syndrome.[33-37] Most authors believe preservation of the whole anal sphincter and mucosa is crucial for maintenance of good continence. APR thus represents a standard surgery when distance between the lower edge of the tumor and the anal ring is <2 cm.[38] However, in this study, 93 percent of patients showed good or relatively good continence (Kirwan's Grade 1–111) at 24 months after stoma closure. Mean Wexner score was 7.8 at 24 months after stoma closure. Bretagnol *et al.*[14] and others have reported similar results.[7,10-12] However, seven patients displayed worsened continence. In addition, three patients could not undergo closure of the diverting stoma because of anal dysfunction. Furthermore, patients who underwent total ISR with or without PESR displayed significantly worsened continence compared with partial and subtotal ISR groups in our experience. Information on the potential functional adverse effects after total ISR should be provided to patients preoperatively.

Fecal incontinence after ISR is primarily caused by anal-sphincter insufficiency. Physiologic studies have shown that removal of the internal anal sphincter is associated with a significant decrease in resting pressure.[7,10,12] Anal sphincter insufficiency also may be caused by injury of the external anal sphincter during ISR. Furthermore, neorectal insufficiency may facilitate fecal incontinence, as demonstrated by randomized studies comparing straight and J-pouch coloanal anastomoses.[14,39,40] Anal functions in ISR procedures need to be investigated to compare straight, J-pouch, and transverse coloplasty coloanal anastomoses. More careful intraoperative management, additional surgery, such as colonic pouch, biofeedback treatment, and careful patient selection may facilitate improved outcomes in terms of anal function.

CONCLUSIONS

Curability with ISR procedures was verified histologically in patients with very low rectal cancer. Acceptable oncologic and functional results were obtained by using ISR procedures in patients with very low rectal cancer <5 cm from the anal verge. These procedures can be recommended for APR candidate patients; however, information on potential functional adverse effects after ISR should be provided to patients preoperatively.

ACKNOWLEDGMENTS

Patients with intersphincteric resection studied in this series were registered from the following institutions: Department of Surgical Oncology, National Cancer Center Hospital East, Kashiwa, Japan; Department of Surgery, National Cancer Center Hospital, Tokyo, Japan; Department of Surgery, Faculty of Medicine, Kurume University, Kurume, Japan; Department of Surgery, Fujita Health University, Toyoake, Japan; Department of Surgery 1, National Defense Medical College, Tokorozawa, Japan; Department of Gastroenterological Surgery, Graduate School of Medicine, Chiba University, Chiba, Japan; Department of Gastroenterological Surgery, Aichi Cancer Center, Nagoya, Japan.

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Int J Colorectal Dis
DOI 10.1007/s00384-006-0113-x

ORIGINAL ARTICLE

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Polyethylene glycol solution (PEG) plus contrast medium vs PEG alone preparation for CT colonography and conventional colonoscopy in preoperative colorectal cancer staging

Accepted: 27 January 2006

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Abstract *Purpose:* This study evaluated the usefulness of combined polyethylene glycol solution plus contrast medium bowel preparation (PEG-C preparation) followed by dual-contrast computed tomography enema (DCCTE) and conventional colonoscopy. The main purpose of these examinations is the preoperative staging of already known tumors. *Materials and methods:* One hundred patients with colorectal tumors were alternately allocated to either a polyethylene glycol solution preparation (PEG preparation) group (n=50) or a PEG-C preparation group (n=50) before undergoing conventional colonoscopy and computed tomographic (CT) colonography. After conventional colonoscopy, multidetector row CT scans were performed. Air images were reconstructed for both groups; contrast medium images were additionally reconstructed for the PEG-C preparation group. DCCTE images were a composite of air images and contrast medium images without use of dedicated electronic cleansing software. Quality scores (the presence or absence of blind spots of the colon) were compared between the two groups. *Results:* Complete tumor images were obtained by DCCTE for all 50 (100%) lesions in the PEG-C preparation group, as compared with only nine of the 50 lesions (18%) in the PEG preparation group (air-contrast CT enema). The overall quality score in the PEG-C preparation group was significantly better than that in the PEG preparation group (P<0.0001). *Conclusions:* DCCTE showed the entire colon without blind spots in nearly all patients in the PEG-C preparation group because the areas under residual fluid were reconstructed as contrast medium images. DCCTE and conventional colonoscopy after PEG-C preparation are feasible and safe procedures that can be used for preoperative evaluation in patients with colorectal cancer.

