lloyd-Davies of Pencoed position with steep Trendelenburg.

Robotic PELM consisted of two phases: abdominal phase and perineal phase. Briefly, the abdominal phase began with medial to lateral mobilisation of the left colon, including full mobilisation of the splenic flexure, central vessel ligation, and TME, and was then followed by dissection toward the LAM. Specifically, the abdominal phase consisted of two phases. The first phase was the colonic phase, consisting of ligation of the inferior mesenteric vessels and mobilisation of the left colon and splenic flexure. The second phase was the pelvic phase, which involved pelvic dissection using TME principles. Our technique for robotic TME using the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) has been described previously(17). Dissection continued to the pelvic floor, consisting of the LAM. The puborectalis muscle was exposed at the contralateral side of the tumor. The LAM on the ipsilateral side of the tumor was then dissection and excised, leaving an adequate margin. It was essential to stop the dissection just above the origin of the LAM and not dissect the mesorectum off the LAM. Therefore, dissection was performed down to the coccyx, where the origin of the LAM was identified. The LAM was first transected from the coccyx slightly distally to its tip and then laterally with an adequate CRM; this was performed under direct vision using monopolar curved scissors to enter the ischiorectal fat.

After completing the pelvic dissection, the perineal phase began. To accomplish this, the patient's hips were first flexed to allow better access to the perineum. An incision was made at the intersphincteric groove on the side of the tumor to approach the intersphincteric space. The dissection then continued between the internal and external anal sphincters to a level approximately 0.5 to 1 cm below the tumor, according to the distance from the anal verge. At this point, the dissection continued transversely to include the deep part of the external sphincter until the ischiorectal fossa fat was visualised. Dissection then continued in a cephalic direction to include the involved part of the LAM; the pelvic cavity was thereby entered. On the contralateral side of the tumor, the incision was made just above the dentate line, and dissection was conducted in a plane medial to the internal sphincter, allowing entry into the pelvic cavity medially to the puborectalis muscle, where the distal rectum was divided in a sleeve fashion (Figure 2).

After total excision of the rectum, the rectum and sigmoid colon were extracted through the anus and transected. A sleeve-fashioned resection was performed to the distal rectum, after which bowel continuity was restored using a hand-sewn coloanal anastomosis (CAA). A diverting loop ileostomy was then created in all patients. The detailed technique for robotic PELM has been described previously with supplementary video clip (18).

Assessment of bowel function

Bowel function was assessed 6 months after temporary ileostomy takedown using the Memorial Sloan Kettering Cancer Center Bowel Function Instrument (MSKCC BFI) and Wexner scoring systems to evaluate whether PELM has impaired bowel function or not (19,20). The patients were interviewed in person during an outpatient clinic appointment. All interviews were conducted by the same interviewer, who fully understood the questionnaire but was unaware of the study. The MSKCC BFI consists of 18 items ranked on a five-point scale. Fourteen items are classified into three subscales: frequency subscale (six items), dietary subscale (four items), and urgency/soilage subscale (four items). The remaining four items are single items. Subscale scores are calculated by adding the scores for each item in the subscale, and the global score is the sum of the three subscale scores. The total score is the sum of the global score and score for each of the four single items. Higher scores indicate better function, with a maximum total score of 90 (20). The Wexner score includes five items about solid, liquid, or gas incontinence; use of a pad; and lifestyle alterations. Each item is ranked on a five-point scale, and the total score ranges from 0 (no incontinence) to 20 (complete incontinence) (19).

Statistical analysis

Statistical analyses were performed using SPSS version 23.0 (IBM Corp, Armonk, NY, USA). Categorical variables were analysed using the χ^2 test. Data are expressed as mean ± standard deviation or median and range for numerical variables and as number of cases (percentage) for categorical variables.

Results

Baseline patient characteristics and perioperative outcomes

All patients underwent preoperative chemoradiation followed by robotic PELM and CAA for low rectal cancer. Baseline patient characteristics and perioperative outcomes are summarised in Table 1. Of the 23 patients included in this study, 43.5% were male and 56.5% were female, with a mean age of 55.3 ± 11.2 years. The mean distance of the primary tumor from the anal verge was 2.8 ± 0.9 cm. Preoperative MRI showed tumor invasion or abutment of the LAM on the right in 39.1% of tumors, on the left in 47.9% of tumors, and posteriorly in 13.0% of tumors. The mean operative time and blood loss were 374.4 ± 124.9 min and 321.7 ± 629.7 mL, respectively. The mean duration of postoperative hospital stay was 11.4 ± 9.1 days.

Overall, seven postoperative morbidities were recorded, including anastomotic leakage (four patients; 17.4%), parastomal hernia (one patient; 4.3%), and acute urinary retention (two patients; 8.7%). Among 23 patients, 17 (73.9%) underwent reversal of the diverting ileostomy. Of the six patients who did not undergo ileostomy reversal, three patients had complications related to anastomotic leakage: two had a chronic sinus demonstrated by MRI and one had a rectovaginal fistula. The other three patients underwent salvage APR because of local recurrence.

