Prediction of Anastomotic Leakage After Laparoscopic Low Anterior Resection in Male Rectal Cancer by Pelvic Measurement in Magnetic Resonance Imaging

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Objective: Anastomotic leakage after laparoscopic low anterior resection in male rectal cancer patients with a narrow pelvis cannot be easily resolved. The objective of this study is to assess numerical information of narrow pelvis and to determine whether prediction of morbidity can be possible.

Methods: Retrospective medical record review was performed. From July 2007 to January 2013, 43 consecutive male patients with low rectal cancer who underwent laparoscopic low anterior resection were divided into the anastomotic leakage–negative group and anastomotic leakage–positive group. Eleven anatomic parameters were measured from preoperative magnetic resonance imaging of pelvis and a new index called "pelvic index" was calculated.

Results: The pelvic index (difference between the interspinous distance and the diameter of the mesorectum divided by the depth of the cavity of the lesser pelvis) in the leakage-positive group was significantly smaller than that in the negative group ($P = 0.038$). Comparison between those 2 groups at the border of the cut-off value of the pelvic index (13.0) showed a significant difference.

Conclusions: Preoperative assessment by the pelvic index can predict the narrow pelvis and risk of anastomotic leakage.

Key Words: rectal cancer, anastomotic leakage, narrow pelvis

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Laparoscopic colectomy has some advantages for the postoperative course, such as postoperative hospital stay and frequency of use of painkillers. Some prospective, randomized, controlled trials have reached the conclusion that the long-term and disease-free survival of patients who undergo laparoscopically assisted colectomy is similar to that for patients who have conventional open surgery.[1–3] However, some difficulties for laparoscopic surgical management of rectal cancer still remain. Laparoscopic rectal surgery is more technically difficult than laparoscopic colon surgery.[3–5] Because surgical performance is limited in the pelvic cavity, laparoscopic low anterior resection sometimes becomes a difficult procedure. In contrast, routine excision of the intact mesorectum during resection of cancers of the middle and lower rectum has resulted in the lowest reported incidence of local recurrence.[6]

Heald and colleagues established total mesorectal excision (TME) for rectal cancer. Currently, this technique is used worldwide as the gold standard for rectal cancer surgery.[7] TME is a standard procedure, which avoids injury of the fascia propria of the rectum and resects at the exact line, which should exist in the space between the appropriate layers. However, some gastrointestinal surgeons have debated over how to overcome the difficulties of low anterior resection of rectal cancer.[8] Anastomotic leakage is the most important postoperative issue that all surgeons should resolve. The anastomotic leakage rate was reported 2.5% and multivariate analysis identified male (hazard ratio, 3.03), old age (hazard ratio, 2.42), and lower anastomosis level (hazard ratio, 2.68) as risk factors for leakage.[9] Generally, the male pelvic structure has a tendency to be narrower than the female pelvic structure. In particular, laparoscopic low anterior resection is limited in the available working space depending on the situation of the male patient's pelvic cavity. Therefore, comprehension of the status of the pelvic cavity preoperatively would result in a safer operation. Especially in the case of rectal cancer operation, the precise status of the patient's pelvic cavity is determined by the bony anatomy and the tumor volume or the amount of visceral fat. Several studies to evaluate the impact of anatomic structure of pelvis in laparoscopic rectal surgical procedure have been performed. Targarona et al[10] showed that some independent predictors such as sex, body mass index, lower pelvis diameter, and tumor size affected conversion, operating time, and morbidity. In contrast, Ogiso et al[11] demonstrated that the difficulty of performing laparoscopic anterior resection for rectal cancer was not related to patients' pelvic dimensions. In this study, we focused on the male-specific risk factor of postoperative anastomotic leakage of laparoscopic low anterior resection in rectal cancer in reference to the article published by Targarona et al.[10] This study aimed to evaluate the degree of the effect of pelvic anatomic factors, including the amount of fat and tumor factors, on postoperative anastomotic leakage, and convert this degree into numerals as the pelvic index.