Keywords Colorectal neoplasms · Bowel preparation · Computed tomography · Colonography · Virtual colonoscopy

Introduction

Computed tomographic (CT) colonography have recently become a popular clinical examination tool with significant improvements being made on the quality of the images due to a rapid progress in computer technology. CT colonography is a minimally invasive examination [1–7] but residual fluid and feces in the large intestine may negatively affect diagnostic accuracy. Standard colonic cleansing leaves residual fluid and feces. This makes differential diagnosis or preoperative staging of colorectal tumors difficult. With the administration of small amounts of oral contrast medium, residual fluid and feces become identifiable [8]. Most previous investigations used fecal tagging as a bowel preparation before CT colonography for screening of colorectal tumor [2, 8–11]. These methods also require dietary restriction during bowel preparation for 1 to 3 days.

To cope with the problem of residual fluid and feces in the large intestine, we recently developed a technique for bowel preparation that combines polyethylene glycol solution plus contrast medium preparation (PEG-C preparation) and reconstructed CT colonography images without the use of dedicated electronic cleansing software. We refer to this technique as dual-contrast CT enema (DCCTE). We previously reported that CT colonography (air-contrast CT enema) images were useful for the preoperative staging of colorectal cancer [12, 13]. Our efforts have been focused on finding a technique that could serve for the improvement of CT colonography images. PEG-C preparation without dietary restriction could possibly be used not only for CT colonography but also for conventional colonoscopy in patients undergoing preoperative assessment of colorectal cancer.

This study had two objectives. The first was to determine whether PEG-C preparation can be safely used for conventional colonoscopy, CT colonography, and surgical operation. The second was to evaluate whether CT colonography images produced by DCCTE were superior to images obtained by air-contrast CT enema after polyethylene glycol solution preparation (PEG preparation).

Table 1 Patient's characteristics

	PEG (*n*=50)	PEG-C (*n*=50)	*P* value
Age, years±SD	68.0 ± 10.4	64.5 ± 11.4	0.114[a] (NS)
Gender, W/M	22/28	20/30	0.839[b] (NS)
Tumor site			0.219[b] (NS)
Cecum/ascending colon	10	6	
Transverse colon	4	2	
Descending colon	1	0	
Sigmoid colon	9	18	
Rectum	26	24	
Depth of invasion (T)			0.111[b] (NS)
pTis	5	1	
pT1	6	12	
pT2	13	8	
pT3	26	29	
Dukes			0.713[b] (NS)
A	19	17	
B	13	11	
C	18	22	
Surgical approach			0.412[b] (NS)
Laparoscopy	28	33	
Open	22	17	

SD Standard deviation, *NS* not significant
[a]Mann–Whitney *U* test
[b]Chi-squared test

Materials and methods

Patients

Between November 2002 and October 2004, a total of 100 patients with colorectal tumor (42 women and 58 men, age range 41–88 years, mean age±SD 66.3±11.0 years) were enrolled. These patients were referred to our institution for preoperative evaluation and treatment of colorectal tumor. All patients were examined by conventional colonoscopy and CT colonography and were not in need of screening of the colon and rectum. The purposes of conventional colonoscopy were pathological diagnosis and endoscopic marking with clips or India ink for (laparoscopic) surgery. The purposes of CT colonography were precise anatomical localization of lesions and preoperative comprehensive staging, with depth of cancer invasion, regional and distant lymphadenopathies, and metastases [12].

Patients were alternately allocated to either a PEG preparation group (*n*=50) or a PEG-C preparation group (*n*=50) before preoperatively undergoing conventional colonoscopy and CT colonography. The clinical characteristics of the two groups are shown in Table 1. Patients with acute bowel obstruction were excluded.