Pathologic outcomes

The tumor regression grades after preoperative chemoradiation based on the Mandard classification [23] were as follows: grade 1, five (21.7%) patients; grade 2, four (17.4%) patients; grade 3, nine (39.1%) patients; and grade 4, five (21.7%) patients (Table 2). The pathologic complete regression rate was 21.7%. LN metastasis was present in eight (34.7%) patients. Two (8.7%) patients had lymphovascular invasion, and five (21.7%) patients had perineural invasion. A total of 21 (91.3%) patients had a negative CRM, which was the primary goal of PELM. Mean distances from tumor to the proximal and distal margins were 17.6 ± 4.2 cm and 1.1 ± 0.7 cm, respectively. No patient had a positive distal margin.

Oncologic outcomes

The median follow-up duration was 44.1 months. The estimated 3-year overall survival rate after PELM was 95.0%, and the estimated 3-year disease-free survival rate was 72.4%. Local recurrence occurred in three of 23 patients during follow-up, and the 3-year local recurrence rate was 14.4%. Local recurrence was located at the anastomosis site in 66% (2 of 3) of these patients and in the presacral space in 33% (1 of 3) (Figure 3). All patients with local recurrence underwent salvage APR for treatment of this recurrence. Notably, all resection margins, including CRM, were negative in the index surgery for those patients with local recurrence.

Systemic recurrence was also observed in three of the 23 patients. This was diagnosed within the first year after index surgery in one patient, within 2 years in another patient, and within 3 years in the remaining patient. Systemic recurrence occurred in the liver, lungs, and para-aortic LN. Treatment details of systemic recurrence are shown in Table 4. No patient had both distant and local recurrences. Only one patient died of disease progression (despite salvage APR) after local recurrence at the anastomosis site.

Functional outcomes

Details of functional outcomes after robotic PELM are shown in Table 3 for 15 of 17 patients who underwent reversal of diverting ileostomy. Data for the other two patients could not be analysed for functional outcomes because the interval after ileostomy reversal was less than 6 months. At 6 months after reversal of the temporary ileostomy, the mean frequency subscale was 29.1 ± 6.2, the mean dietary subscale score was 15.1 ± 4.4, the mean urgency/soilage subscale score was 9.5 ± 3.4, and the mean single items score was 11.2 ± 2.1. The mean MSKCC BFI total score was 64.9 ± 8.8. The mean Wexner score at 6 months after restoration of bowel continuity was 11.0 ± 5.8.

Regarding the change in bowel function during the follow-up period, both MSKCC BFI and Wexner score were improved at 1 year after the restoration of bowel continuity except for the single item score for 12 of 17 patients who underwent reversal of diverting ileostomy. Data for the other three patients could not be analysed for functional outcomes because the interval after ileostomy reversal was less than 1 year. At 1year after reversal of the temporary ileostomy, the mean frequency subscale was 30.3 ± 8.8, the mean dietary subscale score was 16.6 ± 3.3, the mean urgency/soilage subscale score was 10.5 ± 4.8. The mean MSKCC BFI total score was 68.3 ± 11.9. The mean Wexner score at 1 year after restoration of bowel continuity was 10.7 ± 5.3.

Discussion

Based on anatomic studies, we recently proposed a new surgical treatment for low rectal cancer, PELM (15). nCRT followed by robotic PELM with ISR and CAA may provide increased opportunity to preserve the anal sphincter in patients with tumor invading the ipsilateral LAM at the level of the anorectal ring, which is traditionally treated with APR.

Previous investigators have reported that the LAM attaches directly to the longitudinal muscle of the rectum and that the LAM and external sphincter overlap within the anal canal (21,22). In our anatomic and histologic examinations of two human cadaveric pelvises, we observed that the LAM attached directly to the lateral surface of the longitudinal smooth muscle of the rectum. Furthermore, microscopic findings at the level of the anorectal ring showed that the LAM partially overlapped with the external anal sphincter, as smooth and skeletal muscles intermingled with each other.

Achieving a safe resection margin is the primary endpoint of surgical modalities for low rectal cancer. In this study, only two patients (8.7%) had CRM involvement, including the resection margin of the excised LAM. Additionally, no patient had a positive distal resection margin, which supports the oncologic safety of PELM. Of note, the two patients with CRM involvement were among the first cases who underwent PELM. Our results are comparable to the findings of a recent systematic review, which reported positive CRM rates of 13.1%–33.1% and 14.7%–33.1% after APR and extralevator APR (ELAPR), respectively (23,24). Our favourable resection margin results may be attributed to the use of a robotic system to overcome the technical limitations of laparoscopic surgery during LAM dissection(25). Transabdominal resection of the levators using robotic assistance, as described in our technique, provides controlled LAM transection under direct vision. This minimizes the risk of accidental injury to vascular structures along the lateral pelvic wall, which may occur with a perineal approach to LAM transection. Our technique also offers the flexibility of varying the extent of LAM excision depending on the tumor's location. This is particularly beneficial for tumors with LAM infiltration, for which a wider excision under direct visualisation on the affected side is possible with robotic assistance. To secure a CRM for tumors invading the ipsilateral LAM at the level of the anorectal ring, the deep part of the external sphincter should be included in the area of dissection. Therefore, the robotic system may play an important guiding role for finding the correct surgical plane during the perineal phase.

