Evaluation of factors affecting the difficulty of laparoscopic anterior resection for rectal cancer: "narrow pelvis" is not a contraindication

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Abstract

Background This study aims to evaluate the clinical and anatomical factors, particularly pelvic dimensions that influence the difficulty of performing laparoscopic anterior resection for rectal cancer.

Methods We studied 50 consecutive patients who underwent laparoscopic anterior resection with double-stapling technique (DST) anastomosis for rectal cancer between January 2006 and February 2010. Staging was performed by computed tomography. Five pelvic dimensions (anteroposterior and transverse diameters of pelvic inlet and outlet, and pelvic depth) were measured using three-dimensional volume-rendering images. We also examined a number of other clinical characteristics, including gender, history of laparotomy, body mass index (BMI), operator, tumor location, tumor depth, nodal involvement, and tumor diameter. Univariate and multivariate analyses were performed to determine the predictive significance of these variables on surgical difficulty based on operative time and intraoperative blood loss.

Results Males had significantly shorter pelvic inlets and outlets and significantly greater pelvic depth than females. However, gender did not significantly affect surgical outcomes, although males did tend to experience greater blood loss. Maximum tumor diameter ($p = 0.014$), BMI ($p = 0.001$), operator ($p < 0.001$), and tumor location ($p = 0.009$) were independent predictors of operative time, which, in turn, was related to intraoperative blood loss ($p < 0.001$).

Conclusions Maximum tumor diameter, BMI, operator experience, and tumor location can be used to predict the operative time required to complete laparoscopic anterior resection with DST anastomosis for rectal cancer, with no correlations between pelvic dimensions and operative time. The difficulty of the procedure was not related to patients' pelvic dimensions, which led us to conclude that "narrow pelvis" is not a contraindication for this surgery. Based on these results, we suggest that laparoscopic anterior resection should be performed by experienced surgeons in patients with large tumors, high BMI, and/or extraperitoneal rectal cancer.

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Laparoscopic procedures for rectal cancer have been reported to be safe and effective for a number of reasons, including relatively low levels of pain and blood loss, early resumption of bowel movement, and short postoperative hospital stay [1–6]. Additionally, randomized studies have shown that laparoscopic total mesorectal excision (TME) and lymph node dissection are productive surgical techniques with survival and recurrence rates comparable to those of open procedures [4, 6–8]. However, while laparoscopic surgery is the standard treatment for colon cancer, it is not commonly performed in cases of rectal cancer because it is technically challenging and may be associated with disadvantages such as long

operative time [1, 2, 4] and increased rate of positive surgical margins [9].

Rectal surgery is performed through a narrow and funneling bony inlet, which makes access and visualization difficult in the deep pelvis. Even in the relatively simpler open approach, it is difficult to maintain a clear surgical field, to recognize precise anatomy, and to accurately perform rectal mobilization and excision while preserving urogenital functions. Recent studies have suggested that the quality of open rectal surgery is influenced not only by the surgeon's skill but also by the patient's clinical and anatomical factors, such as gender, tumor height, and pelvic size [10–12]. Similar relationships possibly influence the outcomes when using the laparoscopic approach, but evaluation of the influence of such clinical and anatomical factors on laparoscopic rectal surgery has been limited [13, 14]. The purpose of this study is to evaluate the influence of various clinical and anatomical factors, particularly pelvic dimensions, on operative time and intraoperative blood loss, which were selected as dependent variables to represent the level of difficulty in performing laparoscopic anterior resection with double-stapling technique (DST) anastomosis for rectal cancer.

Patients and methods

Patients

We studied 50 consecutive patients who underwent laparoscopic anterior resection with DST anastomosis for rectal cancer located below the inferior edge of the S2 vertebra between January 2006 and February 2010.

The indications for laparoscopic surgery were rectal cancer without involvement of the lateral lymph nodes or invasion of the adjacent organs, as determined by computed tomography (CT) and pelvic magnetic resonance imaging (MRI) during preoperative examinations. An additional indication was evidence of metastatic disease that could not be curatively resected using open surgery.