MATERIALS AND METHODS

We studied 43 consecutive male patients who underwent laparoscopic low anterior resection with double-stapling technique anastomosis for rectal cancer. Table 1 shows a summary of the male patients' characteristics, focusing on the presence of anastomotic leakage. This study

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TABLE 1. Patients Characteristics

	Anastomotic Leakage		
	− (n = 34)	+ (n = 9)	*P*
Age	65.7	65.1	0.9048
BMI	23.6	22.9	0.5017
ASA-PS (n)			
1	23	5	0.1924
2	11	3	
3	0	1	
Underlying disease (n)			
0	14	2	0.7434
1	10	4	
2	7	2	
3	2	1	
4	1	0	
Carcinoembryonic antigen (ng/mL)	4.9 ± 5.2	15.2 ± 17.7	0.0214
Operative time (min)	271.6 ± 77.7	307.0 ± 86.6	0.2209
Blood loss (mL)	38.9 ± 51.6	42.8 ± 70.1	0.6267
Tumor site			
Ra	9	2	0.797
Rb	25	7	
T (n)			
Tis	1	0	0.5157
1	8	2	
2	10	1	
3	15	6	
N (n)			
0	24	3	0.0453
1	7	2	
2	3	4	
Size of tumor (cm)	4.2 ± 2.1	5.2 ± 2.6	0.2074
Stage (n)			
0	1	0	0.3792
1	12	2	
2	10	1	
3a	7	2	
3b	3	3	
4	1	1	

T: the primary tumor site.
N: the regional lymph node involvement.
ASA-PS indicates American Society of Anesthesiologists Physical Status; BMI, body mass index.

was conducted between July 2007 and January 2013 at the Saitama Medical University International Medical Center. Cases of direct invasion into adjacent organs and distant metastasis, such as in the liver and lungs, were excluded. Moreover, none of the patients had received neoadjuvant chemoradiotherapy. The institutional review boards of the Saitama Medical University International Medical Center and Kawasaki Medical School approved the study protocol.

Surgical Method

In Japan, resectable advanced node-positive rectal cancer surgery with lateral lymph nodes dissection rather than preoperative chemoradiotherapy has been commonly performed. Therefore, many digestive surgeons have suggested some advantages of lateral pelvic lymph nodes dissection in advanced rectal cancer with lateral nodal positive in Japan. At the Saitama Medical University International Medical Center, all patients of rectal cancer underwent laparoscopic surgery with TME in earlier days. The actual procedure of laparoscopic low anterior resection was performed as follows. Five ports were inserted and pneumoperitoneum was maintained at an insufflation pressure of 10 mm Hg. The lithotomy-Trendelenburg and right-side-down position was applied. Greater omentum was flipped over the surface of the liver and the transverse colon was placed in the upper abdomen. Small bowel loop was shifted to the right upper quadrant of the abdominal cavity. Mobilization of the sigmoid colon was performed with the medial-to-lateral approach. Division of the main feeder vessel was performed at the origin of the inferior mesenteric artery or at the trunk of the inferior mesenteric artery, while preserving the left colic artery, depending on the case. TME or tumor-specific mesorectal excision was then performed and the rectum was transected intracorporeally by a linear cutting stapler. A vertical incision measuring 4 cm in length was made at the umbilical port site and the proximal side of the resected colon was pulled out. A sufficient safety margin from the tumor was secured extracorporeally and the operative specimen was extracted. Subsequent to reintroduction of the pneumoperitoneum, side-to-end colorectal anastomosis was performed with a circular stapler as the double-stapling technique. A diverting ileostomy was created depending on the case. All operations were performed by 1 expert surgeon (S.Y.), who was the qualified surgeon of endoscopic surgical skill qualification system certified by skill qualification committee in Japanese Society for Endoscopic Surgery.

