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Robotic surgery for rectal cancer can overcome difficulties associated with pelvic anatomy

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Abstract
Introduction Total mesorectal excision (TME) for rectal cancer can be challenging to perform in the presence of difficult pelvic anatomy. In our previous studies based on open and laparoscopic TME, we found that pelvic MRI-based pelvimetry could well reflect anatomical difficulty of the pelvis and operative time increased in direct proportion to the difficulty. We explored different outcomes of robotic surgery for TME based on classifications of difficult pelvic anatomies to determine whether this method can overcome these challenges.
Methods We reviewed data from 182 patients who underwent robotic surgery for rectal cancer between January 2008 and August 2010. Patient demographics, pathologic outcomes, pelvimetric results, and operative and postoperative outcomes were assessed. The data were compared between easy, moderate, and difficult groups classified by MRI-based pelvimetry.
Results Comparing the three groups, there was no difference between the groups in terms of operative and pathologic outcomes, including operation time. High BMI, history of preoperative chemoradiotherapy, and lower tumor levels were significantly associated with longer operation time ($p < 0.001, p < 0.001, p = 0.009$), but the pelvimetric parameter was not.
Conclusion There was no difference between the easy, moderate, and difficult groups in terms of surgical outcomes, such as operation time, for robotic rectal surgery. The robot system can provide more comfort during surgery for the surgeon, and may overcome challenges associated with difficult pelvic anatomy.

Keywords Pelvimetry · Pelvic magnetic resonance imaging (MRI) · Pelvic anatomy · Rectal neoplasm · Robot surgery

Since its introduction by Heald [1], total mesorectal excision (TME) has been the standard operation for rectal cancer, which has been shown to decrease local recurrence. Although the surgical techniques and instruments for TME have improved over the decades [2–4], the TME technique is still difficult for surgeons to perform within a narrow pelvis, making it a challenge to maintain the principles of oncologic surgery and to protect other anatomical features, including pelvic nerves [5, 6]. Furthermore, the risk of complication is high, both intraoperatively and postoperatively.

Some of the main risk factors of TME are associated with male patients, preoperative chemoradiation therapy (CRT), and large tumors [7, 8]. Narrow and deep pelvic anatomy is also known to make pelvic dissection difficult, as many prior studies have reported [9–11]. In previous studies, we found that surgical outcomes, for both open and laparoscopic procedures, were influenced by patient clinical and anatomical factors, based on pelvic magnetic resonance imaging (MRI) [12, 13]. In these studies, difficult pelvic anatomies, such as long sacral length, shallow sacral

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angle, and narrow intertuberous diameter, were significantly associated with longer pelvic dissection time.

Recently, the use of a robotic surgical system has been attempted for rectal cancer surgery, with the expectation that it provides several advantages, including an excellent view of the surgical field and improved dexterity [14–16]. These advantages can facilitate technically demanding operations, and maximize comfort for the surgeon, although scientific evidence of the ergonomic benefits of robotic surgery is lacking. Thus, we designed this study, using MRI-based pelvimetry, to evaluate whether there is a difference in surgical outcome according to the degree of pelvic anatomical difficulty in robotic surgery similar to open or laparoscopic TME.

Patients and methods

Patients who underwent robotic surgery for rectal cancer between January 2008 and August 2010 at Yonsei University Severance Hospital, Seoul, Korea, were retrospectively assessed. Patients who had primary rectal cancer with pathologically proven adenocarcinoma within 15 cm of the anal verge were eligible for this study. All patients with rectal cancer were evaluated by physical examination, colonoscopy, abdomino-pelvic computed tomography (CT), pelvic MRI, and routine laboratory test for the purpose of preoperative staging. Patients with locally advanced disease (clinical T3/4 or N positive) were given neoadjuvant CRT. A total radiation dose of 5040 cGy was delivered in 25 fractions over 5 weeks with 5-fluorouracil (425 mg/m^2) and leucovorin (20 mg/day) during weeks one and five. Operation was performed at 6–8 weeks after CRT, and image studies were performed repeatedly before surgery to evaluate the response of CRT. Robot surgery was performed by five highly experienced laparoscopic surgeons. The robotic technique for rectal cancer was performed using the same surgical principles as with laparoscopic surgery, which are described in previous reports from our institution [17, 18].

MRI pelvic measurement (pelvimetry)

Pelvic MRI was performed using a 1.5 T system (GE, Waukesha, WI, USA) and a phased-array multicoil. Axial T1-weighted fast spin-echo images of the pelvis were obtained using a 24-cm field of view, 5-mm section thickness, 1.5-mm intersection gap, 500–600-ms repetition time and 8–10-ms echo time, and a 256 × 192 matrix; one signal was acquired. Axial, sagittal, and oblique T2-weighted fast spin-echo images of the pelvis were obtained using a 24- to 26-cm field of view, 5- to 6-mm section thickness, 1- to 2.5-mm intersection gap, 4,000- to 6,000-ms repetition time and 75- to 105-ms echo time, a 512 × 256 matrix, and an echo train length of 10–12. Two signals were averaged.

