residue remained after filtering with the 1000-μm filter, hindering the handling of the stool suspension thereafter. We therefore decided to use the 512-μm filter (Figure 2*D*). The dose of the magnetic beads applied was also examined. The cell retrieval rate increased in a dose-dependent manner up to 80 μL. In reality, a sufficient amount of genomic DNA derived from exfoliated colonocytes was obtained, even when 40 μL of magnetic beads were used (Figure 2*E*). Regarding the optimal incubation time of the magnetic beads for the complete binding of HT-29 cells to the beads, 30 minutes of incubation was found to be sufficient for the satisfactory binding of HT-29 cells to the beads (Figure 2*F*). For the retrieval of the cell-magnetic bead complexes on the magnet, a 10-minute reaction period was sufficient (Figure 2*G*).

The cell retrieval rates were 0.8% and 33.5% using the Percoll centrifugation method and the magnetic beads method, respectively, thus underscoring the advantage of the magnetic beads method (Figure 2*H*).

Cytology

Atypical cells were observed in colonocytes isolated from the feces of 32 of 116 patients with colorectal cancer, with a sensitivity rate of 28% (95% CI: 20–37; Table 2, Figure 3*A* and 3*B*). No atypical cells were observed in any of the 83 healthy volunteers, with a specificity rate of 100% (95% CI: 96–100). A significant difference ($P < .0001$) was found in the positivity rate between the patient group and the healthy volunteer group. The sensitivity rates for Dukes' A, B, and C or D colorectal cancers were 23% (7 of 30; 95% CI: 10–42), 32% (10 of 31; 95% CI: 17–51), and 27% (15 of 55; 95% CI: 16–41), respectively. No significant differences in the positivity rates were found among any of the stages. Furthermore, the sensitivity rates for cancers on the right side of the colon, including the cecum, ascending colon, and transverse colon, and for those on the left side of the colon, including the descending colon, sigmoid colon, and rectum, were 9% (3 of 35; 95% CI: 2–23) and 36% (29 of 81; 95% CI: 25–47), respectively. Therefore, the positivity rate was significantly higher for cancers on the left side of the colon ($P < .01$).

DNA Analysis

Overall analysis of stool samples. Sequence analysis showed distinct mutations in each of the analyzed genes in the tumor tissue and colonocytes isolated from feces (Figure 3*C–F*). Genetic alterations were observed in the colonocytes isolated from the feces of 82 of the 116 patients with colorectal cancer, yielding a sensitivity rate of 71% (95% CI: 62–79; Table 2). However, 10 of the 83 healthy volunteers were also positive for genetic alterations, producing a specificity value of 88% (95% CI: 79–94). A significant difference ($P < .0001$) was noted in the positivity rates of the patient group and the healthy volunteer group.

Genetic alterations were observed in 18 of the 30 patients with Dukes' A colorectal cancer, yielding a sensitivity rate of 60% (95% CI: 41–77). Furthermore, genetic alterations were observed among 26 of the 31 patients with Dukes' B colorectal cancer (84%; 95% CI: 66–95) and 38 of the 55 patients with Dukes' C or D colorectal cancer (69%; 95% CI: 55–81). No significant difference in sensitivity was found among any of the stages.

Genetic alterations were observed in colonocytes isolated from feces in 20 out of 35 patients with cancers originating on the right side of the colon (57%; 95% CI: 39–74) and in 62 out of 81 patients with cancers originating on the left side of the colon (77%; 95% CI: 66–85). No significant differences in the sensitivity rates were observed, although the sensitivity rate tended to be higher for cancers on the left side of the colon.

DNA analysis limited to colonocytes isolated from the feces of patients with colorectal cancer tissue involving genetic alterations. We assessed the performance of the present methodology for isolating cancer cells by examining the positivity rate of genetic alterations in colonocytes isolated from the feces of patients who showed alterations in their cancer tissues (Table 3). Among the 116 patients, a total of 93 (80%; 95% CI: 72–87) exhibited genetic alterations in the APC, K-*ras*, or p53 genes or BAT26 positivity in their cancer tissue: 51 patients exhibited APC mutations (44%, 95% CI: 35–53), 33 patients exhibited K-*ras* mutations (28%; 95% CI: 20–38), 62 patients exhibited p53 mutations (53%; 95% CI: 44–63), and 6 patients exhibited BAT26 positivity (5%; 95% CI: 2–11). Among the 93 patients with genetic alterations in their cancer tissues, the alterations were also successfully detected in colonocytes isolated from the feces of 80 patients (86%; 95% CI: 77–92). Among the 39 patients with Dukes' C or D advanced cancer who exhibited a genetic alteration in their cancer tissues, 36 patients exhibited genetic alterations in colonocytes isolated from their feces (92%; 95% CI: 79–98). Furthermore, genetic alterations were detected in colonocytes isolated from the feces of 18 of 24 patients with Dukes' A cancer (75%; 95% CI: 53–90) and 26 of 30 patients with Dukes' B cancer (87%; 95% CI: 69–96). No statistically significant difference was found among these 3 groups. In addition, genetic alterations could be detected in colonocytes isolated from the feces of 20 of 27 patients with cancers originating on the

Table 2. Incidences of Genetic Alterations of the APC, K-*ras*, p53, and MSI (BAT26) Genes as Well as Results From Cytology in all Patients and Healthy Volunteers

