Inter-ischial spine distance is a simple index of narrow pelvis that may predict difficulty during laparoscopic low anterior resection: a retrospective study

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Research article

Abstract

Background

A narrow pelvis makes laparoscopic rectal resection difficult. This study aimed to evaluate whether a simple measurement on computed tomography can predict procedural difficulty.

Methods

A total of 62 patients with low rectal cancer underwent conventional laparoscopic low anterior resection. The inter-ischial spine (IS) distance (i.e., distance between the ischial spines) was measured on an axial computed tomography slice. Operative time, blood loss, and time from insertion of linear staplers to completion of clamping on the distal end of the rectum (clamp time) were compared.

Results

Overall, 42 men and 20 women with low rectal cancer were assessed. The mean tumor size was 34.5 mm. Total or tumor-specific mesorectal excisions were performed in all cases; high ligation and resection of the inferior mesenteric arteries were carried out in 92% of patients. The mean operative time, and blood loss were 206 min, and 15 mL respectively. Four patients (6.5%) experienced postoperative complications, including two anastomotic leaks (3.2%). The mean IS distance was 93.3 mm. With simple linear regression, shorter IS distance correlated with longer operative time (R^2 = 0.08, P = 0.030) and clamp time (R^2 = 0.07, P = 0.046). Using an receiver operating characteristic curve, a narrow pelvis was defined as IS distance < 94.7 mm. Multivariate regression analysis revealed that IS distance < 94.7 mm (odds ratio, 3.51; P = 0.04) was independently associated with a longer clamp time.

Conclusions

The IS distance is a simple and useful measurement for predicting the difficulty of laparoscopic low anterior resection.

Background

Owing to the superior short-term results [1, 2] and non-inferior long-term oncologic outcomes [3, 4] relative to laparotomy, laparoscopic surgery is becoming a standard surgical treatment for colon cancer worldwide. The safety and superior short-term results of laparoscopic low anterior resection performed by expert surgeons for rectal cancer have also been reported [5, 6]. In Japan, more than 30% of patients with low rectal cancer undergo low anterior resection using the laparoscopic approach [7]. However, its short-term safety in the general setting, and the long-term safety, are not well-established [8–11]. One of the

reasons why developing the evidence base for rectal surgery is taking longer than it did for colon surgery could be the difference in the technical difficulty of the two procedures. It is well-known that the narrow pelvis makes laparoscopic rectal resection difficult, making the operative time longer [12, 13] and the handling more difficult [14]. A narrow pelvis also increases the risk of anastomotic leakage [15]. Additionally, the definition of the narrow pelvis remains unclear in terms of surgical anatomy. Several indexes that predict surgical difficulty have been reported using sagittal computed tomography (CT) imaging, 3D-CT, and magnetic resonance imaging (MRI) [12–16]. However, the indexes are quite complicated in terms of the measurement sites, with some requiring calculations. A novel and simple index is required.

The present study aimed to establish a simple CT-derived index for the narrow pelvis that can predict the likelihood of experiencing difficulty during laparoscopic low anterior resection.

Methods

A total of 252 patients with rectal cancer underwent laparoscopic low anterior resection between January 2009 and December 2018 at Hokkaido University Hospital. After excluding cases of upper rectal cancer, we retrospectively assessed the short-term outcomes of 62 conventional laparoscopic low anterior resections for low rectal cancers that were electively performed and evaluated whether the distance measured on axial CT slices can predict procedural difficulty. The distance between the iliopsoas muscles at the pelvic inlet (IM distance) and the distance between the ischial spines (IS distance) were measured (Fig. 1). The size of mesorectum was defined as the sum of the transverse and anterior-posterior diameters of the mesorectum at the S4 level. The operative time, blood loss, and time from the insertion of linear staplers to the completion of clamping on the distal end of the rectum (clamp time) were set as the outcomes of procedural difficulty.

Postoperative complications were evaluated according to the Clavien–Dindo classification [17]. The study protocol was reviewed and approved by the hospital ethics committee of Hokkaido University Hospital, and informed consent was obtained from all patients through the opt-out method in accordance with the guidelines of the Japanese Ministry of Health, Labour and Welfare.

Procedure

The procedure was performed under pneumoperitoneum with 10 mmHg CO_2. Five ports were inserted at the umbilicus, on both sides of the hypogastric region, and at the flank. In particular, the right hypogastric port was inserted just laterally or medially to the root of the inferior epigastric artery. First, in the Trendelenburg position, the whole jejunum and ileum were flipped up to the cranial side. The mesocolon of the sigmoid colon was dissected from the retroperitoneum and mobilized using the medial-to-lateral approach. The left gonadal vessels and ureter were preserved. High ligation and resection of the inferior mesenteric artery (IMA) in advanced cancer were performed. The inferior mesenteric vein and the peripheral part of the left colic artery were resected at the same level as the root of the inferior mesenteric