During a median follow-up period of 44.1 months, the local recurrence rate was 14.4%. Local recurrence rates of 0%–13% have been reported after extralevator (23,26), and in some studies, these rates have been significantly lower than after APR (15%–19%) (23,27). In this regard, using historical comparison groups was a limitation of the current study. The current study was similar to previous studies in that it included patients with low rectal cancer; however, patients receiving PELM may have differed in oncologic outcomes because their tumors were clinically T4 cancers, located at the level of the anorectal ring.

Anastomotic leakage after rectal cancer surgery is one of the main concerns. In the current study, the anastomotic leakage rate after CAA was 17.4%. This rate is similar to the 5.0%–21.5% rates previously reported for CAA after resection of low rectal cancer(28). Moreover, our overall postoperative morbidity rate was 30.4%, which was lower than the morbidity rates reported for APR and ELAPR. This may be explained by the absence of a wide perineal wound with PELM, which has been associated with a high rate of wound complications (10.7%–59.3%) (23).

Besides a safe resection margin, preservation of faecal continence is the most important goal for ensuring good quality of life. ISR, as an alternative to APR, avoids permanent colostomy; however, patients may develop low anterior syndrome (29), which can substantially affect their quality of life. Colostomy might be a more satisfactory option for some of these patients (30). Our results suggest that an intact contralateral anorectal ring and anal sphincter complex can compensate for incontinence that might be caused by PELM. In our patients, the Wexner (10.7 ± 5.3) and MSKCC BFI (68.3 ± 11.9) scores at 1 year after restoration of bowel continuity were comparable to those observed after ISR (31-33). Saito et al. reported a mean Wexner score of 11.2 ± 4 at 6 months after stoma closure in 110 patients, with further monthly improvements in anal function until 24 months after stoma closure (33). Moreover, Ihn et al. reported the mean total MSKCC score 64.5 ± 7.6 at 1 year after stoma closure in 266 patients who underwent sphincter-preserving rectal cancer surgery (31). Our results are also consistent with those of a recently published study in our institution assessing bowel dysfunction after SPS for rectal cancer. The authors dichotomised patients according to median total MSKCC score using 65 as the cut-off for poor bowel function and suggested that bowel function stabilised with time (32).

Our PELM outcomes demonstrated that use of MRI has improved the accuracy of preoperative evaluation, enabling precise selection of patients for specific surgical procedures and thereby allowing patients who may otherwise be considered APR candidates to undergo less extensive surgery (34). Recently, efforts have been made to classify low rectal cancer and standardise surgery based on MRI findings (13,14). However, these studies uniformly recommended APR for low rectal cancer involving the LAM, without considering the laterality of involvement. By contrast, we showed that robotic PELM may be successfully performed, with low CRM involvement and acceptable functional outcomes, in patients with tumor invading the ipsilateral LAM at the level of the anorectal ring.

This study has some limitations. First, we could not obtain complete oncologic outcomes because of the duration of follow-up. Second, the number of patients was quite small. Finally, the anal sphincter function was not evaluated by objective tools such as manometry before PELM. Nonetheless, this study showed the safety and feasibility of this new SPS in well-selected patients who want to avoid loss of the anal sphincter complex and the need for a permanent colostomy. From this perspective, the novel PELM technique is another step in the development of anal sphincter preservation strategies through advances in minimally invasive techniques and anatomic knowledge.

Conclusion

In conclusion, PELM is a new surgical alternative to APR or ELAPR for low rectal cancer invading the ipsilateral LAM at the level of the anorectal ring. The benefits of this SPS can be maximized when combined with robotic surgery, which enables more precise surgery.

References

1. Smith JJ, Garcia-Aguilar J. Advances and challenges in treatment of locally advanced rectal cancer. *J Clin Oncol* 2015; **33**(16): 1797-1808.
2. Schiessel R, Karner-Hanusch J, Herbst F, Teleky B, Wunderlich M. Intersphincteric resection for low rectal tumours. *Br J Surg* 1994; **81**(9): 1376-1378.
3. Gerard JP, Chapet O, Nemoz C, Hartweig J, Romestaing P, Coquard R, Barbet N, Maingon P, Mahe M, Baulieux J, Partensky C, Papillon M, Glehen O, Crozet B, Grandjean JP, Adeleine P. Improved sphincter preservation in low rectal cancer with high-dose preoperative radiotherapy: the lyon R96-02 randomized trial. *J Clin Oncol* 2004; **22**(12): 2404-2409.
4. Weiser MR, Quah HM, Shia J, Guillem JG, Paty PB, Temple LK, Goodman KA, Minsky BD, Wong WD. Sphincter preservation in low rectal cancer is facilitated by preoperative chemoradiation and intersphincteric dissection. *Ann Surg* 2009; **249**(2): 236-242.
5. Park JS, Choi GS, Jun SH, Hasegawa S, Sakai Y. Laparoscopic versus open intersphincteric resection and coloanal anastomosis for low rectal cancer: intermediate-term oncologic outcomes. *Ann Surg* 2011; **254**(6): 941-946.
6. Asoglu O, Tokmak H, Bakir B, Aliyev V, Saglam S, Iscan Y, Bademler S, Meric S. Robotic versus laparoscopic sphincter-saving total mesorectal excision for mid or low rectal cancer in male patients after neoadjuvant chemoradiation therapy: comparison of long-term outcomes. *J Robot Surg* 2020; **14**(3): 393-399.
7. Kinugasa Y, Murakami G, Uchimoto K, Takenaka A, Yajima T, Sugihara K. Operating behind Denonvilliers' fascia for reliable preservation of urogenital autonomic nerves in total mesorectal excision: a histologic study using cadaveric specimens, including a surgical experiment using fresh cadaveric models. *Dis Colon Rectum* 2006; **49**(7): 1024-1032.
8. Denost Q, Rullier E. Intersphincteric Resection Pushing the Envelope for Sphincter Preservation. *Clin Colon Rectal Surg* 2017; **30**(5): 368-376.
9. Adam IJ, Mohamdee MO, Martin IG, Scott N, Finan PJ, Johnston D, Dixon MF, Quirke P. Role of circumferential margin involvement in the local recurrence of rectal cancer. *Lancet* 1994; **344**(8924): 707-711.
10. Marr R, Birbeck K, Garvican J, Macklin CP, Tiffin NJ, Parsons WJ, Dixon MF, Mapstone NP, Sebag-Montefiore D, Scott N, Johnston D, Sagar P, Finan P, Quirke P.