		Patient				Healthy volunteer	
		Tumor tissue		Isolated cell		Isolated cell	
	Marker	No.	Positivity (%) (95% CI)	No.	Sensitivity (%) (95% CI)	No.	Specificity (%) (95% CI)
Overall Patients (n = 116), healthy volunteers (n = 83)	Combined marker	93	80 (72–87)	82	71 (62–79)	10	88 (79–94)
	APC	51	44 (35–53)	47	41 (32–50)	1	99 (93–100)
	K-*ras*	33	28 (20–38)	33	28 (20–38)	1	99 (93–100)
	p53	62	53 (44–63)	45	39 (30–48)	6	93 (85–97)
	BAT26	6	5 (2–11)	4	3 (1–9)	3	96 (90–99)
	Cytology			32	28 (20–37)	0	100 (96–100)
Dukes' stage A (n = 30)	Combined marker	24	80 (61–92)	18	60 (41–77)		
	APC	14	47 (28–66)	11	37 (20–56)		
	K-*ras*	6	20 (77–39)	5	17 (6–35)		
	p53	6	20 (77–39)	9	30 (15–49)		
	BAT26	1	3 (1–17)	1	3 (1–17)		
	Cytology			7	23 (10–42)		
Dukes' stage B (n = 31)	Combined marker	30	97 (83–100)	26	84 (66–95)		
	APC	17	55 (36–73)	17	55 (36–73)		
	K-*ras*	10	32 (17–51)	9	29 (14–48)		
	p53	18	58 (39–75)	13	42 (25–61)		
	BAT26	2	6 (1–21)	1	3 (1–17)		
	Cytology			10	32 (17–51)		
Dukes' stages C and D (n = 55)	Combined marker	39	71 (57–82)	38	69 (55–81)		
	APC	20	36 (24–50)	19	35 (22–49)		
	K-*ras*	17	31 (19–45)	19	35 (22–49)		
	p53	27	49 (35–63)	23	42 (29–56)		
	BAT26	3	5 (1–15)	2	4 (0–13)		
	Cytology			15	27 (16–41)		
Right-sided colon cancer (n = 35)	Combined marker	27	77 (60–90)	20	57 (39–74)		
	APC	11	31 (17–49)	8	23 (10–40)		
	K-*ras*	16	46 (29–63)	12	34 (19–52)		
	p53	17	49 (31–66)	11	31 (17–49)		
	BAT26	2	6 (1–19)	1	3 (1–15)		
	Cytology			3	9 (2–23)		
Left-sided colon cancer (n = 81)	Combined marker	66	81 (71–89)	62	77 (66–85)		
	APC	40	49 (38–61)	39	48 (37–60)		
	K-*ras*	17	21 (13–31)	21	26 (17–37)		
	p53	45	56 (44–67)	34	42 (31–53)		
	BAT26	4	5 (1–12)	3	4 (1–10)		
	Cytology			29	36 (25–47)		

right side of their colon (74%; 95% CI: 54–89) and 60 of 66 patients with cancers originating on the left side of their colon (91%; 95% CI: 81–97). A statistically significant difference was found between the right- and left-side colon cancer patient groups ($P = .03$).

Discussion

We have devised a simple, highly reliable methodology for isolating colorectal cancer cells from nonlaxative-induced, naturally evacuated feces from most patients with colorectal cancer. To date, several methods of isolating colorectal cancer cells from feces have been reported.[21,22,26,27]

Our new funnel-shaped filter system extensively improved the filtration efficiency of the stool suspension by enlarging the filtration area and selecting the optimal pore size; the system was capable of filtrating the entire stool suspension without filter clogging. These properties permit the omission of centrifugation and simplify the overall process because all steps can be performed at room temperature. Furthermore, the use of serum successfully increased the cell retrieval rate. We presume that this increase may be attributed to the suppression of protease activity or the inhibition of nonspecific reactions of the antibodies on the bead surface. Consequently, our new methodology also allows the extraction of high-quality DNA or RNA from exfoliated colonocytes. Very recently, Imperiale et al compared a panel of fecal DNA markers and Hemoccult II as screening tests for colorectal cancer. It is worth noting that, in their study, colonoscopy as a reference standard was used