artery. After the lateral side of the sigmoid colon was mobilized, total or tumor-specific mesorectal excision was performed with dissection along the circumference of the fascia propria of the rectum. In mobilizing the rectum from the pelvic organs, both sides of the ureter, hypogastric nerves, pelvic plexus, and pelvic splanchnic nerves were all preserved. The Denonvilliers fascia was preserved unless the tumor was located at the anterior wall of the rectum. The mesorectum 2 cm distal to the tumor was dissected vertically towards the rectum, and the entire circumference of the rectal wall was exposed. Subsequently, the site of the rectum was enclosed by clip-shaped forceps, the lumen of the rectum was washed with 1 L of physiological saline and 5% of povidone iodine. A linear stapler was inserted from the right hypogastric region port, and the rectum was clamped with the stapler on the distal side of the clip-shaped forceps. The rectum was transected by single or double use of the linear stapler. A small incision was added at the umbilical port, and the mesocolon and the sigmoid colon were extracorporeally cut at 10 cm on the oral side from the tumor. Reconstruction of the intestine was intracorporeally performed using the double-stapling technique with a circular stapler. The anterior part of the intersected stapler was reinforced by a full layer of sutures. A diverting ileostomy was created for patients with anastomosis located in the anal canal, patients who received preoperative therapy, or patients with a positive air leak from the anastomosis.

Statistical analysis

All continuous data are presented as mean and standard deviation. Descriptive statistics for patient characteristics were calculated. All statistical tests were performed using an alpha level of 0.05 (two-sided). Chi-squared and Student's t-tests were used to analyze categorical and non-normal continuous data, respectively. Simple linear regression was performed to assess the relationship between IS/IM distance and the size of the mesorectum and clamp time, operative time, and blood loss during all rectal surgeries. To determine factors that could affect longer clamp time, univariate and multivariate logistic regression analysis with covariates based on preoperative and intraoperative values was also performed. Factors with P-value below 0.2 in the univariate analysis were entered into the multivariate analysis. All statistical analyses were performed using JMP Pro version 13.1.0 (SAS Institute, Inc., Cary, NC, USA).

Results

Patient characteristics and the measured pelvic distance

A total of 62 patients (mean age, 66.2 years; male-to-female ratio, 42:20) were included in this study. The mean body mass index was 22.8 kg/m^2. Two patients (3.2%) had preoperative comorbidities (American Society of Anesthesiologists class III). Of these 62 patients, 63% had tumors located on Ra (defined as the rectal segment between the second sacral joint and peritoneal reflection), 37% had tumors located on Rb (defined as the rectal segment below the peritoneal reflection), 45% were diagnosed with locally advanced cancer, and 10% were identified to have distant metastasis. Low anterior rectal resection with high ligation of the IMA (D3 lymph node dissection) was performed in 92% of patients. The mean operative time and blood loss were 206 min and 15 mL, respectively. The mean time required for

clamping the distal edge of the harvested rectum was 79.8 seconds. Diverting stomas were created in 42% of the patients. No patient required conversion to open surgery. Four patients (6.5%) experienced postoperative complications (Clavien–Dindo grade $\geq$ 3), including anastomotic leakage ($n = 2$), small bowel obstruction ($n = 1$), and cholecystitis ($n = 1$). Overall, 3%, 42%, 21%, 24%, and 10% of patients had a pathological stage of 0, I, II, III, and IV, respectively. In 97% of the patients, a diagnosis of differentiated adenocarcinoma was confirmed. The mean number of harvested lymph nodes was 16.8, with a mean tumor size of 34.5 mm, and histological R0 resection was achieved in all patients with stages 0–III. The mean distance between the iliopsoas muscles at the pelvic inlet was 100.2 mm, whereas the mean distance between the ischial spines was 93.3 mm; the size of the mesorectum measured 125.8 mm (Table 1).

Table 1
Patient characteristics

Characteristics		
Age (years)		66.2 ± 10.8
Sex	Male	42 (68%)
	Female	20 (32%)
BMI (kg/m^2)		22.8 ± 3.4
ASA grade	3	2 (3.2%)
Tumor location	Ra	39(63%)
	Rb	23(37%)
Preoperative bowel obstruction		10(16%)
Distance between iliopsoas muscles at the pelvic inlet (mm)		100.2 ± 12.5
Distance between ischial spines (mm)		93.3 ± 10.4
Size of mesorectum at S4 (mm)		125 ± 12
Stage	0	1(1.6%)
	I	27(44%)
	II	15(24%)
	III	13 (21%)
	IV	6(10%)
Preoperative treatment	NAC	4(6.5%)
	CRT	8(12/.9%)
Node dissection	D2	5 (8%)
	D3	57 (92%)
Diverting ileostomy		26(42%)
Operative time (min)		206 ± 41
Blood loss (mL)		15 ± 35
Time required to clamp the distal rectum (sec)		79.8 ± 36.1
Conversion to open procedure		0

ASA = American Society of Anesthesiologists; BMI, body mass index; NAC, neoadjuvant chemotherapy; CRT, chemoradiotherapy.