Before bowel preparation, two experienced gastroenterologists (K. N. and S. E.) provided all patients with a detailed description of the scheduled procedures and possible complications, such as discomfort, radiation exposure, and urge to defecate. Written informed consent was obtained from each patient before enrolment.

Safety analysis

The osmotic pressure of PEG-C solution and the metabolism of PEG-C solution by colonic bacteria were examined to confirm the safety of the solution. The osmotic pressure of PEG-C solution and the osmolarity (PEG-C solution to physiological saline ratio) was measured six times with a freezing point depression osmometer (OM802, Vogel, Germany). Hydrogen concentrations were determined by gas chromatography using a molecular sieve column and reduction detector (GC-8A, Shimadzu, Japan).

Bowel preparation

Diet was unrestricted to either group until the day before the procedures. On the day of the examination, no breakfast was allowed, and both bowel preparations were performed between 8:00 and 10:00 A.M.

PEG preparation group On the day of the examination, patients were given 2 l of polyethylene glycol solution (Niflec; Ajinomoto Pharma, Tokyo, Japan) over the course of 2 h as standard colonoscopic cleansing.

PEG-C preparation group On the day of the examination, patients were given 1,620 ml of PEG solution over the course of 2 h, followed by 400 ml of PEG-C solution, consisting of 380 ml of PEG solution plus 20 ml of water-soluble contrast medium (Gastrografin, amidotrizoic acid and diatrizoic acid, Nihon Schering, Osaka, Japan). We used water-soluble contrast medium for residual fluid tagging purposes.

Examination techniques

After PEG or PEG-C preparation, all patients underwent conventional colonoscopy. The endoscopists were blinded to the assigned preparation. When necessary, the intestinal lumen was endoscopically marked with clips or India ink to localize tumors precisely during laparoscopic or open colorectal operations. The main tumor was clinically staged by evaluating its morphologic characteristics on the application of sprayed dye, endoscopic ultrasonographic features, and pit pattern [14], assessed with the use of a magnifying colonoscope (CF-Q240ZL/I, Olympus, Tokyo, Japan). Any colonic tumors apart from the main tumor underwent endoscopic polypectomy or endoscopic mucosal resection without reservation.

After conventional colonoscopy, multidetector-row CT (MDCT) scans were obtained on the same day. The patient's large intestine was inflated gently with room air. Immediately before MDCT scanning, a smooth muscle relaxant, 20 mg of scopolamine butylbromide (Buscopan, Nippon Boehringer Ingelheim, Kawanishi, Japan) or 1 mg of glucagon (Glucagon G Novo, Eisai, Tokyo, Japan), was given intravenously. The adequacy of colonic distention was assessed on the anteroposterior scout image. If the colon was adequately distended, MDCT scanning was performed. If not, additional air was insufflated.

Eight-detector row CT scans were performed with an Aquilion M8 CT scanner (Toshiba, Tokyo, Japan). The patients underwent single scans in a single position; dual positioning was not used. One hundred milliliters of nonionic iodinated contrast material (Iopamiron 300, iopamidol, Nihon Schering, Osaka, Japan or Omnipaque 300, iohexol, Daiichi Pharma, Tokyo, Japan) was injected intravenously with a 90-s delay time and an infusion rate of 2 ml/s to evaluate the presence of metastases or invasion. The entire region of the abdomen and pelvis was scanned in a single run. CT images were acquired at 120 kVp and 250 mAs with the use of 8×2-mm collimation, a pitch of 7.0–13.0, and a 1-mm reconstruction interval. Air-contrast images were reconstructed for both groups; contrast medium images were additionally reconstructed for the PEG-C preparation group. The DCCTE images were a composite of air images and contrast medium images (Fig. 1). We did not remove residual fluid electrically with dedicated electronic cleansing software. Virtual three-dimensional endoscopic display, i.e., virtual colonoscopy, was not assessed in this study.