Measurement of the Pelvis

A pelvic magnetic resonance imaging (MRI) examination was performed in all of the patients because of the clinical routine for rectal surgery. In obstetrics, MRI pelvimetric assessment is well-known modality to check for fetal-pelvic disproportion.[12] However, there should be some points of difference of focusing on between safety of delivery and operability of rectal surgery. To set objective criteria for evaluation of the pelvic cavity with rectal cancer, 11 parameters were measured from preoperative pelvic MRI. Measurements were performed 3 times per 1 parameter using electronic caliper of a workstation by 2 digestive surgeons (A.T., Y.O.) to obtain an interobserver comparison. A new index was calculated from several of these parameters. Measurements of the patients' pelvic parameters were performed by a single measurer, who was blinded to the patients' information. The 11 parameters were as follows: a = inlet of the cavity of the lesser pelvis, b = depth of the cavity of the lesser pelvis, c = diameter of the mesorectum at the level of the seminal vesicle, d = thickness of the mesorectum, e = transverse diameter of the lower rectum, f = longitudinal diameter of the lower rectum, g = pelvic inlet, h = pelvic outlet, i = length of the sacrum, j = interspinous distance, and k = intertuberous distance (Fig. 1).

Evaluation of Pelvic Parameters

Sagittal MRI provided information of parameters a, b, and d. Parameter "a" was the length between the inferior margin of the fourth sacral vertebra and the bottom edge of the seminal vesicle, which were the anatomic landmark of sagittal MRI. Parameter "b" was the length between the middle point of the line "a" and the anal verge. Parameter "d" was the maximum distance between the surface of the sacrum and the posterior wall of the lower rectum. Axial MRI at the level that the seminal vesicles were rendered to a maximum showed parameters "c," "e," and "f." Parameter