Characteristics	
Morbidity	4 (6.5%)
Anastomotic leakage	2(3.2%)
Bowel obstruction	1(1.6%)
Cholecystitis	1 (1.6%)
Reoperation	1 (1.6%)
Solid meal	5.8 ± 2.2
ASA = American Society of Anesthesiologists; BMI, body mass index; NAC, neoadjuvant chemotherapy; CRT, chemoradiotherapy.	

Relationship between short-term outcomes and pelvic index

With simple linear regression, a shorter IS distance was associated with clamp time (R^2 = 0.07, P = 0.046) and longer operative time (R^2 = 0.08, P = 0.030). However, IS distance was not associated with blood loss (R^2 = 0.01, P = 0.36; Fig. 2). The IM distance had no relationship with the clamp time (R^2 = 0.0005, P = 0.86), operative time (R^2 = 0.0006, P = 0.84), or blood loss (R^2 = 0.01, P = 0.36). Similarly, the size of the mesorectum had no relationship with the clamp time (R^2 = 0.0012, P = 0.78), operative time (R^2 < 0.0001, P = 0.96), or blood loss (R^2 = 0.0042, P = 0.62).

Patient characteristics and surgical outcomes between patients with narrow and wide pelvises

A longer operative time was defined as 79.8 seconds (mean) and logistic regression analysis was performed. According to the receiver operating characteristic (ROC) curve, we defined a narrow pelvis as that with an IS distance < 94.7 mm.

A total of 36 men and 1 woman with a mean age of 65.7 years were classified as having a narrow pelvis, and 19 men and 6 women with a mean age of 67.0 years were classified as having a wide pelvis. The IS distance was significantly shorter in patients with a narrow pelvis (86.3 mm vs. 103.5 mm; P < 0.001). However, no differences in body mass index (BMI), the frequency of preoperative co-morbidities with American Society of Anesthesiologists (ASA) grade III or above, or tumor location, size, or stage were observed between the two groups. The port locations and the frequency of D3 lymph node dissection or need for diverting stoma were not different between the two groups.

The time required for clamping the distal edge of the rectum (88.9 seconds vs. 65.8 seconds; P = 0.01) and the duration of surgery (217 min vs. 191 min; P = 0.01) were significantly longer in the narrow pelvis group. The number of linear staplers used was similar in both groups. The rates of postoperative

complication and anastomotic leakage (grade III or above) were 8.1% and 5.4% in the narrow pelvis group and 4.0% and 0% in the wide pelvis group, respectively, albeit without significant difference. No differences in the conversion rate, blood loss, number of harvested lymph nodes, or pathological R0 rates were observed (Table 2).

Table 2
Patient characteristics according to pelvis width

		Wide pelvis (n = 25)	Narrow pelvis (n = 37)	P-value
Age (years)		67.0 ± 2.2	65.7 ± 1.8	0.65
Sex		6 (4%):19 (76%)	36 (97%) :1 (3%)	0.0001
BMI (kg/m^2)		23.1 ± 0.7	22.6 ± 0.6	0.54
Location Ra:Rb		17 (68%):8 (32%)	22 (59%):15(41%)	0.49
Tumor stage	0	0	1 (3%)	0.49
	1	5 (20%)	10 (27%%)	
	2	8 (32%)	7 (19%)	
	3	12 (48%)	17 (46%)	
	4	0	2 (5%)	
Node stage	0	18 (72%)	24 (65%)	0.61
	1	4 (16%)	9 (24%)	
	2	3 (12%)	3 (8%)	
	3	0	1 (3%)	
Metastasis stage	0	24 (96%)	32 (86%)	0.21
	1	1 (4%)	5 (14%)	
Stage	0	0	1 (3%)	0.67
	I	11 (44%)	15 (41%)	
	II	6 (24%)	7 (19%)	
	III	7 (28%)	9 (24%)	
	IV	1 (4%)	5 (14%)	
Tumor size (mm)		34.6 ± 3.7	34.4 ± 3.1	0.96
IM distance (mm)		100.6 ± 2.5	100.0 ± 2.1	0.86
IS distance (mm)		103.5 ± 1.2	86.3 ± 1.0	0.001
Size of mesorectum (mm)		127.0 ± 2.5	125.0 ± 2.0	0.54
ASA grade ≥ 3		1 (4%)	1 (3%)	0.78

ASA = American Society of Anesthesiologists; BMI, body mass index; IM, iliopsoas muscle; IS, inter-ischial spine.