In Japan, preoperative radiotherapy or chemotherapy is not routinely administered in the treatment of rectal cancer; it is currently being used in clinical trials or mainly in patients with locally advanced, very low tumors to increase the chance of sphincter-preserving surgery. In this study, no patients underwent preoperative radiotherapy or chemotherapy.

Data for age, gender, history of laparotomy, body mass index (BMI), tumor location, tumor size, tumor staging, operative time, amount of blood loss, conversion to open surgery, pathology, 30-day morbidity, and mortality were collected prospectively. Tumors were staged according to the sixth tumor–node–metastasis (TNM) classification of the International Union against Cancer (UICC) on the basis of the histological findings of the surgical specimens.

Surgical procedures

The surgeries were performed by an experienced expert surgeon (T.Y.) or by trainees with 3–6 years of experience, operating under the expert's supervision.

Anterior resection is used for the treatment of early cancer located just above the dentate line and advanced cancer located >1 cm above the dentate line; these criteria enable the acquisition of adequate distal margin after rectal transection. Here, patients were placed in Lloyd–Davis position with the head and right side of the bed lowered. First, a 12-mm camera port was inserted below the umbilicus using the open method. After creation of a pneumoperitoneum, four working ports were inserted: a 5-mm port in the right and left upper abdominal quadrants each, and a 12-mm port in the right and left lower abdominal quadrants each. The mesocolon was mobilized using the mediolateral approach, and the inferior mesenteric artery was divided near its origin in order to achieve wide lymphadenectomy. This permitted TME, except in cases of intraperitoneal rectal cancer, where tumor-specific mesorectal excision (TSME) was performed instead. The rectum was transected intracorporeally using an Endo-Cutter (Ethicon Endo-Surgery, Cincinnati, OH, USA) and anastomosed with DST. No diverting stoma was created.

Pelvimetry

All patients underwent abdominopelvic CT (Aquilion 16; Toshiba Medical Systems Corporation, Tochigi, Japan). In most cases, the slice interval was adjusted to 5 mm. Sequences were volume-rendered using a DICOM 3D viewer, INTAGE Realia (KGT Inc., Tokyo, Japan). Volume-rendering (VR) images were obtained from the extracted volume data using INTAGE Volume Player (KGT Inc., Tokyo, Japan). A single observer (S.O.) blinded to all clinical information regarding the patients made all measurements in the VR images. Five pelvic dimensions were measured: anteroposterior and transverse diameters in the pelvic inlet (the axis from the superior aspect of the pubis symphysis to the sacral promontory and the longest lateral axis in the iliopectineal line), anteroposterior and transverse diameters in the pelvic outlet (the axis from the inferior aspect of the pubis symphysis to the tip of the coccyx and the distance between the tips of the ischial spines, i.e., interspinous distance), and the pelvic depth (the distance between the sacral promontory to the tip of the coccyx) (Fig. 1).

Fig. 1 Anteroposterior (**A**) and transverse (**B**) diameters in the pelvic inlet, anteroposterior (**C**) and transverse (**D**, **E**) diameters in the pelvic outlet, and length of pelvic depth (**F**) were measured using three-dimensional VR images
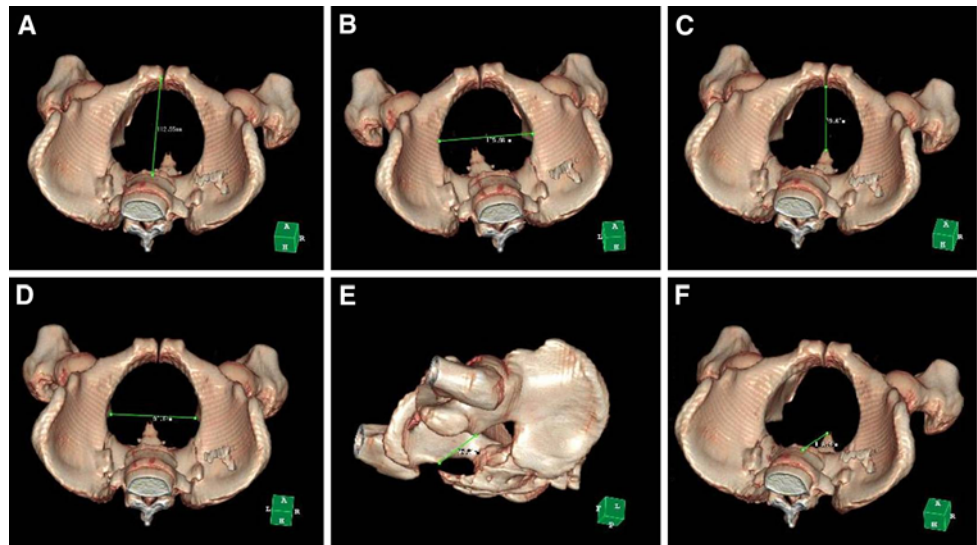
Statistical analysis