The modern abdominoperineal excision: the next challenge after total mesorectal excision. *Ann Surg* 2005; **242**(1): 74-82.

11. Sebag-Montefiore D, Stephens RJ, Steele R, Monson J, Grieve R, Khanna S, Quirke P, Couture J, de Metz C, Myint AS, Bessell E, Griffiths G, Thompson LC, Parmar M. Preoperative radiotherapy versus selective postoperative chemoradiotherapy in patients with rectal cancer (MRC CR07 and NCIC-CTG C016): a multicentre, randomised trial. *Lancet* 2009; **373**(9666): 811-820.
12. Morris E, Quirke P, Thomas JD, Fairley L, Cottier B, Forman D. Unacceptable variation in abdominoperineal excision rates for rectal cancer: time to intervene? *Gut* 2008; **57**(12): 1690-1697.
13. Battersby NJ, How P, Moran B, Stelzner S, West NP, Branagan G, Strassburg J, Quirke P, Tekkis P, Pedersen BG, Gudgeon M, Heald B, Brown G. Prospective Validation of a Low Rectal Cancer Magnetic Resonance Imaging Staging System and Development of a Local Recurrence Risk Stratification Model: The MERCURY II Study. *Ann Surg* 2016; **263**(4): 751-760.
14. Rullier E, Denost Q, Vendrely V, Rullier A, Laurent C. Low rectal cancer: classification and standardization of surgery. *Dis Colon Rectum* 2013; **56**(5): 560-567.
15. Noh GT, Han J, Cheong C, Han YD, Kim NK. Novel anal sphincter saving procedure with partial excision of levator-ani muscle in rectal cancer invading ipsilateral pelvic floor. *Ann Surg Treat Res* 2017; **93**(4): 195-202.
16. Benson AB, Venook AP, Al-Hawary MM, Cederquist L, Chen YJ, Ciombor KK, Cohen S, Cooper HS, Deming D, Engstrom PF, Grem JL, Grothey A, Hochster HS, Hoffe S, Hunt S, Kamel A, Kirilcuk N, Krishnamurthi S, Messersmith WA, Meyerhardt J, Mulcahy MF, Murphy JD, Nurkin S, Saltz L, Sharma S, Shibata D, Skibber JM, Sofocleous CT, Stoffel EM, Stotsky-Himelfarb E, Willett CG, Wuthrick E, Gregory KM, Gurski L, Freedman-Cass DA. Rectal Cancer, Version 2.2018, NCCN Clinical Practice Guidelines in Oncology. *J Natl Compr Canc Netw* 2018; **16**(7): 874-901.
17. Park YA, Kim JM, Kim SA, Min BS, Kim NK, Sohn SK, Lee KY. Totally robotic surgery for rectal cancer: from splenic flexure to pelvic floor in one setup. *Surg Endosc* 2010; **24**(3): 715-720.
18. Yang SY, Kim NK. Robotic Partial Excision of Levator-Ani Muscle for Locally Advanced Low Rectal Cancer Invading Ipsilateral Pelvic Floor. *Ann Coloproctol* 2020; **36**(6): 415-416.