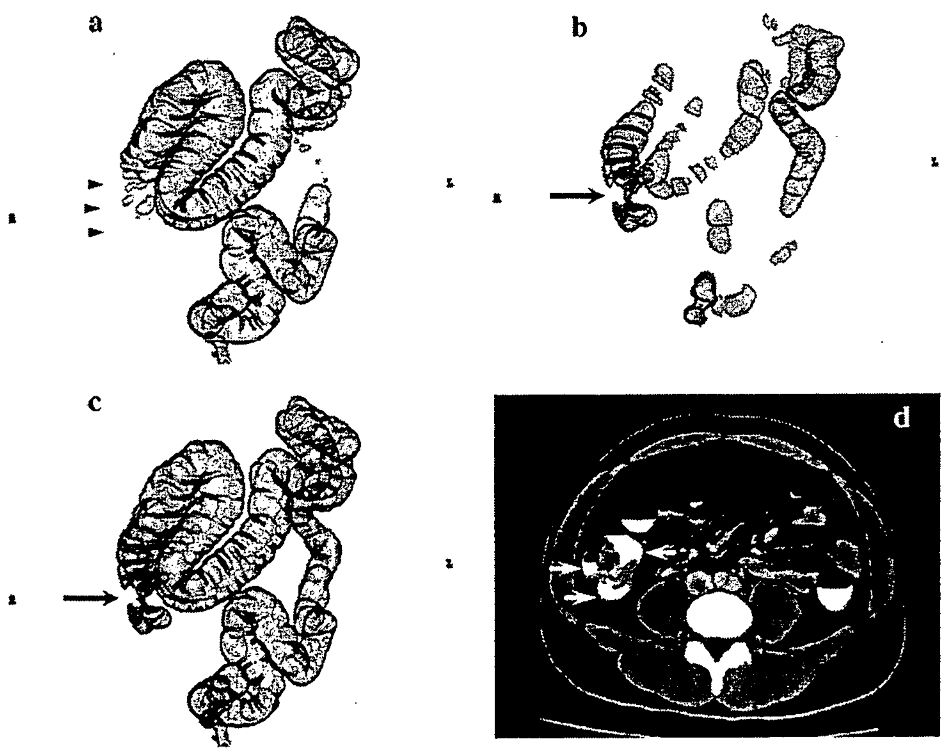

Fig. 1 Dual-contrast CT enema in PEG-C preparation group: **a** Air image (air-contrast CT enema) shows blind spots in the cecum and proximal descending colon. Air images cannot detect the lesion because it is concealed by residual fluid in the cecum (*arrowheads*). **b** Contrast-medium image can detect a severe deformity in the cecum (*arrow*). **c** Dual-contrast CT enema is a composite figure of the air image and contrast medium image. Dual-contrast CT enema clearly demonstrates severe deformity (so-called apple-core-like deformity) (*arrow*) and the course and length of the entire large intestine, without blind spots. **d** In transverse two-dimensional CT image, residual fluid is homogeneously tagged throughout the cecum (*arrow*)

Image analysis

Conventional transverse CT colonographic images were used for the detection of extracolonic abnormalities or metastases and for preoperative staging. Using the data obtained by MDCT, we reconstructed CT colonography (air-contrast CT enema and DCCTE) images with the use of a ZIO M900 workstation (Zio Software, Tokyo, Japan). Air-contrast CT enema images after PEG preparation and DCCTE images after PEG-C preparation were assessed with regard to the ability to detect tumor, tumor localization, and the presence or absence of blind spots of the large intestine. Blind spots are defined as the spots of the large intestine which cannot be reconstructed by air images or contrast medium images. Although endoscopic marking with metal clips was recognizable in conventional transverse CT images, clips were not used for detecting tumor in image analysis. Tumor location at surgery was regarded as the gold standard against the results of air-contrast CT enema and DCCTE. The imaging quality of CT colonography (the presence or absence of blind spots) was scored according to a five-point scale (5, excellent—no blind spots; 4, good—blind spot area only 25%; 3, fair—blind spot area 50%; 2, poor—blind spot area 75%; and 1, very poor—a given segment of the colon was completely blinded by residual fluid). This analysis was performed for five segments of the colon (1, cecum/ascending colon; 2, transverse colon; 3, descending colon; 4, sigmoid colon; and 5, rectum) by scrolling through the CT colonography images (air-contrast CT enema and DCCTE). Two readers [a gastroenterologist (K. N.) and a radiologist (T. I.)] separately and independently interpreted the air-contrast CT enema images and DCCTE images. Additional colorectal polyps missed by conventional colonoscopy were not assessed.