All pelvic MRIs were reviewed, and measurements were performed by two radiologist who was blinded to the patient's clinical information. Pelvimetry parameters (sacral length, sacral depth, pelvic inlet, pelvic outlet, intertuberous distance, and interspinous distance) were obtained using mid-sagittal and axial sections of the pelvis as described in a previous report [8, 9, 13]. The definitions for pelvimetric parameters were as follows: sacral length is the distance between the sacral promontory and the tip of the coccyx; sacral depth is the perpendicular line from the sacral length to the deepest portion of the sacral hollow; pelvic inlet is the length from the sacral promontory to the top of the symphysis pubis; pelvic outlet is the length from the tip of the coccyx to the bottom of the symphysis pubis on the mid-sagittal section in pelvic MRI; intertuberous distance is the narrowest distance between the pubic tubercle at the pelvic floor; and interspinous distance is the narrowest distance between the ischial spines at maximal femur head level on the axial section in pelvic MRI.

In previous report [12], we studied MRI-based pelvimetry from a sample of 74 patients who underwent laparoscopic total mesorectal excision (L-TME), and we found that long sacral length, shallow sacral angle, narrow intertuberous distance, and large tumor size were significantly associated with longer pelvic dissection time. The cutoff values of the upper quartile were 115 and 45 mm for sacral length and tumor size, respectively; the cutoff values of the lower quartile were 30 and 89 mm for sacral depth and intertuberous distance, respectively. Based on these results, we defined the ranges for risk factors and categorized patients into three groups as follows: the easy group had no risk factors, the moderate group had one to two risk factors, and the difficult group had $\geq$3 risk factors.

Statistical analyses

Data assessed included patient demographics, pathologic outcomes, pelvimetric results, and operative and postoperative outcomes. Descriptive results were presented as means and standard deviations (SD) for continuous variables, and as frequencies and percentages for categorical variables. All data were collected under the approval of the Institutional Review Board (IRB) of Yonsei University College of Medicine.

Clinical data were compared between the easy, moderate, and difficult groups by Kruskal–Wallis test. And linear regression was performed to determine which variables were associated with poor operative and pathologic outcomes. Statistical analyses were performed using SPSS

Table 1 Patient demographics and tumor characteristics

	Patients ($n = 182$)
Sex (M:F) (%)	117 (64.3 %): 65 (35.7 %)
Mean age (year)	57.6 (26–79)
Mean BMI (Kg/m^2)	23.4 ± 2.7 (14.8–30.5)
Abdominal operation history (%)	15 (8.2 %)
Number of preoperative CRT (%)	50 (27.5 %)
ASA score (1/2/3)	111/65/6
Mean tumor size (mm)	32.4 ± 1.9 (1–80)
Tumor location	
<6 cm	59 (32.4 %)
6 to <10 cm	90 (49.5 %)
≥10 cm	33 (18.1 %)
TNM stage (0/1/2/3/4)	5/57/52/62/6
Number of retrieved LN	14.8 ± 9.2 (2–47)
<12	106 (58.2 %)
≥12	76 (41.8 %)
CRM involvement (<1 mm)	10 (5.5 %)
DRM (mm)	22.0 ± 14.3

M male, *F* female, *BMI* body mass index, *CRT* chemoradiotherapy, *ASA* American Society of Anesthesiologists, *LN* lymph node, *CRM* circumferential resection margin, *DRM* distal resection margin

Table 2 Pelvimetric results

	Patients ($n = 182$)
Sacral length (mm)	120.5 ± 12.9 (81.8–150.5)
Sacral depth (mm)	36.4 ± 6.0 (16.0–54.0)
Pelvic inlet (mm)	114.0 ± 9.6 (90.8–142.3)
Pelvic outlet (mm)	80.2 ± 8.1 (60.2–102.2)
Intertuberous distance (mm)	112.6 ± 12.0 (84.0–145.3)
Interspinous distance (mm)	96.4 ± 11.4 (65.6–125.7)

Data presented as mean ± standard deviation (range)

version 20.0 (IBM, Armonk, NY, USA). A p value <0.05 was considered statistically significant.

Results

A total of 182 patients were enrolled in the study. Patients were predominantly male (64.3 %), and the mean age was 57.6 years old (Table 1). The mean body mass index (BMI) was 23.4 kg/m^2. Fifty patients (27.5 %) received preoperative CRT. Tumor characteristics and pathologic outcomes are summarized in Table 1.