The sample size was calculated to detect moderate correlation (correlation coefficient: $|r| = 0.4$) with α of 0.05 (two-sided) and β of 0.2 (power of 80%), suggesting a total study population of 47 patients. All statistical analyses were performed using SPSS version 15.0 (Statistical Package for Social Sciences™; SPSS, Inc., Chicago, IL, USA). Statistical significance was defined as $p < 0.05$. Where appropriate, we used Fisher's exact test, chi-square test, Student's t test, Welch's test, or Pearson's product-moment correlation coefficient to investigate relationships between patients' clinical and anatomical characteristics and surgical difficulties. Multivariate analysis was performed using a multiple linear regression model with a stepwise method (significance level to enter = 0.05; significance level to stay = 0.1).

To assess intraobserver variation, measurements of the pelvic dimensions of 10 patients were repeated after an interval of 4 weeks, with the observer blinded to the initial results [10, 14]. According to the Pearson's product-moment correlation coefficient, the intraobserver variation was 0.946. The two sets of measurements were highly correlated ($p < 0.001$), indicating that they accurately described pelvic anatomy.

Results

Patient and tumor characteristics are summarized in Table 1. Anastomosis height was significantly greater in males than in females ($p = 0.014$). All five pelvic dimensions differed significantly between male and female patients. Females had significantly longer measurements for the pelvic inlet and outlet (all $p < 0.003$), while males

had significantly greater pelvic depth ($p < 0.001$). Overall, this indicated that male pelvises were significantly narrower and deeper than female pelvises.

Although males tended to experience more blood loss during surgery ($p = 0.11$), there were no significant differences between the genders in surgical outcomes (Table 2). In no case was there conversion to open surgery, death or positive circumferential resection margins (CRM). Complications were identified in two male patients: one wound infection and one anastomotic leakage. The overall morbidity rate was 4%, and the anastomotic leakage rate was 2%.

Univariate analysis showed that age ($p = 0.012$), BMI ($p = 0.009$), operator ($p = 0.006$), and maximum tumor diameter ($p = 0.003$) were significantly associated with operative time (Table 3). Although operative time tended to increase as anteroposterior pelvic inlet diameter decreased ($p = 0.151$) and pelvic depth increased ($p = 0.103$), these relationships were not significant.

Stepwise linear regression analysis showed that the optimal model for predicting operative time included maximum tumor diameter, BMI, operator, and tumor location ($p < 0.001$, Table 4). Operative time increased as maximum tumor diameter and BMI increased, but decreased with an expert performing the operation and for intraperitoneal tumor location. Operative time, in turn, was the only factor significantly associated with blood loss ($p < 0.001$); no other variables had any relationship with blood loss.