The Hounsfield units (HU) values for residual fluid in the cecum/ascending colon and the rectum were measured for all patients in the PEG and PEG-C preparation groups. The HU values were measured by manually circling regions of interest. The mean HU values for residual fluid were calculated.

Statistical analysis

The statistical significance of differences in patients' characteristics was assessed with the use of the Mann–Whitney U test and chi-squared test. The Mann–Whitney U test was used to compare differences in quality scores between the PEG preparation group and PEG-C preparation group according to segment, differences in inter-reader quality scores, differences in HU values of residual fluid between the PEG preparation group and PEG-C preparation group, and differences in HU values of residual fluid between the cecum/ascending colon and the rectum. Differences with P values of less than 0.05 were considered statistically significant.

Results

The osmotic pressure of PEG-C solution was 384±3.3 mOsm/l (mean±SD). The ratio of PEG-C solution osmolarity to physiological saline osmolarity was 1.337±0.012. The fecal suspensions generated only 824 to 845 ppm hydrogen, an explosive gas, when incubated with PEG-C solution for 2 h (Table 2). This corresponds to 1/50 of the minimum explosive concentration of hydrogen (> 40,000 ppm) [15].

The PEG and PEG-C preparations were completed safely and successfully in all 100 patients. No side effects (vomiting, bowel obstruction, or bowel perforation) were associated with bowel preparation.

After PEG or PEG-C preparation, conventional colonoscopy was preoperatively performed in all 100 patients. The quality of bowel preparation was satisfactory in all patients for conventional colonoscopy. Colonoscopic examination and treatment were successfully performed after PEG-C preparation, with no problem in any patient. To localize tumors during surgery, endoscopic marking with clips was used for 37 of the 50 cases in the PEG preparation group and 35 of the 50 cases in the PEG-C preparation group. The differences in frequency of clip usage were not statistically significant. Preoperative staging by conventional transverse CT colonographic images using MDCT data was performed in all 100 patients without any problem.

In the PEG preparation group, the detection rate of tumor on air-contrast CT enema was 96% (48 of the 50 lesions). One slightly elevated (pTis) lesion and 1 ulcerated (pT2) lesion were not detected (Fig. 2) because of residual fluid. Complete tumor images were obtained by air-contrast CT enema for only nine of the 50 lesions (18%). In the PEG-C preparation group, complete tumor images were obtained by DCCTE for all 50 lesions (100%). Even when tumors were hidden by residual fluid in the colon, the DCCTE successfully detected all tumors not detected on air-contrast CT enema (Fig. 1). The DCCTE showed regions of the large intestine that would have been concealed by residual fluid after PEG preparation (Fig. 1). Accurate tumor

Table 2 Hydrogen concentrations (ppm) after incubation of PEG-C solution with human feces

No. of trials	Time of incubation (h)				
	0	2[a]	4	6	8
1	<500	824	1,269	1,412	1,306
2	<500	845	1,353	1,526	1,445

Minimum explosive concentration for hydrogen > 40,000 ppm
ppm Parts per million
[a]Time of the PEG-C preparation ≤2 h

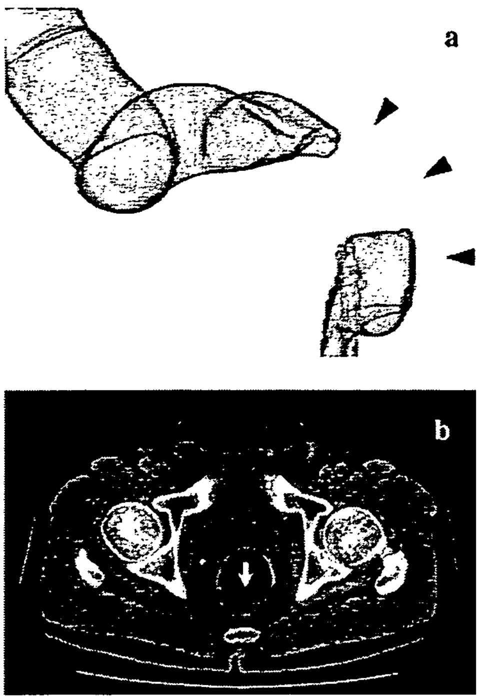

Fig. 2 Air-contrast CT enema in PEG preparation group: **a** Air-contrast CT enema shows a blind spot in the rectum. The ulcerated lesion (*pT2*) in the rectum was not detected (*arrowheads*). **b** In the transverse two-dimensional CT image, the tumor was concealed by residual fluid in the rectum (*arrow*).