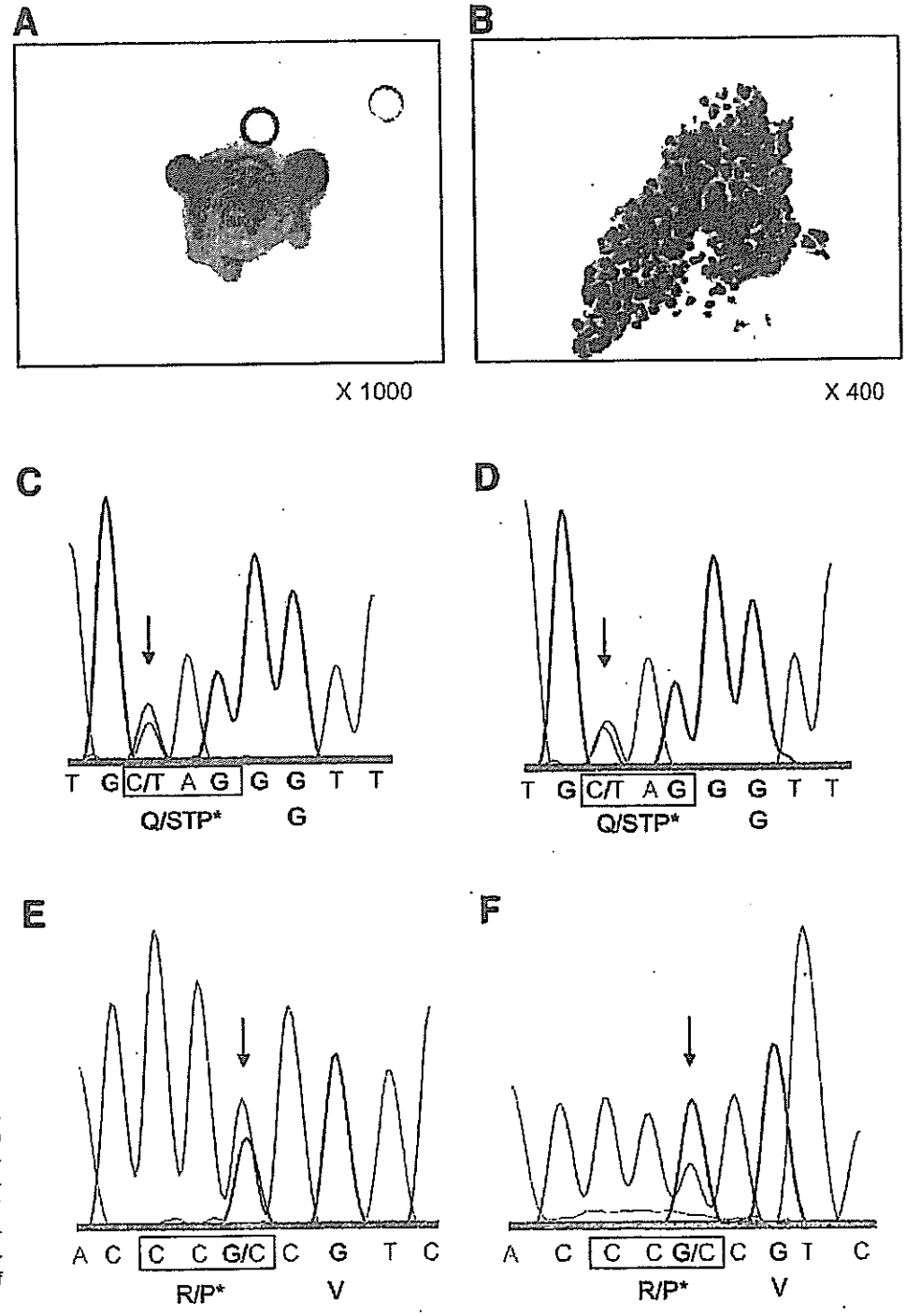

Figure 3. Cytology and DNA sequencing. Papanicolaou staining of colonocytes isolated from the feces of patients with colorectal cancer. (*A*) A patient with ascending colon cancer, Dukes' stage A. (*B*) A patient with rectal cancer, Dukes' stage C. Detection of mutations in tumor tissues and colonocytes isolated from the feces of patients with colorectal cancer. (*C*) A point mutation of the APC gene in a tumor tissue specimen obtained from a patient with rectal cancer, Dukes' stage B. (*D*) An identical mutation was detected in colonocytes isolated from the feces of the patient. (*E*) A point mutation of the p53 gene in a tumor tissue specimen obtained from a patient with ascending colon cancer, Dukes' stage A. (*F*) An identical mutation was detected in colonocytes isolated from the feces of the patient. *Wild/mutant.

in all subjects. They conducted those tests in a blinded fashion and showed that sensitivity of DNA analysis was 4-fold higher than that of Hemoccult test.[28] We believe that this report may prompt a study of fecal DNA test for colorectal cancer screening.

The idea to isolate cancer cells from feces originally derived from a study that described the abnormal expression of the CD44 gene in many tumors, including colon cancer and bladder cancer.[21,29,30] In the course of a series of studies, we predicted that normal mucous cells would die and be exfoliated during turnover and that the cancer cells would likely survive for a long time in the feces.

Although cytology is highly specific compared with direct sequence analysis, its sensitivity, especially for cancers on the right side of the colon is relatively low. From a technical aspect, our cytology method does not allow the

Table 3. Incidences of Genetic Alterations in Colonocytes Isolated From the Feces of Patients With Colorectal Cancer Tissue Involving Genetic Alterations of the APC, K-*ras*, p53, or MSI (BAT26) Gene

	Combined marker		APC		K-ras		p53		BAT 26	
	No.	% (95% CI)	No.	% (95% CI)	No.	% (95% CI)	No.	% (95% CI)	No.	% (95% CI)
Overall	80/93	86% (77–92)	46/51	90% (79–97)	29/33	88% (72–97)	42/62	68% (55–79)	4/6	67% (22–96)
Dukes' stage A	18/24	75% (53–90)	11/14	79% (49–95)	5/6	83% (36–100)	5/6	83% (36–100)	1/1	100% (3–100)
Dukes' stage B	26/30	87% (69–96)	16/17	94% (71–100)	9/10	90% (56–100)	12/18	67% (41–87)	1/2	50% (1–99)
Dukes' stages C and D	36/39	92% (79–98)	19/20	95% (75–100)	15/17	88% (64–99)	21/27	78% (58–91)	2/3	67% (9–99)
Right-sided	20/27	74% (54–89)	8/11	73% (39–94)	12/16	75% (48–93)	11/17	65% (38–86)	1/2	50% (1–99)
Left-sided	60/66	91% (81–97)	38/40	95% (83–99)	17/17	00% (81–100)	31/45	69% (53–82)	3/4	75% (19–99)

NOTE. Number of positive cases in tumor tissue and colonocytes isolated from feces/number of positive cases in tumor tissue, with 95% confidence interval.

observation of cells unless there are 5×10^4 cells per slide. Technical improvements might increase the benefits of feces cytology. However, we believe that cytology is not suitable as a method for identifying cancer because of its low sensitivity, at least at present. From a practical point of view, we have conducted a study to determine the effect of the time and temperature after evacuation on the recovery rates of fecal colonocytes, and we have found that we can obtain almost the same number of colonocytes from stool materials 3 days after evacuation in comparison with 6 hours after evacuation if fecal material is kept at 4°C (data not shown). This observation may be important for the potential clinical application of this method.

Direct sequence analysis of colonocytes isolated from the feces of 83 healthy volunteers revealed mutations in 8 subjects (9%; 95% CI: 4–18), the breakdown of which was as follows: 1 APC1 mutation, 1 K-*ras* mutation, and 6 p53 mutations. Points of mutations identified of the p53, APC, and K-*ras* genes observed in the 83 healthy volunteers in this study were identical to that reported previously in tumors. These mutations of p53, APC, and K-*ras* in tumors are recorded in the database of OMIM. PCR errors were unlikely because multiple PCR reactions and sequence reactions were separately conducted. However, genetic alterations in precancerous lesions may have been present, although endoscopy findings macroscopically verified the absence of adenoma and carcinoma. The individuals in whom the present methodology revealed genetic alterations should be monitored to assess whether these findings were false-positive results or a predictor of tumorigenesis.

Oncogenes in feces are presumably derived from cancer cells exfoliated from the cancer tissue, and genetic alterations would not be detected in colonocytes isolated from feces if the original cancer tissue did not contain genetic alterations. In fact, among the 93 patients who exhibited genetic alterations in their cancer tissues, alterations were detected in colonocytes from the stools of 80 patients, producing a true sensitivity rate of 86% (80 of 93), although the present overall sensitivity was 71%. Furthermore, our methodology allows the isolation and retrieval of colorectal cancer cells from both early stage cancer and right-side colon cancer. Because the methodology allows processing at room temperature, we are currently constructing an automated, mechanized processing system on a commercial basis. A problem of our test was its relatively low specificity for a screening test as described previously. We consider that mutations observed in the healthy subjects might be attributable to the fact that they belonged to a high-risk group for colorectal cancer because these 83 volunteers were selected from among colonoscopy examinees recruited by the newly established National Cancer Center Research Center for Cancer Prevention and Screening, and the detection rate of cancers appeared to be considerably higher in the all examinees at the center than in the general population in Japan (unpublished observation). Therefore, we speculate that precancerous lesions with mutations of the genes tested might have been present in the colorectal epithelium of some of these healthy volunteers. We think that a prospective randomized study would be needed to determine the actual specificity of our method in a real screening population and to verify its clinical usefulness.

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Total Pelvic Exenteration with Distal Sacrectomy for Fixed Recurrent Rectal Cancer

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Four percent to 33% of patients with rectal cancer develop locoregional relapse after undergoing radical surgery with curative intent. Without treatment, the mean survival time for patients with local recurrence is only approximately 8 months, an associated severe symptomatic disease—especially pain—occurs, and their quality of life becomes remarkably deteriorated, probably with a miserable prognosis [1–4].