Table 2 shows the pelvimetric results. Mean sacral length was 120.5 mm; mean sacral depth was 36.4 mm; mean pelvic inlet was 114 mm; mean pelvic outlet was 80.2 mm; mean intertuberous distance was 112.6 mm; and mean interspinous distance was 96.4 mm. Once we categorized the participants based on the risks defined in our previous study, 31 patients were included in the easy

Table 3 Operative outcomes for risk groups based on pelvimetry

	Easy group[a] ($n = 31$)	Moderate group[a] ($n = 138$)	Difficult group[a] ($n = 13$)	p
Median operative time (min)	339	322.5	309	*0.630*
Anastomotic complication	3 (9.7 %)	10 (7.2 %)	1 (7.1 %)	*0.658*
Overall complication	8 (26.7 %)	20 (14.5 %)	2 (15.4 %)	*0.854*
CRM involvement	2 (6.5 %)	7 (5.1 %)	1 (7.7 %)	*0.753*
DRM (mm)	3 (9.7 %)	12 (8.7 %)	1 (7.7 %)	*0.057*
Median number of retrieved LN	13	14.5	17	*0.396*

Risk factor: sacral length > 115 mm, sacral depth < 30 mm, intertuberous distance < 89 mm, tumor size > 45 mm

CRM circumferential resection margin, *DRM* distal resection margin, *LN* lymph node

[a] Easy group = no risk factor; moderate group = 1–2 risk factors; difficult group = ≥3 risk factors

Table 4 Clinico-anatomical factors associated with robotic operation time

	Univariate		Multivariate	
	β	p	β	p
Sex	−0.122	*0.100*		
Age	−0.055	*0.465*		
BMI	0.269	*<0.001*	0.282	*<0.001*
Abdominal operation history	0.000	*0.996*		
Preoperative CRT	0.281	*<0.001*	0.179	*0.024*
ASA score	0.101	*0.175*		
Tumor size	−0.247	*0.001*	−0.093	*0.234*
Tumor location	−0.192	*0.009*	−0.161	*0.032*
TNM stage	−0.067	*0.372*		
CRM involvement	−0.083	*0.263*		
DRM	−0.113	*0.130*		
Sacral length	0.071	*0.341*		
Sacral depth	0.014	*0.849*		
Pelvic inlet	0.058	*0.439*		
Pelvic outlet	0.098	*0.186*		
Intertuberous distance	−0.007	*0.926*		
Interspinous distance	0.013	*0.859*		

BMI body mass index, *CRT* chemoradiotherapy, *ASA* American Society of Anesthesiologists, *CRM* circumferential resection margin, *DRM* distal resection margin

Table 5 Risk factors related to poor operative outcomes

	Risk factor	p	OR	95 % CI
Anastomotic complication	Preoperative CRT	*0.002*	6.6	1.9–22.0
	Age < 58 (median)	*0.014*	5.0	1.3–18.4
Overall complication	Operative time	*0.002*	1.008	1.003–1.012
	Abdominal operation history	*0.020*	4.0	1.2–12.9
CRM involvement	No parameter			

CRT chemoradiotherapy, *CRM* circumferential resection margin

group, 138 were included in the moderate group, and 13 were in the difficult group.

There were no significant differences in age, BMI, preoperative CRT, and tumor characteristics between the groups, but male proportion was directly correlated to anatomical difficulty (easy, 48.4 %; moderate, 66.7 %; difficult, 76.9 %; $p = 0.012$). Operative and pathologic outcomes of the three groups are presented in Table 3. There were no differences between groups in terms of mean operation time, anastomotic or overall complications, circumferential and distal resection margin (CRM/DRM) involvement, and retrieved lymph node (LN).

Risk factors related to operation time and poor surgical outcomes are presented in Tables 4 and 5. A multivariate analysis suggests that high BMI, history of preoperative CRT, and lower tumor level were significantly associated with longer operation time ($p < 0.001$, $p < 0.001$, $p = 0.009$, respectively). No aspect of the pelvimetric parameters showed significant relationships with operation time. History of preoperative CRT and younger age was related to anastomotic complication ($p = 0.02$, $p = 0.014$, respectively). In terms of overall complications, operation time and previous abdominal operation history were related risk factors ($p = 0.002$, $p = 0.020$, respectively).