19. Jorge JM, Wexner SD. Etiology and management of fecal incontinence. *Dis Colon Rectum* 1993; **36**(1): 77-97.
20. Temple LK, Bacik J, Savatta SG, Gottesman L, Paty PB, Weiser MR, Guillem JG, Minsky BD, Kalman M, Thaler HT, Schrag D, Wong WD. The development of a validated instrument to evaluate bowel function after sphincter-preserving surgery for rectal cancer. *Dis Colon Rectum* 2005; **48**(7): 1353-1365.
21. Macchi V, Porzionato A, Stecco C, Vigato E, Parenti A, De Caro R. Histo-topographic study of the longitudinal anal muscle. *Clin Anat* 2008; **21**(5): 447-452.
22. Tsukada Y, Ito M, Watanabe K, Yamaguchi K, Kojima M, Hayashi R, Akita K, Saito N. Topographic Anatomy of the Anal Sphincter Complex and Levator Ani Muscle as It Relates to Intersphincteric Resection for Very Low Rectal Disease. *Dis Colon Rectum* 2016; **59**(5): 426-433.
23. De Nardi P, Summo V, Vignali A, Capretti G. Standard versus extralevator abdominoperineal low rectal cancer excision outcomes: a systematic review and meta-analysis. *Ann Surg Oncol* 2015; **22**(9): 2997-3006.
24. Zhou X, Sun T, Xie H, Zhang Y, Zeng H, Fu W. Extralevator abdominoperineal excision for low rectal cancer: a systematic review and meta-analysis of the short-term outcome. *Colorectal Dis* 2015; **17**(6): 474-481.
25. Kang J, Hur H, Min BS, Lee KY, Kim NK. Robotic coloanal anastomosis with or without intersphincteric resection for low rectal cancer: starting with the perianal approach followed by robotic procedure. *Ann Surg Oncol* 2012; **19**(1): 154-155.
26. Han JG, Wang ZJ, Wei GH, Gao ZG, Yang Y, Zhao BC. Randomized clinical trial of conventional versus cylindrical abdominoperineal resection for locally advanced lower rectal cancer. *Am J Surg* 2012; **204**(3): 274-282.
27. Hawkins AT, Albutt K, Wise PE, Alavi K, Sudan R, Kaiser AM, Bordeianou L. Abdominoperineal Resection for Rectal Cancer in the Twenty-First Century: Indications, Techniques, and Outcomes. *J Gastrointest Surg* 2018; **22**(8): 1477-1487.
28. Cong JC, Chen CS, Ma MX, Xia ZX, Liu DS, Zhang FY. Laparoscopic intersphincteric resection for low rectal cancer: comparison of stapled and manual coloanal anastomosis. *Colorectal Dis* 2014; **16**(5): 353-358.
29. Bretagnol F, Troubat H, Laurent C, Zerbib F, Saric J, Rullier E. Long-term functional results after sphincter-saving resection for rectal cancer. *Gastroenterol Clin Biol* 2004; **28**(2): 155-159.

30. Grumann MM, Noack EM, Hoffmann IA, Schlag PM. Comparison of quality of life in patients undergoing abdominoperineal extirpation or anterior resection for rectal cancer. *Ann Surg* 2001; **233**(2): 149-156.
31. Ihn MH, Kang SB, Kim DW, Oh HK, Lee SY, Hong SM. Risk factors for bowel dysfunction after sphincter-preserving rectal cancer surgery: a prospective study using the Memorial Sloan Kettering Cancer Center bowel function instrument. *Dis Colon Rectum* 2014; **57**(8): 958-966.
32. Park YY, Yang SY, Han YD, Cho MS, Hur H, Min BS, Lee KY, Kim NK. Predictive Factors for Bowel Dysfunction After Sphincter-Preserving Surgery for Rectal Cancer: A Single-Center Cross-sectional Study. *Dis Colon Rectum* 2019; **62**(8): 925-933.
33. Saito N, Moriya Y, Shirouzu K, Maeda K, Mochizuki H, Koda K, Hirai T, Sugito M, Ito M, Kobayashi A. Intersphincteric resection in patients with very low rectal cancer: a review of the Japanese experience. *Dis Colon Rectum* 2006; **49**(10 Suppl): S13-22.
34. Nougaret S, Reinhold C, Mikhael HW, Rouanet P, Bibeau F, Brown G. The use of MR imaging in treatment planning for patients with rectal carcinoma: have you checked the "DISTANCE"? *Radiology* 2013; **268**(2): 330-344.

Legends

Table 1. Baseline characteristics and perioperative outcomes

Table 2. Surgical pathology results

Table 3. Defecation functional outcomes of 15 patients who underwent ileostomy reversal

Table 4. Details for all 23 patients

Figure 1. Pretreatment pelvic magnetic resonance imaging. Axial (A) and coronal (B) views of a tumor extending across the mid-line, beyond the ipsilateral levator ani muscle (LAM) at the level of the anorectal ring, for which abdominoperineal resection (APR) or extralevator APR was indicated. Axial (C) and coronal (D) views of a tumor invading the ipsilateral LAM at the level of the anorectal ring, for which partial excision of LAM was indicated.

Figure 2. Schematic coronal view of the extent of resection for partial excision of the levator ani muscle through the intersphincteric plane and sleeve-fashioned distal rectum resection. The red arrow indicates the abdominal phase, and the blue arrow indicates the perineal phase.

Figure 3. (A) Three-year overall survival (OS). (B) Three-year disease-free survival (DFS). (C) Local recurrence.