For cases with locally recurrent rectal cancer (LRRC), external beam radiotherapy, intraoperative radiotherapy, chemotherapies, and surgical treatments have been used singly or as part of a multimodality approach over the last several decades, resulting in certain outcomes that are not yet satisfactory [5–21]. For the purpose of attaining thorough margin-free resection, what we have been performing actively as our standard curative approach for fixed recurrent tumor (FRT) is radical resection with removal of affected neighboring organs and pelvic walls, including the sacrum, as originally reported by Wanebo and Marcove [6]. This article describes the surgical indications, contraindications, surgical techniques, oncologic outcomes, and complications of total pelvic exenteration with distal sacrectomy (TPES).

Patterns of growth in the pelvis

By cause and growth pattern of local recurrence, LRRC can be classified into three main categories.

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Anastomotic recurrence and perianastomotic recurrence

These suture line recurrences after low anterior resection are caused by implantation of cancer cells into the stump of anastomosis or insufficient resection of the rectal wall or mesorectum (Fig. 1). In the case of extramural invasion, however, it is difficult to distinguish between these two recurrences. When there is no extramural invasion or neighboring organ invasion, the basic surgical procedure is abdominoperineal resection (APR).

Perineal recurrence

Perineal recurrence is a recurrence that occurs after APR near the pelvic floor or perineal wound. From its early stage, perineal recurrence invades the coccyx, gluteal maximus muscle, or pelvic wall. Surgical margin-free resection seldom can be obtained by local excision alone. Many patients need resection of the pelvic wall or intrapelvic organs.

Pelvic recurrence

By occupied site, pelvic recurrence (Fig. 2) can be subdivided into anterior, lateral, and dorsal recurrences. Anterior pelvic recurrence is an LRRC that invades the anterior organs (ie, urogenital organs). For resecting this recurrent tumor, the basic surgical procedure is total pelvic exenteration (TPE). In women, if there is no obvious bladder invasion, it is possible to preserve urinary organs. This recurrence frequently is caused by insufficient resection for T4 rectal cancer. Lateral pelvic recurrence occurs because of lateral lymph node metastasis after total mesorectal excision or insufficient lateral node dissection. It begins to infiltrate the pelvic wall in its early stage. Dorsal pelvic recurrence is presacral extramural recurrence after APR or low

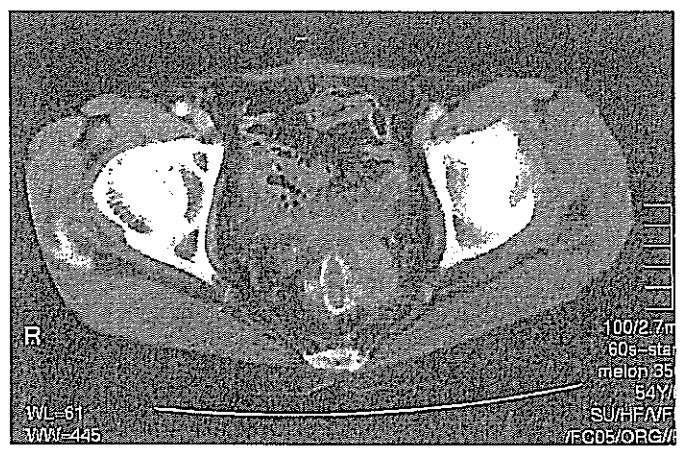

Fig. 1. Perianastomotic recurrence. A 54-year-old female patient underwent TPES for her FRT with 556 mL blood loss and no complication. At initial surgery 4 years ago, she received low anterior resection with D3 lymph node dissection and postoperative 60 Gy radiotherapy.

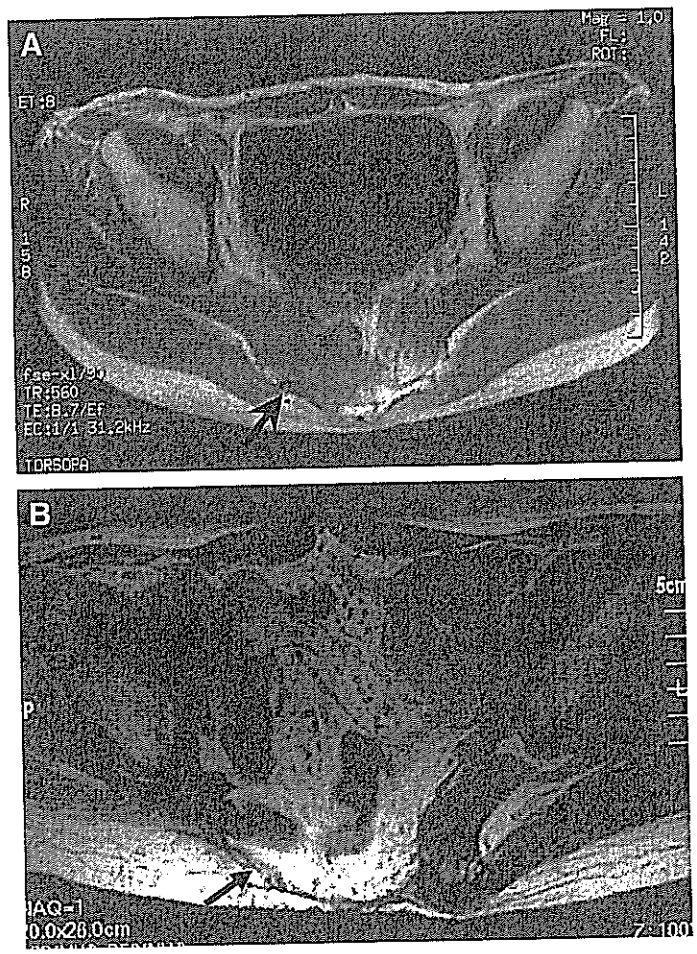

Fig. 2. (*A*) Dorsolateral pelvic recurrence with sacral bone invasion. A 47-year-old male patient underwent TPES for his FRT (*arrow*) with 673 mL blood loss and no complication. At initial surgery 1.5 years ago, he received low anterior resection. (*B*) Postoperative MRI. The patient is alive without re-recurrence 4 years after TPES.

anterior resection that invades the pelvic wall. It forms itself into FRT from its early stage. The cause of this recurrence may be extramesenteric lymphatic spread, insufficient resection of the mesorectum, or a cut into the mesorectum during operation. This pattern of recurrence is common patterns.