Discussion

In this study, multivariate analysis showed that larger maximum tumor diameter, higher BMI, trainee performing

Table 1 Patients' clinical and anatomical characteristics

	Male ($n = 30$)	Female ($n = 20$)	p Value
Age (years)	66 (60, 79)	70 (58, 75)	0.93
Previous laparotomy (no.)	9	9	0.43
BMI (kg/m^2)	21.5 (18.7, 22.6)	21.4 (18.0, 23.4)	0.87
Operator			0.82
Expert (no.)	17	12	
Trainee (no.)	13	8	
Tumor location of lower edge			0.20
Intraperitoneal (no.)	19	9	
Extraperitoneal (no.)	11	11	
Tumor depth			0.81
Tis/T1/T2 (no.)	19	12	
T3/T4 (no.)	11	8	
Nodal involvement			0.75
N0 (no.)	22	13	
N1/N2 (no.)	8	7	
Maximum tumor diameter (cm)	4.0 (1.8, 5.2)	3.3 (2.0, 4.1)	0.38
Procedure			0.72
High anterior resection (no.)	2	1	
Low anterior resection (no.)	28	19	
Anastomosis height from anal verge (cm)	6.0 (4.0, 6.8)	4.0 (4.0, 5.0)	**0.014**
Pelvic dimensions			
Inlet			
Anteroposterior (cm)	11.0 (10.3, 11.8)	11.9 (11.5, 12.7)	**<0.001**
Transverse (cm)	12.3 (11.9, 12.7)	12.9 (12.4, 13.3)	**0.002**
Outlet			
Anteroposterior (cm)	10.0 (9.4, 10.3)	10.6 (10.1, 11.4)	**0.003**
Transverse (cm)	9.7 (9.1, 10.0)	11.1 (10.7, 11.9)	**<0.001**
Depth (cm)	12.4 (11.4, 12.7)	11.2 (10.0, 11.8)	**<0.001**

All continuous variables are described as median (first quartile, third quartile)

Bold font in table means that the p-values were statistically significant

Table 2 Surgical outcomes in relation to gender

	Male ($n = 30$)	Female ($n = 20$)	p Value
Operative time (min)	305 (271, 325)	277 (254, 333)	0.26
Blood loss (ml)	25 (8, 58)	5 (0, 23)	0.11
Complication (no.)	2	0	0.66
Anastomotic leakage (no.)	1	0	0.84
Conversion (no.)	0	0	na
Mortality (no.)	0	0	na
Positive CRM (no.)	0	0	na

CRM circumferential resection margin

the operation, and extraperitoneal tumor location were significantly associated with longer operative time in laparoscopic anterior resection with DST anastomosis for rectal cancer, while pelvic dimensions had no correlations with operative time. Furthermore, operative time was the only factor significantly associated with intraoperative blood loss. The present findings are valuable in suggesting that pelvic dimensions were not definitive factors as compared with maximum tumor diameter, BMI, operator experience, and tumor location in predicting the difficulty of performing this procedure.

Interest in pelvimetry began with attempts to predict cephalopelvic disproportion in pregnant women prior to labor. Pelvimetry has been utilized for patients with rectal cancer, using MRI [10–12] and CT [13, 14] images; in these cases, measurements were made on two-dimensional reconstructed (axial and sagittal) images. However, these cross-sectional images only permit measurement of distances between points that exist in the same orthogonal coordinate axis. We preferred the use of three-dimensional VR images, because they allow precise measurements along any axis and can be especially beneficial in cases with anatomically strained pelvis or mismatched alignments between patients and imaging devices. The precision and sensitivity of this technique were demonstrated by its ability to correctly indicate that male pelvises are narrower and deeper than female pelvises, as well as by the strong correlation between the two sets of

Table 3 Correlations between operative time and operative parameters

Variable	p Value
Gender (male versus female)	0.131
Age	**0.012**
Previous laparotomy	0.430
BMI	**0.009**
Operator (expert vs. trainee)	**0.006**
Tumor location (intraperitoneal versus extraperitoneal)	0.338
Tumor depth (Tis/T1/T2 vs. T3/T4)	0.247
Nodal involvement (N0 vs. N1/N2)	0.471
Maximum tumor diameter	**0.003**
Anastomosis height from anal verge	0.338
Pelvic dimensions	
Inlet	
Anteroposterior	0.151
Transverse	0.250
Outlet	
Anteroposterior	0.481
Transverse	0.324
Depth	0.103

Bold font in table means that the p-values were statistically significant

4 Variables included in the final stepwise linear regression model explaining variations in operative time

	B	β	p Value
Intercept	190.871		<0.001
Maximum tumor diameter (cm)	8.075	0.289	0.014
BMI (kg/m^2)	6.828	0.382	0.001
Operator (expert)	–66.755	–0.576	<0.001
Tumor location (intraperitoneal)	–42.945	–0.373	0.009
$R^2 = 0.463$			
Model utility test: $p < 0.001$			

measurements in the intraobserver variation test ($r = 0.946$, $p < 0.001$).