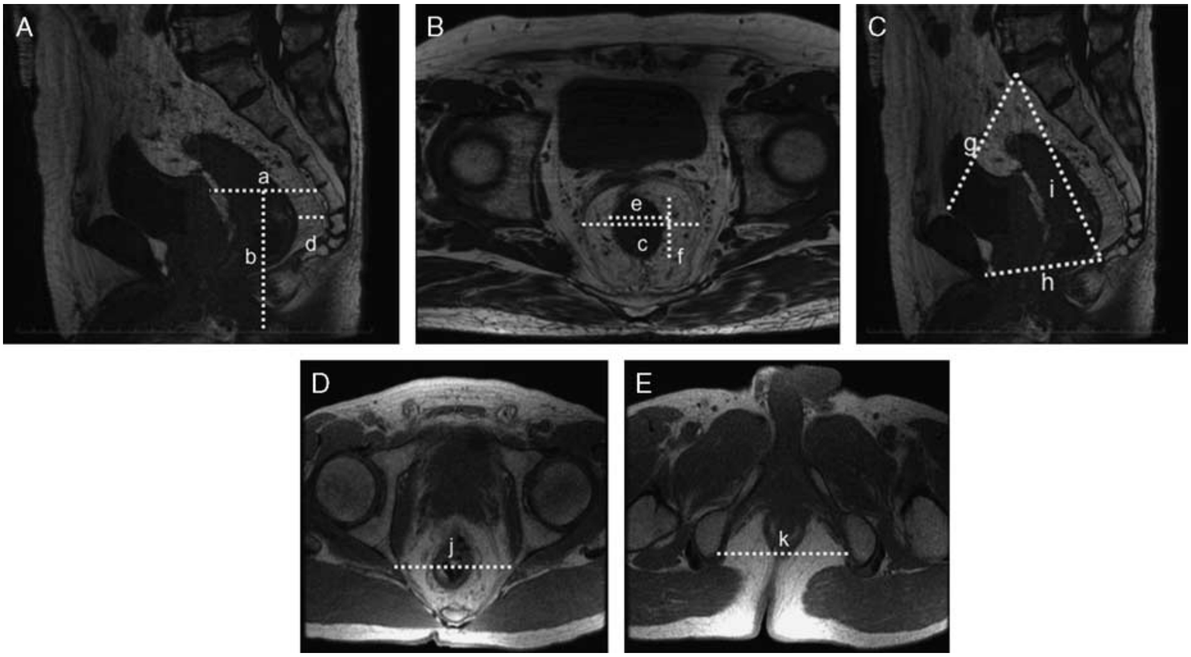

FIGURE 1. (A) a: inlet of cavity of lesser pelvis; the length between the inferior margin of fourth sacral vertebra and bottom edge of seminal vesicle. b: depth of cavity of lesser pelvis; length between the middle point of line "a." d: thickness of mesorectum; the distance between surface of the sacrum and posterior wall of lower rectum. (B) c: diameter of mesorectum; transverse diameter of the mesorectum and the lower rectum at the level of seminal vesicle. e: transverse diameter of lower rectum at the level of seminal vesicle. f: longitudinal diameter of lower rectum at the level of seminal vesicle. (C) g: pelvic inlet; the length from the superior aspect of the pubic symphysis to the sacral promontory. h: pelvic outlet; the length from the inferior aspect of the pubic symphysis to the coccyx. i: length of sacrum; the distance from the sacral promontory to the coccyx. (D) j: interspinous distance; the narrowest distance between the ischial spines. (E) k: intertuberous distance; the distance between the lowest aspect of the ischial tuberosities.

"c" was diameter of the mesorectum at the level of the seminal vesicle and "e" was transverse diameter of the lower rectum. Parameter "f" was the longitudinal diameter of the lower rectum at the level of the seminal vesicle. Parameters from "g" to "k" were also applied as the pelvimetric parameters in obstetrics.[10] Parameter "g" was the length from the superior aspect of the pubic symphysis to the sacral promontory. Parameter "h" was the length from the inferior aspect of the pubic symphysis to the coccyx. Parameter "i" was the distance from the sacral promontory to the coccyx. Parameter "j" was the narrowest distance between the ischial spines, and parameter "k" was the distance between the lowest aspect of the ischial tuberosities (Fig. 1).[13] Mobility of rectum in the cavity of the lesser pelvis during the operation could be limited by some factors. In particular, mobility in the horizontal plane can be related to the space that is determined by the pelvic structure and the thickness of the mesorectum. We considered that this space could represent the distance between parameters "j" and "c" (ie, "j − c").

Evaluation of Postoperative Anastomotic Leakage

Anastomotic leakage was diagnosed at the discretion of the providing surgeon by clinical or radiologic means. Clinical symptoms included abdominal pain, abdominal distension, muscle defense, and fever. Biochemical tests showed leukocytosis and elevated C-reactive protein. Radiologic examination such as abdominopelvic computed tomography was carried out to detect abnormal ascites or air bubbles near the anastomosis. As a result, patients were divided into the postoperative anastomotic leakage–negative group and the anastomotic leakage–positive group.

Statistical Analysis

All statistical analyses were performed using JMP version 11 (SAS, Cary, NC). Statistical significance was defined as $P < 0.05$. We used Fisher exact test, χ^2 test, and Student t test. A receiver operating characteristic curve was used to determine the optimal cut-off value for a new index for prediction of postoperative morbidity and this was entered into the multivariate model.

RESULTS

No anastomotic leakage occurred in female patients (n = 31) in the same period. Therefore, the overall rate of anastomotic leakage in lower rectal cancer surgery was 12.1% (9/74). The following results are limited to male patients. The mean age was approximately 65 years in both groups. There were no significant differences between the anastomotic leakage–negative and anastomotic leakage–positive groups regarding body mass index, American Society of Anesthesiology Physical Status, and the number of comorbidities. Mean serum carcinoembryonic antigen (CEA) levels in the anastomotic leakage–negative group were significantly lower than those in the anastomotic leakage–positive group ($P = 0.021$). There were no significant differences in operating time and blood loss between the groups (Table 1).