TABLE 1. Baseline characteristics and perioperative outcomes

Characteristics and outcomes	*Value (N=23)*
Age (y)	55.3 ± 11.2
Sex	
Male	10 (43.5%)
Female	13 (56.5%)
ASA physical status classification	
I	3 (13.0%)
II	17 (73.9%)
III	3 (13.0%)
BMI, mean (kg/m^2)	22.7 ± 3.8
Tumor distance from anal verge (cm)	2.8 ± 0.9
Excised side of levator ani muscle	
Right	9 (39.1%)
Left	11 (47.9%)
Posterior	3 (13.0%)
Duration of operation (min)	374.4 ± 124.9
Intraoperative blood loss (mL)	321.7 ± 629.7
Postoperative length of hospital stay (d)	11.4 ± 9.1
Overall complications	7 (30.4%)
Anastomotic leakage*	4 (17.4%)
Parastomal hernia	1 (4.3%)
Acute urinary retention	2 (8.7%)
Clavien Dindo classification of complications	
Grade I	0
Grade II	4 (17.3%)
Grade III	3 (13.1%)
Grade IV	0
Grade V	0
Major complications (CD grade ≥III)	3 (13.0%)
Ileostomy reversal	17 (73.9%)
Permanent stoma	3 (13.1%)
Adjuvant chemotherapy	19 (82.6%)

* Out of 4 patients with anastomotic leakage, 2 patients had wound infections.
Data are mean ± standard deviation or number (percentage).
ASA, American Society of Anesthesiologists; BMI, body mass index; CD, Clavien Dindo.

TABLE 2. Surgical pathology results

Characteristics	***Value (N=23)***
Mandard grade	
I	5 (21.7%)
II	4 (17.4%)
III	9 (39.1%)
IV	5 (21.7%)
ypT stage	
pCR	5 (21.7%)
ypT1	4 (17.4%)
yPT2	5 (21.7%)
yPT3	7 (30.4%)
ypT4	2 (8.7%)
ypN stage	
ypN0	15 (65.2%)
ypN1	7 (30.4%)
ypN2	1 (4.3%)
Histologic subtype	
Well differentiated	1 (4.3%)
Moderately differentiated	17 (73.9%)
Poorly differentiated	4 (17.4%)
Mucinous	1 (4.3%)
LVI (+)	2 (8.7%)
PNI (+)	5 (21.7%)
Tumor size (cm)	1.7 ± 1.6
Circumferential resection margin (+)	2 (8.7%)
Distance of resection margin (cm)	
Proximal	17.6 ± 4.2
Distal	1.1 ± 0.7

Data are mean ± standard deviation or number (percentage).
LVI, lymphovascular invasion; PNI, perineural invasion.

TABLE 3. Details for all 23 patients

#	TRG	ypTN	CRM (mm)	CRM (+)	Adjuvant CTx	Ileostomy reversal	F/U period (mo)	Recurrence type	Treatment for recurrence	Result of salvage operatio n	Death	Complete incontinence
1	1	ypT0N0	2	No	No	Yes	92				No	No
2	3	ypT1N0	3	No	FL	No	70				No	-
3	2	ypT1N0	5	No	No	Yes	58				No	No
4	3	ypT2N0	1.2	No	Capecitabine	No	53				No	-
5	3	ypT2N0	3	No	FL	APR	27	Local	APR	CRM (+)	Yes	-
6	4	ypT3N1b	4	No	FOLFOX	Yes	52				No	No
7	1	ypT0N0	2	No	Capecitabine	Yes	52				No	No
8	1	ypT0N0	1.5	No	Capecitabine	Yes	51				No	Yes
9	1	ypT0N1a	2	No	Capecitabine	Yes	51				No	Yes
10	2	ypT2N1a	3	No	No	Yes	50				No	Yes
11	2	ypT2N0	3	No	Capecitabine	APR	48	Local	APR	CRM (+)	No	-
12	3	ypT4N1b	0	Yes	FOLFOX	Yes	28	Systemic	C-FOLFIRI		No	No
13	3	ypT3N0	1.5	No	FOLFOX	Yes	27				No	N.A.
14	4	ypT3N1a	4	No	FOLFOX	Yes	27				No	No
15	3	ypT3N0	4	No	FOLFOX	APR	26	Local	APR	CRM (-)	No	-
16	3	ypT3N2a	2	No	FOLFOX	Yes	25				No	No
17	1	ypT0N0	1.5	No	Capecitabine	Yes	23	Systemic	B-FOLFOX		No	No
18	2	ypT1N0	1.2	No	No	Yes	79	Systemic	B-FOLFOX		No	No
19	3	ypT4N0	0.5	Yes	Capecitabine	No	40				No	-