		Wide pelvis (n = 25)	Narrow pelvis (n = 37)	P-value
Lymph node dissection D2:D3		4 (16%):21 (84%)	1(3%):36 (97%)	0.06
Diverting stoma		8 (32%)	18 (49%)	0.19
Operative time (min)		191.4 ± 7.9	217.9 ± 6.8	0.01
Blood loss (mL)		7.2 ± 6.9	21.6 ± 5.9	0.12
Port site medial:lateral		9 (36%):15 (64%)	13 (35%):24 (65%)	0.85
Number of linear staplers	1	12 (48%)	13 (35%)	0.20
	2	12 (48%)	24 (65%)	
	3	1 (4%)	0	
Clamp time (sec)		65.8 ± 7.0	88.9 ± 5.7	0.01
R0		24	32	-
(except stage IV)		(100%)	(100%)	
Postoperative complication		1 (4%)	3 (8%)	0.51
Anastomotic leakage		0	2 (5%)	0.23
Harvested nodes		18.2 ± 1.6	15.9 ± 1.4	0.26
Conversion		0	0	-

ASA = American Society of Anesthesiologists; BMI, body mass index; IM, iliopsoas muscle; IS, inter-ischial spine.

Analysis of factors affecting operative time and longer time required to clamp the distal rectum

Univariate regression analysis using preoperative and intraoperative factors revealed that IS distance < 94.7 mm (odds ratio [OR], 4.01; 95% confidence interval [CI], 1.23–13.0; P = 0.02) was associated with a longer time required for clamping the distal rectum (≥ 79.8 seconds). Multivariate regression analysis using the factors with P-value below 0.2 also showed that IS distance < 94.7 mm (OR, 3.51; 95% CI, 1.05–11.7; P = 0.04) was independently associated with a longer time required for clamping the distal rectum (Table 3).

Table 3
Relationship between clamping and pelvic index

Risk	Odds ratio	95% CI	P-value	Odds ratio	95% CI	P-value
IS distance < 94.7 mm/ ≥94.7 mm	4.01	1.23-13.0	0.02	3.51	1.05−11.7	0.04
Age ≥65 / <65	1.65	0.55−4.96	0.37			
Man/woman	2.31	0.70−7.59	0.17			
Port location lateral/medial	2.20	0.74−6.51	0.42			
Number of staplers 2 / 1	2.303	0.77−6.85	0.13	1.61	0.47−5.53	0.44
Preoperative obstruction	1.68	0.43−6.58	0.45			
Rb / Ra	0.98	0.34−2.85	0.98			
Tumor size ≥ 50 mm / <50 mm	1.17	0.35−3.92	0.80			
BMI ≥ 25 / <25	0.45	0.13−1.65	0.23			
IM distance < 100 mm / ≥100 mm	0.94	0.34−2.65	0.92			
Preoperative therapy	2.64	0.73−9.57	0.14	1.55	0.3−7.43	0.58
Stoma	2.18	0.76−6.23	0.14	1.38	0.38−5.02	0.61
Univariate analysis Multivariate analysis						
BMI, body mass index; CI, confidence interval; IM, iliopsoas muscle; IS, ischial spine.						

Univariate regression analysis using preoperative and intraoperative factors indicated that IS distance < 94.7 mm (OR, 4.52; 95% CI, 1.44−14.2; P = 0.009), male sex (OR, 8.14; 95% CI, 2.04−32.4; P = 0.003), patients who received preoperative therapy (OR, 8.20; 95% CI, 1.58−42.4; P = 0.01), and creation of a diverting ileostomy (OR, 8.35; 95% CI, 2.57−27.1; P = 0.004) were associated with a longer operative time (≥ 206 min). Multivariate regression analysis using the factors with a P-value below 0.2 showed that creation of a diverting ileostomy (OR, 8.35; 95% CI, 1.02−19.6; P = 0.04) was independently associated with a longer operative time (Table 4).

Table 4
Relationship between operative time and pelvic index

Risk	Univariate Analysis			Multivariate Analysis		
	Odds ratio	95% CI	P-value	Odds ratio	95% CI	P-value
IS distance < 94.7 / ≥94.7	4.52	1.44–14.2	0.009	1.82	0.28–11.9	0.53
Age ≥65 / <65	0.68	0.23–1.97	0.48			
Man/woman	8.14	2.04–32.4	0.003	3.84	0.45–32.7	0.22
Port location lateral/medial	0.98	0.33–2.90	0.98			
Number of staplers 2 / 1	0.81	0.28–2.35	0.71			
Preoperative obstruction	0.82	0.20–3.27	0.78			
Rb / Ra	1.28	0.44–3.67	0.64			
Tumor size ≥ 50 mm / <50 mm	1.11	0.32–3.83	0.86			
BMI ≥ 25 / <25	1.65	0.50–5.37	0.40			
IM distance < 100 mm / ≥100 mm	0.80	0.28–2.26	0.68			
Preoperative therapy	8.20	1.58–42.4	0.01	2.89	0.38–22.2	0.30
Stoma	8.35	2.57–27.1	0.0004	4.47	1.02–19.6	0.04

BMI, body mass index; IM, iliopsoas muscle; IS, ischial spine.