Why total pelvic exenteration with distal sacrectomy is the standard surgery for fixed recurrent tumor

Therapeutic policies for LRRC vary remarkably. The probable reasons for this are as follows: (1) there are various LRRCs, ranging from mobile recurrences to huge masses that occupy the pelvis, (2) an inappropriate surgical intervention may cause an iatrogenic cancer spread, leading to impaired quality of life, and (3) although treatments other than complete resection may not bring cure, the invasiveness of surgeries such as TPES is

considered excessive. In non-fixed recurrent tumors, complete resection can be achieved more often with limited surgery, such as APR or low anterior resection, and the outcomes are relatively favorable. LRRC grows within the narrow pelvis, and when the tumor size becomes larger to some extent, it can invade the pelvic wall easily and appear in the form of FRT. A challenge for the surgeon is the surgical treatment for FRTs with lateral or dorsal involvement, which comprises a larger percentage.

Such fixation is infrequently confined to one site and is of small range; many of those cases show fixations to the components surrounding the LRRC (eg, bony pelvis, including sacrum and coccyges; non-bony pelvis, including coccygeus muscle, piriform muscle, internal iliac vessels, inferior hypogastric plexus, sacral nerve plexus, obturator internus muscle, and sacrospinous and sacrotuberous ligaments; and residual anterior organs in the pelvis). Their anatomic planes are distorted, and it is difficult to determine and hold uninvolved margins during resection. For FRT cases, composite resection is inevitably required to encompass potentially involved pelvic walls, especially the distal sacrum. Only this strategy enables the R0 extirpation en bloc. Especially after APR, the LRRC grows while being sandwiched between the anterior organs and sacrum. Wanebo and Marcove [6] tackled this difficult problem using the new technique of abdominosacral resection, followed by several surgeons in 1980s [8,9,10,12].

Techniques to preserve the anterior organs and inferior hypogastric plexus for surgical treatment of FRT have been reported [16]. Those approaches, however, are likely to reduce local radicality, because the anatomic pathway around the autonomic nerve plexuses and ureter disappears and is replaced by scar tissue caused by initial surgery, especially after extended surgery. FRT in the deep pelvis also is often fixed more extensively than expected before surgery, which also justifies our experience-based strategy that TPES is positioned as the standard surgery for FRT. This technique is considered to be demanding and formidable because of high rates of mortality and morbidity [6,12,13,19]; consequently, combination of limited resection and intraoperative radiotherapy is likely to become standard in the treatment of FRT [17,22–29]. Whether an emphasis is placed on composite resection or multimodality treatment, surgeons have the same view that the key treatment to obtain local control and survival benefit is R0 surgery [22,28–31]. Is it really possible to carry out R0 resection for FRT by conventional surgery? Having been able to ensure R0 resection for FRT and develop secure surgical techniques, we consider that there are no therapies superior to TPES in treating FRT.

Evaluation by imaging and patient selection

Once the diagnosis of LRRC is made, detailed study should be conducted in terms of surgical indication from two aspects: (1) whether distance metastasis

is present and (2) to what extent the tumor spreads within the pelvis. Extrapelvic disease is searched for by the whole body CT scan. MRI and F-18-fluorodeoxy glucose position emission tomography (FDG-PET) are also useful in detecting extrapelvic disease and distinguishing between recurrent disease and scar tissue. CT, MRI, and FDG-PET are useful in distinguishing between solitary and multifocal recurrences in the pelvis and between anterior organ involvement and dorsolateral pelvic wall involvement.

We investigated a total of 196 consecutive patients who underwent laparotomy to remove LRRC between 1983 and 2003. The study excluded patients whose recurrent rectal cancer developed after local excision. We performed a limited surgery, such as APR, in 62 patients, TPE in 41, and TPES in 69. The remaining 24 patients had unresectable LRRC. Clinical and pathologic characteristics of 69 patients are listed in Table 1.

Patients with documented distant metastasis are not candidates for surgical treatment, because the curative potential is low and their life expectancy is not long enough to evaluate treatment outcome. With regard to surgical indication, we conducted TPES for FRT localized in the pelvis. Locally unresectable diseases include tumors that grow into sciatic notch,

Table 1
Clinical and pathologic characteristics of 69 patients

Characteristics	Number
Median age (range) (y)	57 (29–73)
Sex	
Male	55
Female	14
Body mass index (range)	22.9 (15.0–28.7)
Median time to local recurrence (range) (mo)	23 (7–118)
Liver metastasis	
No	65
Yes	5
Initial surgery	
Sphincter-preserving surgery; SPS	33
Abdominoperineal resection; APR	36
Radiotherapy for primary rectal cancer	
Yes	4
No	65
Radiotherapy for local recurrence before re-resection	
Yes	32 (median, 50 Gy; range, 30–80 Gy)
No	37
Dukes classification for primary growth	
A	4
B	18
C	47
Histologic type	
Well-differentiated adenocarcinoma	26
Moderately	34
Poorly	9

encase the external iliac vessels, extend to the sacral promontory, obstruct the bilateral ureters, and cause leg edema secondary to lymphatic or venous obstruction [30,31]. For patients with one or two liver metastases amenable to surgical resection, however, concomitant hepatectomy with surgical treatment of LRRC may be warranted. Lung metastasis and other extrapelvic diseases are excluded from surgical indications.

Surgical technique

TPE for primary pelvic malignancy is performed by first dividing loose connective tissues, such as the Retzius, retrorectal, and obturator spaces, and then dissecting along the parietal pelvic fascia. In recurrent cancer cases, however, those spaces disappear and are replaced by dense scar tissue. Because of this condition, TPES for FRT is a challenging procedure. The operation is performed in the following order.

Abdominal phase

The patient is placed in the lithotomy position. After detaching adhesions caused by initial surgery, the surgeon confirms the localization of the recurrent tumor within the pelvis and the absence of extrapelvic diseases and then makes a final decision to proceed to TPES. First, the Retzius space is opened. The endopelvic fascia and pubo-prostatic ligaments can be identified bilaterally and divided using electric cautery to expose the levator ani muscle. The dorsal vein complex together with the divided endopelvic fascia is bunched with the forceps and doubly tied and divided.