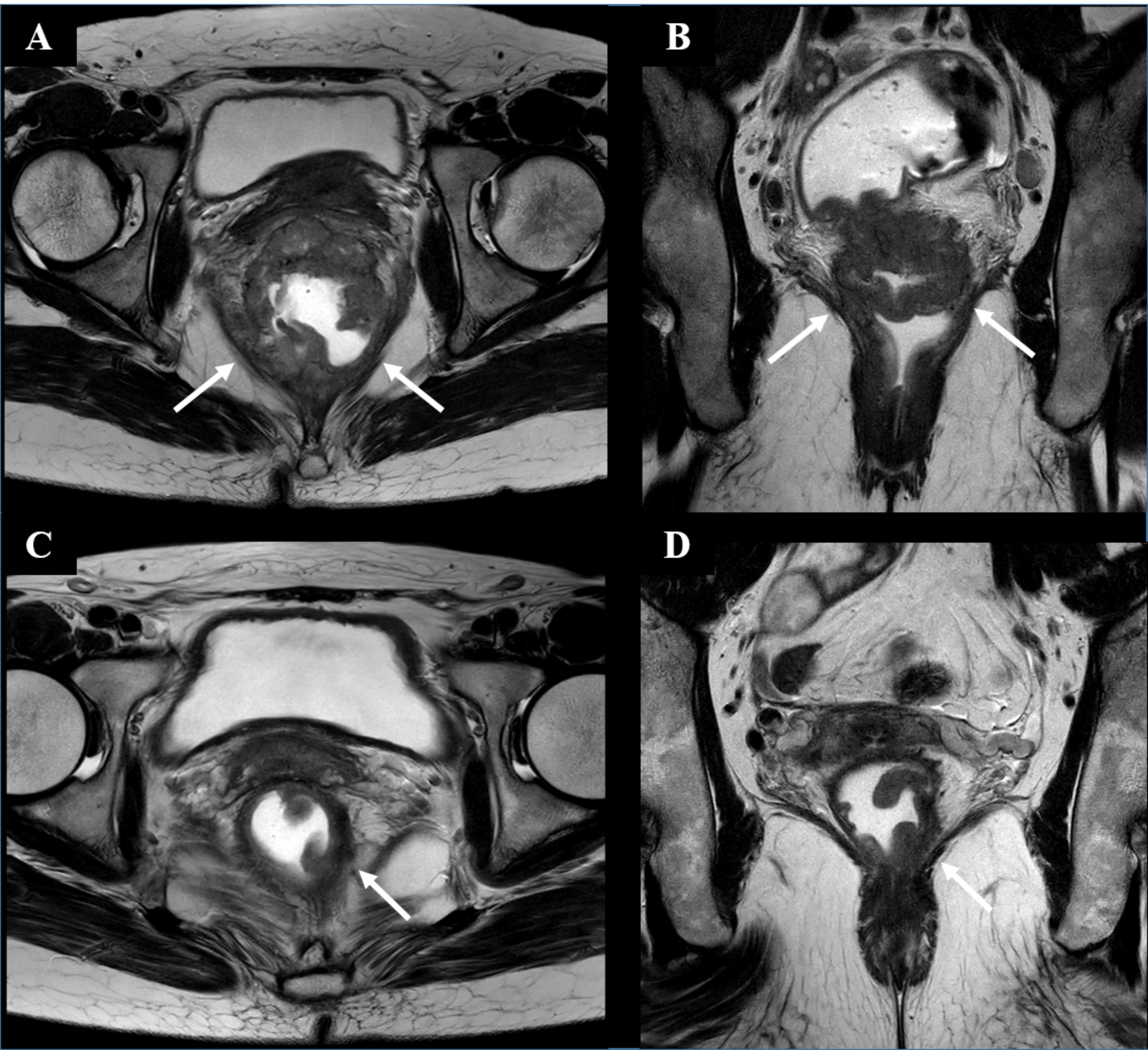
20	4	ypT3N1b	1.2	No	FOLFOX	Yes	41	No	No
21	4	ypT2N0	1.5	No	Capecitabine	Yes	30	No	No
22	3	ypT3N1b	1.5	No	FOLFOX	Yes	22	No	No
23	4	ypT1N0	1.8	No	Capecitabine	Yes	14	No	N.A.

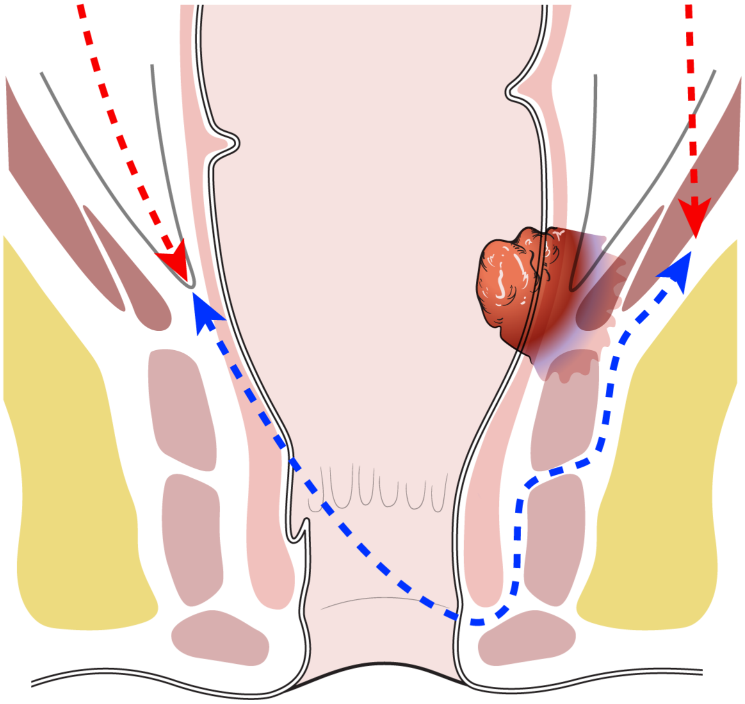
B-FOLFOX, bevacizumab with fluorouracil plus leucovorin and oxaliplatin; APR, abdominoperineal resection; CRM, circumferential resection margin; CTx, chemotherapy; C-FOLFIRI, cetuximab with fluorouracil plus leucovorin and irinotecan; FL, fluorouracil plus leucovorin; FOLFOX, fluorouracil plus leucovorin and oxaliplatin; F/U, follow-up; N.A., not available; TRG, tumor regression grade (Mandard grade).