Discussion

The IS distance is a simple index for the narrow pelvis that can predict the difficulty of laparoscopic low anterior resection for rectal cancer. A narrow pelvis made the procedure difficult in terms of the time taken to clamp the distal end of the rectum, when we defined the narrow pelvis as an IS distance < 94.7 mm. Moreover, operative times were longer in the presence of a narrow pelvis. Measuring the distance between the ischial spines using an axial CT image provides a simple definition of a narrow pelvis.

Some previous studies have developed narrow pelvis indexes. Tsuruta et al. reported that a pelvic index > 13 in male patients was associated with anastomotic leakage [15]. However, complicated measurements were needed to calculate their pelvic index, because their index was defined as the difference between the interspinous distance and the diameter of the mesorectum, divided by the depth of the cavity of the lesser pelvis. Hamabe et al. reported that sacral promontory shape was related to the insertion of an additional port in reduced-port surgery [14], and Targarona et al. reported that the pubic coccyx axis was associated with prolonged operative time [13]. These narrow pelvis indexes are based on angles, and intuitively judging surgical difficulty is difficult. Shimada et al. reported the antero-posterior/transverse ratio of the pelvic inlet to be associated with prolonged operative time [12]. This index requires three-dimensional CT measurements because of the need to measure the pelvic inlet while correcting for the angle of the pelvic axis. All these previously published indexes require multiplanar measurements using MRI or reconstructed CT images. However, in the current study we found the IS distance to be a novice and simple index requiring only the axial slice of a CT scan to predict the difficulty of performing a laparoscopic low anterior resection. The axial slice of a CT scan is simple to interpret and one of the most popular images that can be available for surgeons.

In the current study, we used the time taken to clamp the distal end of the rectum as an outcome, which may not be popular. However, many surgeons may experience difficulty in managing to clamp the distal end of the rectum, especially in the pelvis at a level deeper than the peritoneal reflection. Therefore, when we designed the current study, we hypothesized that being able to clamp the distal end of the rectum may be more difficult in the presence of a narrow pelvis. As per the results of the simple linear regression and logistic regression, a shorter IS distance was significantly associated with a longer clamp time and operative time. Regarding the operative time, the narrow pelvis in our definition was not associated with a longer operative time in multivariate regression analysis. This might be because many other factors influence the operative time. Tsuruga et al. reported that the pelvic index was associated with a longer operative time but not merely the IS distance [15]. This could also be because several factors could influence the operative time. The creation of a stoma was the only independent factor that was significantly associated with a longer operative time. The creation of the stoma itself takes several minutes. Furthermore, a diverting ileostomy was created in patients where the anastomosis was located in the anal canal, patients who had received preoperative therapy, and patients with positive air leakage from the anastomosis. These are generally difficult cases [18–20] and it is natural that these operations took longer to complete. With this in mind, the process to clamp the distal end of the rectum is a simple index that directly reflects the difficulty of the pelvic aspect of the operation, and it is reasonable to use it as an index of the difficulty. One thing to consider is that the clump time may be dependent on the technical experience of the operator. However, all of the operations in the current study were performed among surgeons who had been qualified as skilled in Endoscopic Surgical Skill Qualification System (ESSQS) to eliminate the possible bias of individual surgeons' skills. In Japan, the Japan Society for Endoscopic Surgery introduced the ESSQS [21–23] to maintain and improve the quality of laparoscopic surgery, and laparoscopic colorectal procedures performed with ESSQS-qualified surgeons have been proven to improve postoperative results [24].

In the current study, the rate of R0 resection and postoperative complication rate were too small to be reliable outcomes for operative difficulty. The cutoff point was calculated from the ROC curve. The area under the curve derived from the ROC curve was not high, and this might be because of the limited number of patients in this study. The difference in the pelvic shape between men and women is an important issue to discuss because the width of the pelvis could not be measured using the IS distance in a straightforward manner. However, multivariate regression revealed that the IS distance was an independent factor for predicting the difficulty of low anterior resection, and IS distance can be a common factor regardless of a patient's sex.

Predicting the difficulty of low anterior resection can be useful in deciding who the operator will be and in determining the surgical approach. In difficult cases, it may be best that an expert surgeon performs the operation. For instance, a certificated surgeon by the ESSQS may be appropriate to perform difficult cases. Determining the surgeon according to the IS distance may result in better surgical outcomes because procedures beyond a surgeon's capacity may be avoided by that surgeon. Laparoscopic surgery using the robotic assistant and the trans-anal endoscopic approach could be another option to improve the surgical outcomes in difficult cases with a narrow pelvis [25, 26], although the merit of these approaches has not been fully shown to date. IS distance may be useful in determining these appropriate surgical approaches.

The current study is weak in terms of small number, single faculty and retrospective evaluateion. Therefore, future prospective studies with a large number of patients from multiple institutions are required.