Discussion

In this study, we could not find any differences in postoperative or pathologic outcomes between the anatomical groups, as represented by pelvimetry. Previous studies have offered conflicting results, which showed that pelvic dissection time was significantly longer in patients with difficult pelvic anatomy who underwent open or laparoscopic TME. Akiyoshi et al. [8] studied 79 patients who underwent laparoscopic TME and found that the pelvic outlet was an independent predictor of operation time and anastomotic leakage ($p = 0.0362$, $p = 0.0305$, respectively). Baik et al. [13] reported that narrow obstetric conjugate and shorter interspinous distance were factors leading to poor postoperative specimen quality in their study of 100 patients who underwent TME ($p = 0.022$, $p = 0.030$, respectively). Kim et al. [12] also demonstrated similar results in a prospective study of 74 patients who underwent laparoscopic TME; they found that the mean pelvic dissection time for the difficult anatomy group was 94.12, 60.72 min for the moderate group, and 41.47 min for the easy group ($p < 0.001$). Moreover, intraoperative transfusion and incomplete TME quality were most common in the difficult anatomy group ($p = 0.032$, $p = 0.032$, respectively). The current study, however, not only demonstrated the difference between the three groups in terms of operation time and other factors, but also revealed, unexpectedly, that mean operation time was shorter in the difficult group than in the easy group, although not significantly so.

We assumed that difficult pelvic anatomy did not affect operative outcomes in patients who underwent robotic surgery because the robotic procedure could compensate for the level of surgical difficulty. As is well established, the robotic system has several advantages to open or laparoscopic surgery, like an excellent three-dimensional view, adequate traction, and counter traction because of a third robotic arm, and improved dexterity through the use of an internal articulated Endo-Wrist that provides seven degrees of freedom [14–16]. In particular, the advantages are particularly favorable for deep and narrow spaces, like the pelvis or mediastinum; thus, the robotic system has been widely adapted for use in urological, gynecological, and cardiac surgery, as well as for rectal surgery [19–21]. According to current evidence, however, most studies showed similar outcomes between robotic and laparoscopic surgery, especially in regard to operation time, which was generally longer than laparoscopic surgery [17, 22, 23]. A critical disadvantage of robotic surgery is the cost, which is much higher than that of conventional laparoscopic surgery [24, 25]. We are anticipating positive results from our ongoing studies in terms of sexual and voiding function and oncological outcomes of robotic surgery [26, 27], and there are a few reports that the operation time for robotic surgery is shorter in cases of intersphincteric resection and coloanal anastomosis with extremely low rectal cancer [28, 29]. Despite these findings, the superiority of robotic surgery compared to laparoscopy is still debatable. Many surgeons claim that increased surgical comfort is one of greatest virtues of robotic surgery, but these are generally only subjective impressions. Even with these ergonomic benefits, it is hard to overcome or justify the expense of robotic surgery, especially when the scientific evidence for ergonomic benefit is lacking. Based on the results of our study, however, we conclude that robotic TME was feasible without increasing operation time or morbidity, even among patients with difficult pelvic anatomy, whose outcomes were similar to those in the easy anatomy group.

Factors, such as a large tumor, narrow pelvis, and shallow sacral angle, reduce the pelvic space, limit the maneuverable space, and make for unsatisfying counter traction turns, leading to a suboptimal operation field. The robotic system provides a stable camera view and powerful counter traction, all of which is under the surgeon's control and makes for an ideal surgical exposure. Additionally, an internal articulated Endo-Wrist enables unconstrained movement, even in circumstances of limited space. This may lead to comparable results between patients with difficult pelvis anatomy and those with easy anatomy, probably due to the increased comfort the surgeons' experience.

This study has several limitations. First, we assessed total operation time, in contrast with our previous study where we assessed pelvic dissection time only. Unlike pelvic dissection time, total operation time cannot be affected only the effect of robotic system, but also several factors such as type of operation. Because patient demographics were evenly distributed in three groups, the limitation could be compensated statistically. Second, the current study included several surgeons having variable experiences, and this matter seemed to affect operative time importantly. However, the heterogeneity can be merit to apply other surgeons universally. Third, this is a retrospective study, and factors related to oncological outcome, such as TME completeness, could not be assessed. Forth, there is high variability in the sample sizes for each of the anatomy groups (easy, 31 patients; moderate, 138 patients; difficult, 13 patients) although statistical results can be accepted because the three groups showed normal distribution each. Despite these limitations, this study is valuable because our total sample size was relatively large. Also, we matched the surgical difficulty by MRI-based pelvimetry with the mechanical advantage of advanced robot technology, and objectified the results of improved robotic ergonomics, which are unique benefits of this study.

In conclusion, there were no differences between the easy, moderate, and difficult anatomy groups in terms of operation time or other outcomes for robotic rectal surgery. Therefore, we conclude that the robot system can provide increased comfort for surgeons even with difficult pelvic anatomy, and may overcome the difficulty.

Disclosure Se Jin Baek, Chang Hee Kim, Min Soo Cho, Sung Uk Bae, Hyuk Hur, Byung Soh Min, Seung Hyuk Baik, Kang Young Lee, Nam Kyu Kim have no actual or potential personal, political, or financial conflicts of interest with regards to this study.

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