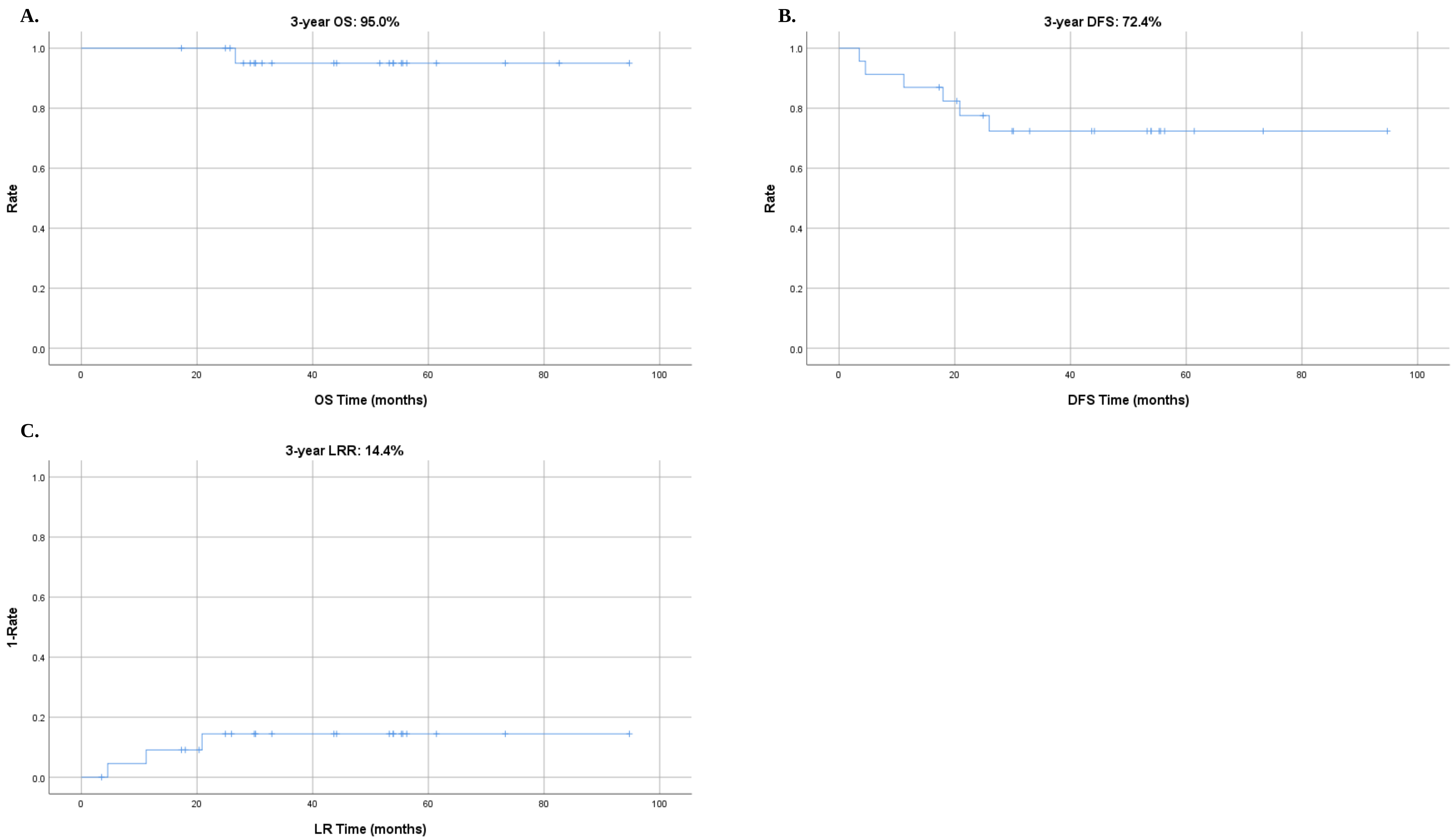
TABLE 4. Defecation functional outcomes of patients who underwent ileostomy reversal

Outcome	Score (6 months after ileostomy repair)[a]	Score (1yr after ileostomy repair)[b]
Wexner score	11.0 ± 5.8	10.7 ± 5.3
MSKCC BFI score		
Total score	64.9 ± 8.8	68.3 ± 11.9
Frequency subscale	29.1 ± 6.2	30.3 ± 8.8
Dietary subscale	15.1 ± 4.4	16.6 ± 3.3
Urgency/soilage subscale	9.5 ± 3.4	10.5 ± 4.8
Single items[c]	11.2 ± 2.1	10.9 ± 3.4

Data are mean ± standard deviation.
[a] 15 of 17 patients who underwent reversal of diverting ileostomy
[b] 12 of 17 patients who underwent reversal of diverting ileostomy
[a] Sum of the four single item scores
MSKCC BFI, Memorial Sloan Kettering Cancer Center Bowel Function Instrument.


A
B
C
D




A.
3-year OS: 95.0%
Rate
OS Time (months)
B.
3-year DFS: 72.4%
Rate
DFS Time (months)
C.
3-year LRR: 14.4%
1-Rate
LR Time (months)
0.0
0.2
0.4
0.6
0.8
1.0
0
20
40
60
80
100