Conclusions

The distance between the ischial spines is a simple and useful method to predict the difficulty of handling the narrow pelvis in laparoscopic low anterior resection. Predicting the difficulty using this index might lead to a safer rectal cancer resection when considering the specific operator or the surgical approach.

Abbreviations

ASA
American Society of Anesthesiologists
BMI
body mass index
CI
confidence interval
CT
computed tomography
ESSQS

Endoscopic Surgical Skill Qualification System

IM

iliopsoas muscle

IMA

inferior mesenteric artery

IS

ischial spines

MRI

magnetic resonance imaging

OR

odds ratio

ROC

receiver operating characteristic

Declarations

References

1. The Clinical Outcomes of Surgical Therapy Study Group. A comparison of laparoscopically assisted and open colectomy for colon cancer. N Engl J Med. 2004;350:2050–9.

2. Guillou PJ, Quirke P, Thorpe H, Walker J, Jayne DG, Smith AM, et al. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. Lancet. 2005;365:1718–26.

3. Fleshman J, Sargent DJ, Green E, Anvari M, Stryker SJ, Beart RW Jr, et al. Laparoscopic colectomy for cancer is not inferior to open surgery based on 5-year data from the COST Study Group trial. Ann Surg. 2007;246:655–62.

4. Colon Cancer Laparoscopic or Open Resection Study Group. Buunen M, Veldkamp R, Hop WC, Kuhry E, Jeekel J, et al. Survival after laparoscopic surgery versus open surgery for colon cancer: long-term outcome of a randomised clinical trial. Lancet Oncol. 2009;10:44–52.

5. Yamamoto S, Inomata M, Katayama H, Mizusawa J, Etoh T, Konishi F, et al. Short-term surgical outcomes from a randomized controlled trial to evaluate laparoscopic and open D3 dissection for stage II/III colon cancer: Japan Clinical Oncology Group Study JCOG 0404. Ann Surg. 2014;260:23–30.

6. Kitano S, Inomata M, Mizusawa J, Katayama H, Watanabe M, Yamamoto S, et al. Survival outcomes following laparoscopic versus open D3 dissection for stage II or III colon cancer (JCOG0404): a phase 3, randomised controlled trial. Lancet Gastroenterol Hepatol. 2017;2:261–8.

7. Matsubara N, Miyata H, Gotoh M, Tomita N, Baba H, Kimura W, et al. Mortality after common rectal surgery in Japan: a study on low anterior resection from a newly established nationwide large-scale clinical database. Dis Colon Rectum. 2014;57:1075–81.

8. Jeong SY, Park JW, Nam BH, Kim S, Kang SB, Lim SB, et al. Open versus laparoscopic surgery for mid-rectal or low-rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): survival outcomes of an open-label, non-inferiority, randomised controlled trial. Lancet Oncol. 2014;15:767–74.

9. Bonjer HJ, Deijen CL, Abis GA, Cuesta MA, van der Pas MH, de Lange-de Klerk ES, et al. A randomized trial of laparoscopic versus open surgery for rectal cancer. N Engl J Med. 2015;372:1324–32.

10. Stevenson AR, Solomon MJ, Lumley JW, Hewett P, Clouston AD, Gebski VJ, et al. Effect of laparoscopic-assisted resection vs open resection on pathological outcomes in rectal cancer: the ALaCaRT randomized clinical trial. JAMA. 2015;314:1356–63.

11. Fleshman J, Branda M, Sargent DJ, Boller AM, George V, Abbas M, et al. Effect of laparoscopic-assisted resection vs open resection of stage II or III rectal cancer on pathologic outcomes: the ACOSOG Z6051 randomized clinical trial. JAMA. 2015;314:1346–55.

12. Shimada T, Tsuruta M, Hasegawa H, Okabayashi K, Ishida T, Asada Y, et al. Pelvic inlet shape measured by three-dimensional pelvimetry is a predictor of the operative time in the anterior resection of rectal cancer. Surg Today. 2018;48:51–7.

13. Targarona EM, Balague C, Pernas JC, Martinez C, Berindoague R, Gich I, et al. Can we predict immediate outcome after laparoscopic rectal surgery? Multivariate analysis of clinical, anatomic, and pathologic features after 3-dimensional reconstruction of the pelvic anatomy. Ann Surg. 2008;247:642–9.

14. Hamabe A, Takemasa I, Uemura M, Nishimura J, Mizushima T, Ikeda M, et al. Feasibility of single-port laparoscopic surgery for sigmoid colon and rectal cancers and preoperative assessment of operative difficulty. J Gastrointest Surg. 2014;18:977–85.

15. Tsuruta A, Tashiro J, Ishii T, Oka Y, Suzuki A, Kondo H, et al. Prediction of anastomotic leakage after laparoscopic low anterior resection in male rectal cancer by pelvic measurement in magnetic resonance imaging. Surg Laparosc Endosc Percutan Tech. 2017;27:54–9.