Tumor characteristics included tumor staging in accordance with the Japanese Classification of Colorectal

TABLE 2. Measurements of the 11 Pelvic Parameters

Index (mm)	Anastomotic Leakage –	Anastomotic Leakage +	*P*
a. Inlet of cavity of lesser pelvis	60.3 ± 12.4	61.6 ± 9.2	0.3862
d. Thickness of mesorectum	15.2 ± 6.3	16.2 ± 6.2	0.3257
e. Transverse diameter of lower rectum	33.1 ± 7.4	37.6 ± 8.4	0.0857
f. Longitudinal diameter of lower rectum	35.6 ± 8.1	40.0 ± 7.4	0.0708
g. Pelvic inlet	105.7 ± 12.7	105.1 ± 5.7	0.4163
h. Pelvic outlet	84.9 ± 9.3	91.4 ± 12.4	0.0867
i. Length of sacrum	127.9 ± 13.1	125.9 ± 11.1	0.3249
k. Intertuberous distance	85.7 ± 9.7	86.0 ± 8.2	0.4685
b. Depth of cavity of lesser pelvis	83.4 ± 9.8	86.7 ± 8.6	0.3394
c. Diameter of mesorectum	70.7 ± 9.1	78.0 ± 9.2	0.0488
j. Interspinous distance	90.3 ± 7.5	91.0 ± 8.5	0.4208
j – c	19.6 ± 9.7	12.9 ± 7.5	0.0488
100 (j – c)/b (PI: pelvic index)	23.8 ± 11.4	15.4 ± 9.6	0.038

Carcinoma and the size of the tumor. We found that the rate of node-negative cases in the anastomotic leakage–negative group was higher than that in the anastomotic leakage–positive group ($P = 0.045$, Table 1).

When comparing pelvic parameters from "a" to "k," only parameter "c" showed a significant difference between the groups. We consider that the larger the "j – c" value is, the easier manipulation during the operation is. Moreover, difficulty in operability is thought to increase in proportion to the depth of the pelvic cavity, which could be represented as parameter "b." Therefore, we considered that the new index, which was calculated from these parameters [$100 \times (j - c)/b$], could reflect flexible operability during laparoscopic surgery. We examined whether this new index, calculated from parameters "j," "c," and "b," is useful as a predictor for morbidity. Parameter "c" in the anastomotic leakage–negative group was lower than that in the anastomotic leakage–positive group ($P = 0.049$, Table 2). Parameter "j – c" in the anastomotic leakage–negative group was significantly lower than that in the anastomotic leakage–positive group ($P = 0.049$, Table 2). Consequently, the new index, [ie, $100 \times (j - c)/b$] in the anastomotic leakage–negative group was significantly higher than that in anastomotic leakage–positive group ($P = 0.038$, Table 2).

We attempted to calculate the cut-off value from a receiver operating characteristic curve (Fig. 2). The cut-off value of the pelvic index was 13.0. The sensitivity was 0.6667 and 1 – specificity was 0.2059. In patients who had a pelvic index value < 13.0, the number of patients in the anastomotic leakage–negative group was 7 and that in the anastomotic leakage–positive group was 6. In patients who had a pelvic index ≥ 13.0, the number of patients in the anastomotic leakage–negative group was 27 and that in the anastomotic leakage–positive group was only 3. Consequently, if a pelvic index was ≥ 13.0, there was a high possibility that anastomosis would not leak ($P = 0.007$, Table 3). Positive predictive value was 0.46 (6/(6 + 7)) and negative predictive value was 0.90 (27/(3 + 27)).