Next, the level of sacral amputation is determined. The anterior area from the aortic bifurcation to the sacral promontory is exposed to enter the anterior surface of the sacrum. The dissection is made using electric cautery down to the distal sacrum, at which point sacral amputation is planned, as is resection of the thickened Waldeyer's fascia with the presacral venous plexuses and scar tissue. During this process, bleeding occurs more or less; however, hemostasis can be obtained using combination of electric cautery and gauze pack. The area from the common iliac artery to the bifurcation between the internal and external iliac arteries is exposed. During dissection of the obturator space while preserving the obturator nerve, components of the sacral nerve plexus, such as the lumbosacral nerve and S1 and S2 sacral nerves, can be identified. Marking the S2 sacral nerve with a rubber loop ensures recognition of sacral nerves during sacrectomy (Fig. 3).

The next step is resection of the internal iliac vessels. The way to manipulate the internal iliac vessels is as follows. First, the trunk of the internal iliac artery is doubly tied and divided at the distal portion of the branching of the superior gluteal artery. Second, several branches that perforate the pelvic wall are divided. Finally, the trunk of the internal iliac vein is doubly tied and divided. Blood loss during TPES mostly occurs from

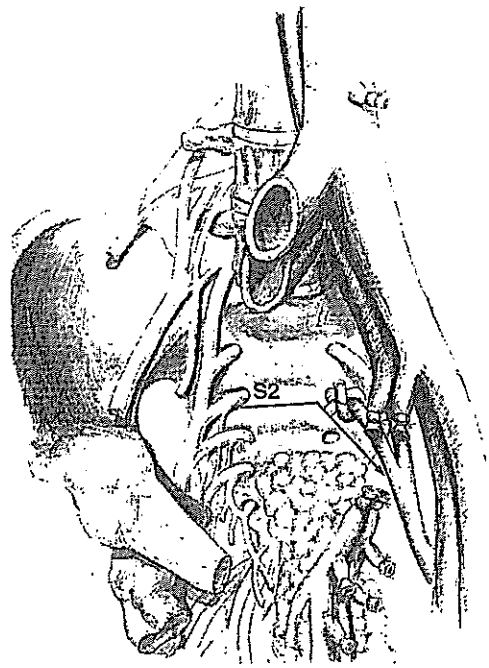

Fig. 3. Line of sacrectomy and marked second sacral nerve.

the venous plexus [31]. By taking the appropriate steps to avoid congestion of the venous plexus at the earliest possible opportunity, the operation can be performed with a minimum amount of blood loss from the venous plexus. Resection of the internal iliac veins is the most important part of this operation, and it requires advanced technical skills and careful maneuvers. FRT extends along the internal iliac vessels more frequently than the primary rectal cancer [32]; bilateral resection of the internal iliac vessels is one of the pivotal steps in TPES. Combined resection of the internal iliac vessels during the abdominal phase greatly contributes to reducing blood loss during sacrectomy.

Perineal phase

Incision of the perineal skin conforms to APR. The levator ani muscle is divided at its attachment and a connection is made through to the pelvic cavity. If the perineal phase is performed after the venous plexus is resected, a considerable amount of blood loss will occur from congested veins around the urogenital diaphragm. The perineal phase should occur before ligation of the trunk of the internal iliac veins so that the phase can be performed with less blood loss.

Sacral phase

The patient is placed in the prone position after temporary closure of abdominal wound. At that point, the padded operating frame for laminectomy

is used to prevent an increase in abdominal or vertebral venous pressure. Bleeding caused by the increase of vertebral venous pressure makes sacral amputation complicated. The median incision is made approximately 10 cm longer toward the head from the planned line of sacral amputation. The gluteus maximus muscle is detached from the sacrum so that the posterior surface of the sacrum can be exposed fully. The next step of this phase involves detaching the sacrotuberous and sacrospinous ligaments and piriform muscle that fix the sacrum. After dissecting these structures, the sacral nerve plexus also can be checked.

The surgeon inserts an index finger into the pelvic cavity from the lower edge of the sacroiliac joint and checks the dissected level of the anterior surface of the sacrum to determine the level of sacral amputation. The medial sacral crest is scraped, laminectomy is performed, and the root of the second sacral nerve is identified. The caudal end of the dura usually extends to around the lower edge of the S2. The dura, together with the cauda equine, is tied and divided. The surgeon performs sacral amputation using chisel and hammer at a stretch (Fig. 4). Hemostasis is performed quickly using electric cautery and bone wax. In men, after checking the stump of the urethra, the urethra is closed tightly to prevent transurethral infection. The origins of the gluteus maximus muscle, the subcutis, and the skin are closed tightly.

Urinary diversion, prevention of pelvic sepsis, and wound closure

The patient is placed in the lithotomy position. Reconstruction of the urinary tract using ileal conduit and colostomy is performed. Mobilization of the right colon from the cecum to the hepatic flexure enables construction of a high urostoma. After constructing the ileal conduit, an ileoileostomy

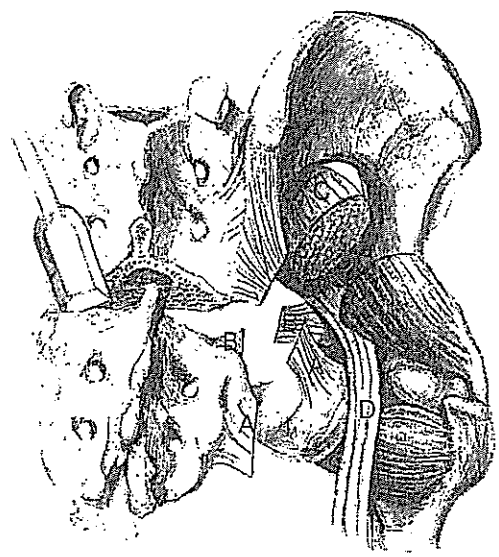

Fig. 4. Sacral amputation in prone position. (*A*) Sacrotuberous ligament. (*B*) Sacrospinous ligament. (*C*) Piriform muscle. (*D*) Sciatic nerve.

should be lifted up above the pelvic brim and fixed to the mesentery so that it will not fall in the pelvic cavity. This procedure is invariably required to prevent anastomotic leakage secondarily caused by pelvic sepsis, especially after radiotherapy. If the greater omentum is long enough with favorable blood flow, omentoplasty into the pelvic cavity should be performed. In patients who have recurrent tumor invading the perineal skin, it is necessary to combine a wide resection of the perineal skin. In such cases, reconstruction should be performed with a musculocutaneous flap [20,30]. It is appropriate that gastrostomy be performed before closing the abdomen, because enteroparalysis continues for a while after TPES. A thick drain is placed in the pelvis, and then the abdomen is closed.