16. Ogiso S, Yamaguchi T, Hata H, Fukuda M, Ikai I, Yamato T, et al. Evaluation of factors affecting the difficulty of laparoscopic anterior resection for rectal cancer: "narrow pelvis" is not a contraindication. Surg Endosc. 2011;25:1907–12.

17. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004;240:205–13.

18. van der Pas MHGM, Deijen CL, Abis GSA, de Lange-de Klerk ESM, Haglind E, Fürst A, et al. Conversions in laparoscopic surgery for rectal cancer. Surg Endosc. 2017;31:2263–70.

19. Qin Q, Ma T, Deng Y, Zheng J, Zhou Z, Wang H, et al. Impact of preoperative radiotherapy on anastomotic leakage and stenosis after rectal cancer resection: post hoc analysis of a randomized controlled trial. Dis Colon Rectum. 2016;59:934–42.

20. Shiomi A, Ito M, Maeda K, Kinugasa Y, Ota M, Yamaue H, et al. Effects of a diverting stoma on symptomatic anastomotic leakage after low anterior resection for rectal cancer: a propensity score matching analysis of 1,014 consecutive patients. J Am Coll Surg. 2015;220:186–94.

21. Kimura T, Mori T, Konishi F, Kitajima M. Endoscopic surgical skill qualification system in Japan: five years of experience in the gastrointestinal field. Asian J Endosc Surg. 2010;3:66–70.

22. Yamakawa T, Kimura T, Matsuda T, Konishi F, Bandai Y. Endoscopic Surgical Skill Qualification System (ESSQS) of the Japanese Society of Endoscopic Surgery (JSES). BH Surg. 2013;3:6–8.

23. Mori T, Kimura T, Kitajima M. Skill accreditation system for laparoscopic gastroenterologic surgeons in Japan. Minim Invasive Ther Allied Technol. 2010;19:18–24.

24. Ichikawa N, Homma S, Funakoshi T, Ohshima T, Hirose K, Yamada K, et al. Impact of technically qualified surgeons on laparoscopic colorectal resection outcomes: results of a propensity score-matching analysis. BJS Open. 2020;4:486–98.

25. Sylla P, Rattner DW, Delgado S, Lacy AM. NOTES transanal rectal cancer resection using transanal endoscopic microsurgery and laparoscopic assistance. Surg Endosc. 2010;24:1205–10.