DISCUSSION

The space of the pelvic cavity is occupied by different organs depending on sex, and a spatial allowance does not exist in this cavity. For this property of a small pelvic cavity, the operability of rectal surgery is limited, especially in laparoscopic surgery. The deepest portion of a small pelvic cavity is the space between peritoneal reflection and levator ani muscles. Anatomic characteristics of this space, which consists of digestive and urogenital organs and visceral fat tissue, can affect the degree of difficulty of laparoscopic manipulation. Moreover, the capacity of the space widely differs according to sex. The female pelvis is generally bigger than the male pelvis. In cohort study of rectal cancer patients using MRI pelvimetry, there was a highly significant difference between the interspinous and intertuberous transverse diameter of the pelvis of the females and males.[14] In the field of obstetrics, measurement of the dimension of the bony birth canal of the female pelvis is made by some representative markers, such as obstetric

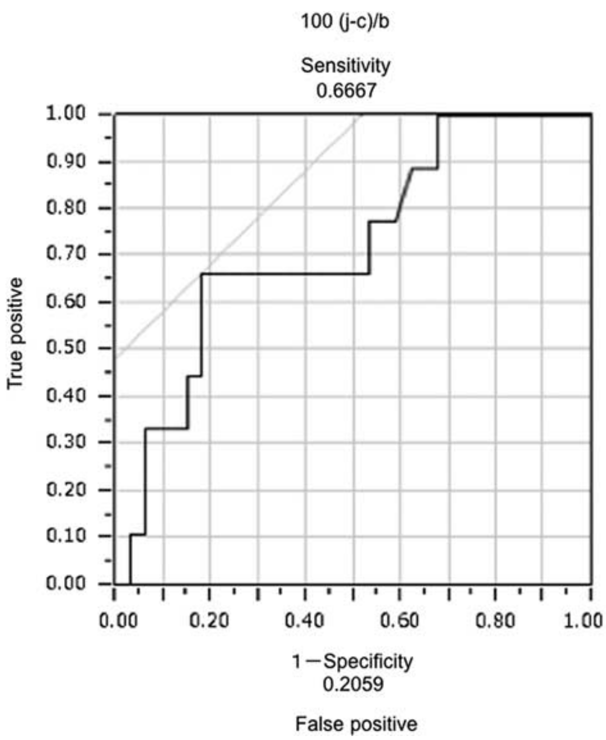

FIGURE 2. The pelvic index as predicting factor assessed by receiver operating characteristic (ROC) curve.

TABLE 3. Evaluation of the Cut-off Value of Pelvic Index

	100 (j – c)/b (PI: Pelvic Index)			
Anastomotic Leakage	**< 13**	**≥ 13**	**n**	***P***
−	7	27	34	0.007
+	6	3	9	
n	13	30	43	

conjugate, which is the distance from the sacral promontory to the middle point of the pubic symphysis, the external conjugate, which is the distance between the spinous process of the fifth lumbar vertebra and the upper edge of the pubic symphysis, or the interspinous distance between the anterior superior iliac spines.[12,15] However, these markers are only measured based on imaging studies of the patient's skeletal structure. Some previous studies have focused on pelvic anatomy regarding the difficulty of laparoscopic rectal surgery[13,16] or the pathologic quality of resected specimens of rectal cancer.[17] Although previous studies were highly suggestive of the difficulty of rectal surgery, we approached the problem from a different angle. Namely, the obstetric view of pelvic anatomy, as described above, might have been insufficient for application to rectal surgery. In particular, in the male pelvis, which is generally smaller than the female pelvis, the amount of visceral fat tissue in the mesorectum is not negligible when taking into account a pelvic surgical procedure. In several previous studies of rectal cancer patients, preoperative MRI was investigated to find whether it had the validity for prediction of circumferential resection margin positivity.[18,19] Recently MRI pelvimetry was advocated as a new tool for use in preoperative decision making of TME.[20] Besides, usability of MRI-based pelvimetry in robotic surgery also was shown in both TME for rectal cancer and prostatectomy.[21,22] Some advantages by high resolution of pelvic MRI have been recognized.[23] Moreover, the impact of visceral fat amount on technical difficulty of laparoscopic surgery was reported.[24] Therefore, we established new parameters that are related to pelvic structure, which focused on the amount of visceral fat. We studied male rectal cancer cases because the operative procedure in male rectal surgery is generally more difficult than in females. In particular, the diameter of the mesorectum at the level of the seminal vesicle and the thickness of the mesorectum should be considered. In the current study, the thickness of the mesorectum did not show a significant difference in the rate of incidence of anastomotic leakage. However, the diameter of the mesorectum at the level of the seminal vesicle showed a significant difference. The diameter of the mesorectum at the level of the seminal vesicle consists of the thickness of the mesorectum and the diameter of the rectum. An important issue is how mobility in the horizontal direction would be obtained under peritoneal reflection in laparoscopic rectal surgery. The gap between the interspinous distance and the diameter of the mesorectum at the level of the seminal vesicle indicates this mobility. This gap in the anastomotic leakage–positive group was significantly smaller than that in the anastomotic leakage–negative group.