localization by air-contrast CT enema and DCCTE were 96 and 100%, respectively.

Tables 3 and 4 show the quality of images obtained by CT colonography after PEG preparation and PEG-C preparation, respectively. With PEG preparation, the average image quality scores per segment ranged from 4.34±0.92 (transverse colon) to 2.34±1.29 (rectum) for reader 1 and from 4.54±0.58 (transverse colon) to 2.62±1.24 (rectum) for reader 2 (Table 5). With PEG-C preparation, the average image quality scores per segment ranged from 5.0±0.0 (cecum/ascending colon) to 4.86±0.45 (rectum) for reader 1 and from 5.0±0.0 (descending colon) to 4.92±0.27 (sigmoid colon and rectum) for reader 2 (Table 5). The DCCTE demonstrated nearly all areas of the colon and rectum, without blind spots. There were clear differences between PEG preparation and PEG-C preparation in all segments. The inter-reader differences in quality scores were not statistically significant (Table 6).

Table 7 shows the HU values of residual fluid in the cecum/ascending colon and the rectum for the PEG and PEG-C preparation groups. In the PEG preparation group, the HU values of residual fluid were 65 HU or less. In the PEG-C preparation group, the HU values of residual fluid were 130 HU or higher, and the mean HU value was 433 HU in the cecum/ascending colon and 329 HU in the rectum.

Discussion

An accurate preoperative staging for colorectal cancer is essential for a correct therapeutic plan, including surgery (limited or extensive resection), radiotherapy, or chemotherapy (advanced stage disease). the increased popularity of laparoscopic surgery for the treatment of colorectal cancer has heightened the importance of preoperative diagnosis. Accurate tumor localization is imperative because the colon and rectum cannot be palpated laparoscopically. A survey of the members of the American Society of Colon and Rectal Surgeons reported that 18 of 278 respondents (6.5%) had previously chosen the wrong segment of the colon for laparoscopic colectomy, requiring conversion to standard laparotomy and an additional resection [16].

An accurate preoperative diagnosis is also important because laparoscopic approaches to colorectal tumor, including factors such as port positions, incision site and size, and extent of resection, are based on lesion size and location. Although the conventional colonoscopy has high diagnostic accuracy for colorectal tumor, the error rate for preoperative tumor localization ranges from 14 to 22% [12, 17]. By contrast, CT enema can precisely define the

Table 3 Distribution of quality scores with PEG preparation (air-contrast CT enema)

	Quality scores (presence or absence of blind spots of the large intestine)				
	1 (reader 1/reader 2)	2 (reader 1/reader 2)	3 (reader 1/reader 2)	4 (reader 1/Reader 2)	5 (reader 1/reader 2)
Cecum/ascending colon	3/2	8/6	15/6	19/29	5/7
Transverse colon	1/0	1/0	6/2	14/19	28/29
Descending colon	14/10	12/10	14/14	9/12	1/4
Sigmoid colon	1/1	4/4	5/4	9/17	31/24
Rectum	17/8	13/22	10/6	6/9	4/5
Total	36/21	38/42	50/32	57/86	69/69
Percentage	(14.4/8.4)	(15.2/16.8)	(20.0/12.8)	(22.8/34.4)	(27.6/27.6)

Quality scores: 5, excellent—no blind spots; 4, good—blind spot area only 25%; 3, fair—blind spot area 50%; 2, poor—blind spot area 75%; and 1, very poor—a given segment of the colon was completely blinded by residual fluid

Table 4 Distribution of quality scores with PEG-C preparation (dual-contrast CT enema)