Surgical invasiveness and oncologic outcomes after total pelvic exenteration with distal sacrectomy

Margins were microscopically negative in 57 patients (83%) and positive in 12. A comparison between two periods (1983–1992 and 1993–2003) showed a mean blood loss decrease from 4229 to 2102 mL ($P < 0.001$), with a favorable learning curve (Table 2). There was no difference in operative time and hospital stay. The most common level of sacral amputation was the S3 superior margin in 26 cases, followed by the S3 inferior margin and S2 inferior margin (Table 3). Overall mortality and complication rates were 3% and 58%, respectively. There was no hospital death in the latter period. The most frequent complication was sacral wound dehiscence in 51%, followed by pelvic sepsis in 39%. The incidence of pelvic sepsis in the latter period decreased significantly to 27%, compared with 72% in the former period ($P = 0.038$). Enteroperineal fistulae were observed in four cases.

Survival curves show overall 3- and 5-year disease-specific survival rates of 58% and 40%, respectively. In 57 patients with R0, including 5 patients with hepatic metastasis, 3- and 5-year disease-specific survival rates were 67% and 49%, respectively, whereas there was no 4-year survivor in patients with margin-positive, which showed significantly poor prognosis ($P < 0.001$) (Fig. 5). There was no survival difference between patients with and without radiotherapy before re-resection. Fourteen patients had lateral node metastases around the internal iliac vessels. Of these 14 patients, 6 are alive and 3 were long-term survivors for 64, 71, and 141 months, respectively.

Table 2
Surgical invasiveness and hospital stay

Operative burden	Former period (1983–1992) mean $n = 18$	Latter period (1993–2003) mean $n = 51$	P-value
Operative time (min)	769 (370–990)	702 (480–1100)	NS
Blood loss (mL)	4229 (1800–16,300)	2102 (673–8468)	$P < 0.0001$
Hospital stay (d)	37.5 (23–200)	34 (21–257)	NS

Table 3
Level of distal sacrectomy and complications

Level of sacrectomy	Sepsis in pelvis	Ileus	Fistula[a]
Middle amputation			
S2 inferior margin (n = 12)	6	2	1
S2-3 (n = 26)	9	1	1
Low amputation			
S3 inferior margin (n = 16)	8	1	2
S3-4 (n = 10)	2	1	
S4 inferior margin (n = 5)	2		

[a] Fistula: enteroperineal fistula caused by anastomotic leakage.

Of 57 patients with R0 resection, 34 developed re-recurrence. The most common site was the lung (18 patients) followed by the pelvis (12 patients).

Oncologic outcomes reported in the literature

Factors such as type of surgery, combined therapy, and postoperative follow-up period are diversified, and comparison of reported oncologic outcomes for LRRC is of small significance. For example, a study that includes patients with recurrence after local excision naturally should show favorable outcome, whereas in a study conducted only with cases of FRT, unfavorable outcome can be predicted. Lopez-Kostner et al [33] reported a 5-year survival rate of 32% in 43 patients who underwent surgical treatment, 11 of whom developed recurrence after local excision. On the other hand, Bozzetti et al [18] showed a 5-year survival rate of less than 10% in patients who underwent surgery alone and pointed out a limitation of outcome after surgical treatment alone. Regarding 5-year survival after

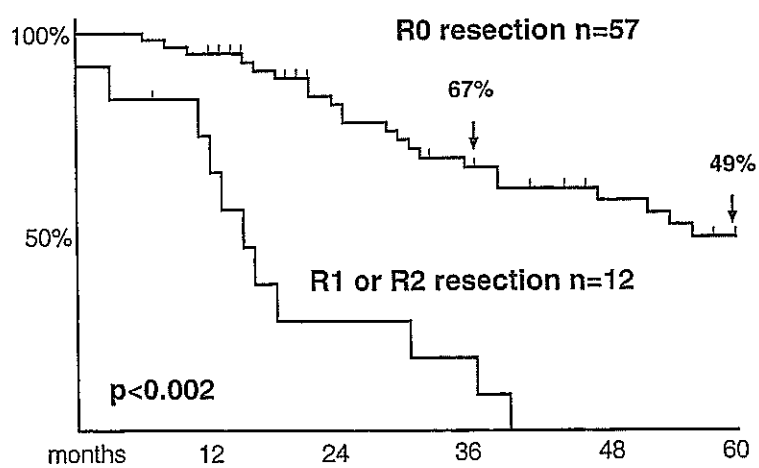

Fig. 5. Disease-specific survival curve. The difference between the two groups was significant ($P < 0.001$).

composite resection, Wanebo et al [19] reported a rate of 31%, Maetani et al [10] reported a rate of 25%, and Yamada et al [21] reported a rate of 18%. Those are not satisfactory outcomes. Incidence of local re-recurrence ranges from 27% to 61% [10,19,31].

As for outcome after multimodality therapy, there are many reports in which the ordinary dosages of radiation used preoperatively were 45 to 50 Gy. Intraoperative dosages of 10 to 15 Gy in R0 cases and 15 to 20 Gy in R-positive cases also were reported [24–29]. Valentini et al [24] reported a 5-year survival rate of 22%, and Mannaerts et al [23] reported a 3-year survival rate of 60%. In the series by Shoup et al [25], who investigated outcomes after resection plus intraoperative radiotherapy, patients with R0 had a median disease-free survival of 31 months and a median disease-specific survival of 66 months.

Lung metastasis and local re-recurrence account for nearly 90% of all re-recurrence patterns [31], and measures to prevent these two types of re-recurrence are important. Compared with 20 years ago, when the only effective antitumor agent was 5-fluorouracil, some effective antitumor agents (eg, CPT-11, UFT, capecitabine, and oxaliplatin) have become available. We think that surgical treatment, combined with composite resection and intraoperative radiotherapy, is indispensable for improving local control rates and that an effective chemotherapy regimen after re-resection is indispensable for inhibiting lung metastasis.

Prognostic factors and staging system

Several factors, such as type of initial surgery, tumor size, presence of symptoms, and serum carcinoembryomic antigen level, have been regarded as significant prognostic indicators, although a consensus has not been reached yet. Willet et al [11] and Wanebo et al [19] found improved resectability in patients who underwent initial low anterior resection compared with patients who had initial APR. If FRT developed after low anterior resection, however, there was no difference in resectability and survival between them [31]. Shoup et al [25] indicated that vascular invasion and R1/R2 resection are factors for poor prognosis. In either report, the most important factor is whether R0 resection was attained [19,24,25,27,31]. Researchers already have shown that in surgical treatment for primary rectal cancer, surgery-related and biologic factors are crucial [34]. Surgical margin status and complications are exclusively determined by a surgeon's technical skills. Complicated surgeries, such as TPES or abdominosacral resection, should be undertaken only in specialized centers with an experienced complex treatment team.