Generally, a narrow pelvis should be interpreted as a pelvis with a small volume. However, difficulty in surgical maneuvers in the pelvic cavity is not necessarily affected by volume. This difficulty should be affected by the depth of the lesser pelvis. In the current study, the depth (parameter "b") of the lesser pelvis did not show a significant difference between the groups, but the mean value of leakage in the anastomotic leakage–negative group tended to be smaller than that of the anastomotic leakage–positive group. Accordingly, we attempted to establish a new index, which could estimate the difficulty of the operative procedure in the pelvic cavity.

We considered that the bigger the gap between the interspinous distance and the diameter of mesorectum at the level of seminal vesicle (ie, "j – c"), and the smaller the depth of the lesser pelvis (b), the easier the surgical procedure in the pelvic cavity should be. Therefore, the pelvic index $[100 \times (j - c)/b]$ was created as a new indicator that would express how easy the operation would be. The pelvic index in the anastomotic leakage–positive group was significantly smaller than that in the anastomotic leakage–negative group.

The cut-off value of the pelvic index, which was calculated from a receiver operating characteristic curve, was 13.0 (Fig. 2). The sensitivity was 0.6667 and 1 – specificity was 0.2059. Consequently, comparison between the anastomotic leakage–negative and anastomotic leakage–positive groups at the border of the cut-off value showed a significant difference. The rate of anastomotic leakage was 10.0% (3/30) in the pelvic index ≥ 13.0, whereas the rate was 46.2% (6/13) in the index < 13.0 ($P = 0.007$, Table 3). Negative predictive value was 0.90 (27/30), which was so high. Therefore we consider that when a pelvic index calculated from preoperative imaging studies is 13.0, the anastomosis would not leak postoperatively.

Mean serum CEA levels in the anastomotic leakage–negative group were significantly lower than those in the anastomotic leakage–positive group ($P = 0.0214$). Moreover, there were significant differences in dispersion of lymph node metastasis factors (N factors) between the leakage-negative group and leakage-positive group ($P = 0.0453$). The degree of N factors that were positive in the leakage-positive group was higher than that in the leakage-negative group. Whether CEA or N factor has an independent effect on the risk of anastomotic leakage is unknown and merits further investigation. Therefore, in this study, we just paid attention to relation between pelvic structure and postoperative anastomotic leakage through evaluation of narrow pelvis. Consequently, this study suggests that the pelvic index could provide both the numerical information to identify narrow pelvis and the prediction of postoperative anastomotic leakage.

This study has limitations inherent to a retrospective medical record review obtained at a single institution. The limitations include that none of the patients had received neoadjuvant chemoradiotherapy and that there was no interobserver variability of measurements. Moreover, the patients in this study were consulted at a tertiary referral hospital. Therefore, our findings in rectal surgery may not be able to be generalized. In the future, more cases need to be studied. Further prospective studies using the pelvic index will hopefully elucidate the appropriate marker for prediction of postoperative morbidity in rectal cancer.

CONCLUSIONS

The pelvic index proposed in this study would give 1 important preoperative information in laparoscopic rectal surgery in males whether the pelvis is narrow or not. A pelvic index ≥ 13.0 indicates that the risk of postoperative anastomotic leakage is low. Consequently, preoperative measurements with pelvic MRI and calculation of the pelvic index could lead to prediction of a narrow pelvis and risk of anastomotic leakage.

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