26. Baik SH, Ko YT, Kang CM, Lee WJ, Kim NK, Sohn SK, et al. Robotic tumor-specific mesorectal excision of rectal cancer: short-term outcome of a pilot randomized trial. Surg Endosc. 2008;22:1601–8.
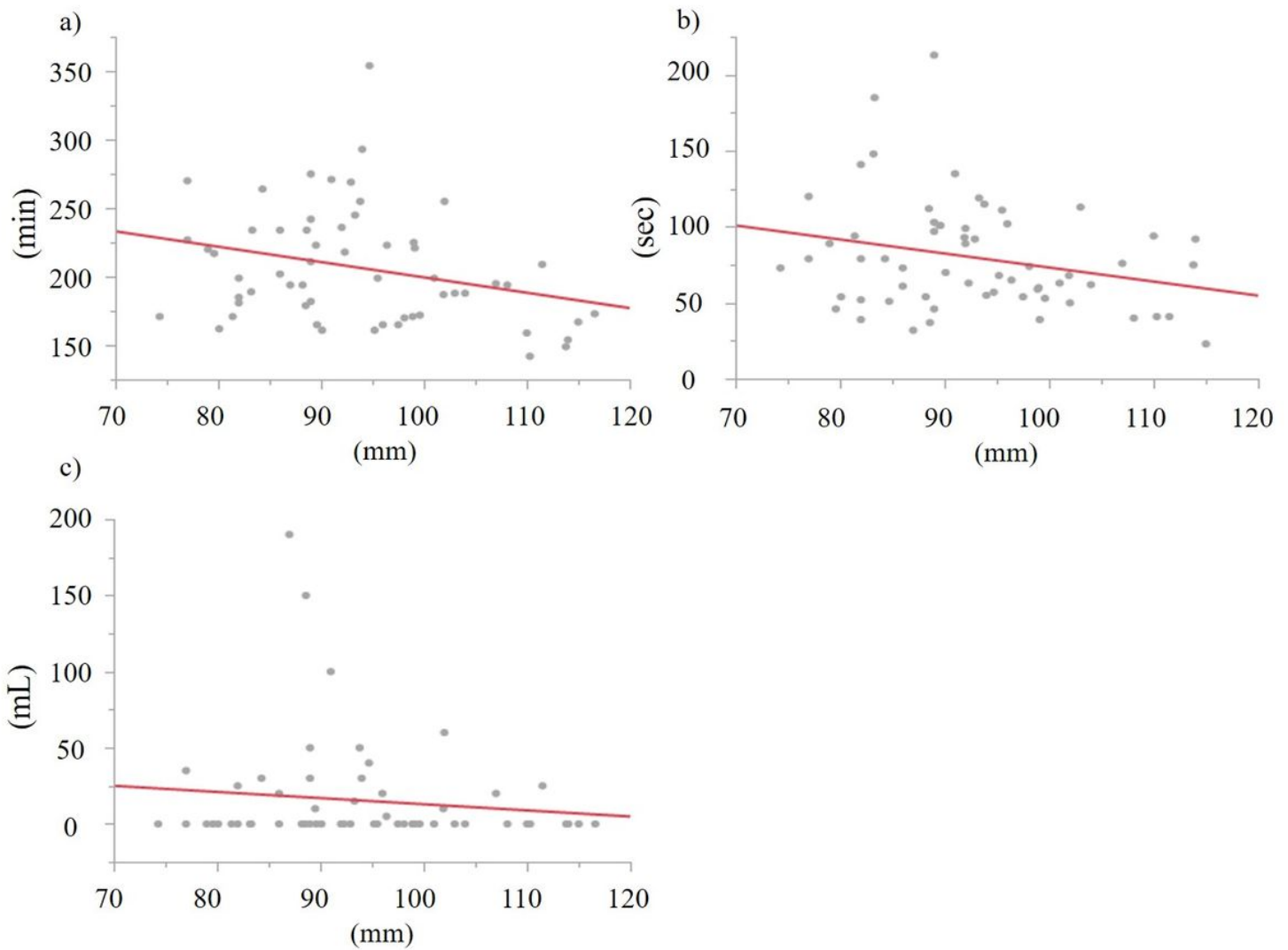
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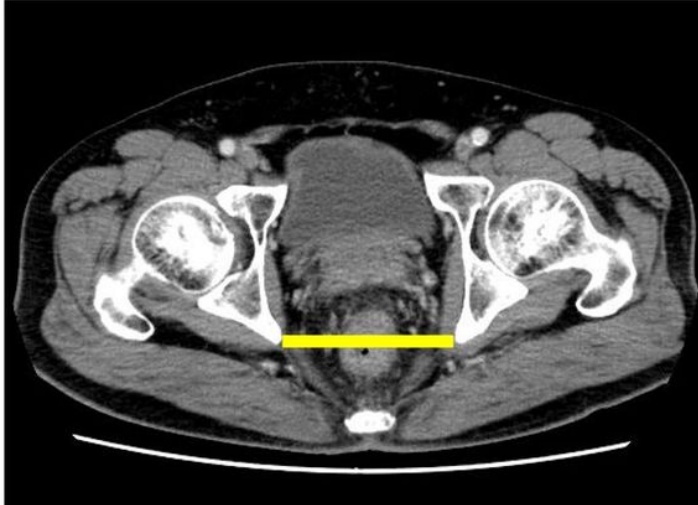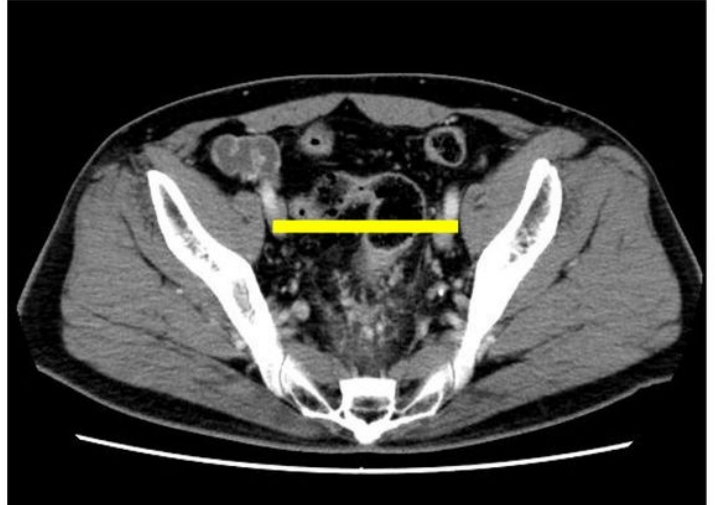
Figure 1

The definitions of the distance between the ischial spines (IS distance) and the distance between the iliopsoas muscles (IM distance) (a) The IS distance was defined as the distance between both sides of the ischial spines. (b) The IM distance was defined as the distance between both sides of the iliopsoas muscle at the level of the pelvic inlet.

Figure 2

Association between the inter-ischial spine (IS) distance and the surgical outcomes Association between inter-ischial spine distance and (a) operative time (R^2 = 0.08, P = 0.030); (b) time from the insertion of linear staplers to the completion of clamping on the distal end of the rectum (R^2 = 0.07, P = 0.046); and (c) blood loss (R^2 = 0.01, P = 0.36), as assessed by simple linear regression.