Suzuki et al [14] judged the degree of fixation to surrounding structures according to surgical and pathologic findings and proposed their own staging method. Valentini et al [24] also reported a similar staging system in

which they judged from CT scan imaging. They mentioned that degree of fixation is an independent prognostic factor. Wanebo et al [19] proposed a new staging system for stages TR1-2 to TR5, which are determined by extent of invasion. A staging system that uses degree of fixation or other prognostic factors is constructed so that treatment modalities for LRRC, especially surgical treatment, are placed in an appropriate position.

Summary

For primary rectal cancer, there is a difference in therapy between Western countries and Japan. In Western countries, initial surgery is total mesorectal excision or less limited surgery plus radiotherapy. For this reason, fibrosis caused by radiation occurs in the pelvis. On the other hand, in Japan, although preoperative radiotherapy is not given, total mesorectal excision or more extended surgery is performed as initial surgery, and the intrapelvic spaces are covered with postoperative scar tissue. In identifying an anatomic index and doing hemostasis, this scar tissue brings the surgeon more difficulty than the fibrosis caused by radiotherapy. Approximately half of our patients are irradiated preoperatively for recurrence. In those patients, operation is performed under an unfavorable condition because the fibrosis caused by radiation is added to the scar tissue caused by dissection. Composite resection, such as TPES, has been thought to be demanding and formidable because of high mortality and morbidity rates. Improvement of surgical techniques has allowed TPES to be completed with a blood loss of approximately 2000 to 3000 mL, however, which has resulted in a favorable learning curve with low morbidity and mortality rates.

We have excluded tumors that grow into the sacral promontory or sciatic notch from surgical indications. If high sacral amputation is performed, increased surgical invasiveness, more serious complications, and inevitable walking disorders are observed; as a result, a patient may have a remarkably deteriorated quality of life [6,9,12,19]. We have limited the level of sacral amputation in TPES to the S2 lower edge or below to preserve the second sacral nerve. Consequently, patients were able to have favorable quality of life after TPES, except for living with double stomas and temporary pain caused by resection of sacral nerves, and they were able to return to their original occupations [31,35].

If oncologic outcome obtained is superior to that after multimodality treatment, composite resection for FRT also may become an acceptable treatment. Finally, it should be noted that when extended surgeries, such as TPES, are performed for FRT, each of the departments concerned should review surgical indications and the surgeries must be worked on in the form of team medicine. One must realize that only through such process can negative resection margins be obtained as a great boon to patients.

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Original Paper

Postsurgical Surveillance for Recurrence of UICC Stage I Colorectal Carcinoma: Is Follow-up by CEA Justified?

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KEY WORDS: UICC stage I colorectal carcinoma; Follow-up; Surveillance; CEA

ABBREVIATIONS: Carcinoembryonic Antigen (CEA)

ABSTRACT

Background/Aims: This study was undertaken to investigate whether it will be possible to reduce the times and types of postoperative examinations for surveillance in patients with UICC stage I colorectal carcinoma. In addition, the value of CEA in postoperative surveillance is discussed.

Methodology: A review was performed of 541 patients who underwent curative resection for UICC stage I colorectal carcinoma between January, 1985 and December, 1998. Periodic check-up was routinely conducted to identify recurrence.

Results: The median follow-up was 82 months. The recurrence rate was 2.9% in the UICC stage Ia (pT1N0M0) group, and 5.6% in the Ib (pT2N0M0) group. Cancer-specific survival rates at 5 years were 99.3% and 97.6%, respectively (p=0.0354). Recurrences occurred more frequently in patients with lower rectal carcinoma (p=0.0415). Curative-intent salvage surgery was performed in 61.9% (13/21) for recurrent lesions. Between the patients who were CEA positive (13/21; 61.9%) and those who were CEA negative at the time of recurrence, there was no significant difference in the prognosis.

Conclusions: The incidence of recurrence was low after curative surgery in patients with UICC stage I colorectal carcinoma, and it is therefore possible to reduce times and types of postoperative examinations. CEA measurement alone appears to be sufficient.

INTRODUCTION

Currently, a main topic for discussion with regard to the surveillance after colorectal carcinoma surgery is whether intensive follow-up for detecting recurrence earlier and initiating the treatment of it practically contributes to the improvement in prognosis for colorectal carcinoma patients. In nonrandomized cohort studies and randomized studies, significant differences in the time of confirming recurrence, the surgical resectability of recurrent lesion, and the 5-year survival rate between intensive follow-up group and control group (traditional follow-up or no follow-up group) were reported (1-5). At the same time, there are other studies that have reported no significant difference in these points (6-12). However, in those previous studies, the numbers of cases that were reviewed ranged from 98 to 1247, and there were a variety of disease stages from UICC stages I through IV. One study reported that although the resectability after recurrence was higher by more than 10% in an intensive follow-up group than in the control group, no significant difference was obtained, probably due to the small number of cases (13). In two studies using meta-analysis that were reported lately, the 5-year survival rates were 9% to 14% greater in the intensive follow-up group than in the control group (14,15).

Recently, advances in diagnostic techniques have enabled the detection of colorectal carcinoma at earlier stages in Japan (16). At our institution, the proportion of UICC stage I cases in all colorectal carcinoma patients receiving the first-line treatment was 14% (12/86) in 1980, but it increased to 25% (71/284) in 2000. It is important to conduct a cost-effective follow-up in view of the risk for recurrence (17,18). In fact, for UICC stage I colorectal carcinoma patients, the rate of recurrence is lower, and hence fewer times and screening examinations may be reasonable and warranted for the postoperative surveillance, compared with UICC stages II-IV colorectal carcinoma patients (19).

In the present study, we utilized the prospective follow-up database at a single institution to analyze the long-term outcomes of UICC stage I colorectal carcinoma patients, and to investigate whether it will be possible to reduce the times and types of screening examinations for postoperative surveillance. In addition, the present study discusses the value of CEA (carcinoembryonic antigen) in performing surveillance after curative surgery for UICC stage I colorectal carcinoma.

METHODOLOGY

Between January, 1985 and December, 1998,

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