In this study, we chose to evaluate cases of rectal cancer that underwent laparoscopic anterior resection with DST anastomosis, because intracorporeal rectal transection and anastomosis is one of the most difficult procedures in laparoscopic rectal surgery and therefore should be considered separately from cases that undergo abdominoperineal resection or intersphincteric resection with transanal hand-sewn anastomosis. We selected operative time and intraoperative blood loss as dependent variables representing technical difficulties during this procedure. Other variables, including complications, anastomotic leakage, conversion, mortality, and positive CRM, occurred at such low rates that they could not be analyzed. This indicates that the procedure can be performed safely and without morbidity or conferring any oncologic disadvantage.

It is not immediately clear why anastomosis height was significantly greater in males than in females. Unlike previous authors [13, 15], we did not find that operative outcome differed significantly between the two genders. These results may partly be explained by the fact that pelvic procedures can be completed more easily in wider and shallower female pelvises, but may also be disrupted by the presence of the uterus.

Patients in this study had BMI ranging from 12.0 to 27.8 kg/m^2; these values are lower than those in Western populations. Nevertheless, our results agreed with previous reports that found a positive association between operative time and BMI [14]. This is likely associated with greater mesorectal volume, which restricts the pelvic working space for the procedures. Therefore, visceral fat may be an even better predictor of surgical difficulty than BMI [16, 17]. Further, larger maximum tumor diameter reflects larger tumor volume, which again restricts the pelvic working space. Space can also be restricted by the location of tumors; i.e., when tumors are positioned extraperitoneally, surgeons have a narrower space in which to perform rectal dissection, transection, and anastomosis, since the pelvic width becomes narrower as one approaches deeper into the pelvis. Thus, cumulatively, higher BMI, larger maximum tumor diameter, and extraperitoneal tumor location impact operative time by limiting pelvic free space for the procedures and reducing visibility, maximum retraction, and access to the depths of the pelvis via the pelvic inlet.

In keeping with our previous finding, operative time was longer when procedures were performed by trainees [18]. Pelvic space cannot be expanded by pneumoperitoneum, as can be done in the upper abdomen, and limited working space directly affects the difficulty of safe and quick access, required to optimize visibility and retraction. We presume that these issues do not present as great a problem to expert surgeons because they have more experience in creating an appropriate surgical field and obtaining a good view for identifying and dissecting anatomical structures even in a limited pelvic working space.

Although pelvic depth tended to correlate with operative time, we did not find any significant patterns linking pelvic dimensions with operative outcomes. These results are contrary to those previously reported elsewhere [13, 14]. We hypothesize that this is because BMI, maximum tumor diameter, and tumor location have greater effect on pelvic working space than do pelvic dimensions. Additionally, this study included cases of both intraperitoneal and extraperitoneal rectal cancer, while a similar previous study focused only on extraperitoneal rectal cancer [14]. Furthermore, the procedures in our study were performed by both experts and trainees, rather than experts only [14].

Thus, these differences in inclusion criteria may explain why we did not detect any significant correlations between pelvic dimensions and operative time.

Our study has certain limitations. The sample size of this study was small, although the study was not statistically underpowered. However, future examinations with larger sample size would elucidate our results further. Additionally, other variables, including complications, anastomotic leakage, conversion, mortality, and positive CRM, should be examined to generalize the present findings.

In summary, our results indicate that "narrow pelvis" is not a contraindication for laparoscopic resection of rectal cancer. We also recommend that this procedure be performed by experienced surgeons in patients with large tumors, high BMI, and/or extraperitoneal rectal cancer.

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