	Quality scores (presence or absence of blind spots of the large intestine)				
	1 (reader 1/reader 2)	2 (reader 1/reader 2)	3 (reader 1/reader 2)	4 (reader 1/reader 2)	5 (reader 1/reader 2)
Cecum/ascending colon	0/0	0/0	0/0	0/1	50/49
Transverse colon	0/0	0/0	0/0	1/1	49/49
Descending colon	0/0	0/0	0/0	2/0	48/50
Sigmoid colon	0/0	0/0	1/0	0/4	49/46
Rectum	0/0	0/0	2/0	3/4	45/46
Total	0/0	0/0	3/0	6/10	241/240
Percentage	(0/0)	(0/0)	(1.2/0)	(2.4/4.0)	(96.4/96.0)

Quality scores: 5, excellent—no blind spots; 4, good—blind spot area only 25%; 3, fair—blind spot area 50%; 2, poor—blind spot area 75%; and 1, very poor—a given segment of the colon was completely blinded by residual fluid

anatomical locations of lesions. We previously reported that accurate tumor localization by air-contrast CT enema was 97.3% [12]. This study shows that DCCTE is expected to enhance the accuracy of tumor localization because the imaging of complete tumor is superior to that on air-contrast CT enema.

An accurate assessment of the course and length of the large intestine also plays a key role in deciding the optimal approach for laparoscopic treatment as well as the type of anastomosis, extent of resection, and stoma site. The DCCTE delineated the course and length of nearly the entire large intestine without blind spots because the areas under residual fluid were reconstructed as contrast medium images. One of the major advantages of PEG-C preparation is the induced difference in HU values between the residual fluid and the colonic wall. Callstrom et al. [8] used a threshold value of 150 HU for the electronic removal of well-tagged stool. With PEG-C preparation, the contrast medium was diluted by residual fluid, but nearly all HU values of residual fluid in the colon remained higher than 150 HU. The values were high enough to differentiate the residual fluid from the colonic wall and tumors (Table 7). The variability of the HU values of residual fluid in the PEG-C group was relatively low (Table 7).

For well-tagged residual fluid, enough amounts of contrast media are needed. Fewer amounts of contrast media are preferred for patient acceptability because water-soluble contrast medium tastes bitter. We used only 20 ml of water-soluble contrast medium in PEG-C preparation. In the PEG-C preparation group, the HU values of residual fluid were *high* enough to reconstruct good contrast medium images (Table 7). PEG-C preparation is also safe for conventional colonoscopy, CT colonography, and surgery. Intracolonic explosions are rare complications of electrocautery during endoscopic treatment or surgery. These explosions result from the ignition of hydrogen or methane, two products of colonic bacterial fermentation. The PEG-C solution is virtually unfermented by colonic bacteria. The PEG-C preparation is, therefore, useful in cleansing the large intestine of patients who undergo CT colonography as well as conventional colonoscopy before surgery for colorectal tumor. In addition, the PEG-C preparation does not require any dietary restrictions. However, the administration of 2 l of PEG with PEG-C solution is of less volume than that of European standard bowel preparation and it warrants further examination.

The DCCTE does not require removal of residual fluid from the large intestine before examination and can be performed before conventional colonoscopy. However, conventional colonoscopy procedures immediately after CT colonography are technically difficult even for experienced colonoscopists owing to the presence of air in the colon [12]. Such air makes examinations time-consuming and uncomfortable for patients. MDCT scans are, therefore, performed after conventional colonoscopic examination at our hospital.

In addition to the creation of CT colonography images, preoperative MDCT data can be used for the detection of extracolonic abnormalities or metastases and for clinical staging in patients with colorectal cancer [18–20]. Because patients with colorectal cancer usually undergo preoperative staging by abdominal and pelvic CT and conventional

Table 5 Mean quality scores of CT colonography (presence or absence of blind spots)

	Cecum/ascending colon		Transverse colon		Descending colon		Sigmoid colon		Rectum	
	PEG	PEG-C	PEG	PEG-C	PEG	PEG-C	PEG	PEG-C	PEG	PEG-C
Reader 1	3.30	5.00	4.34	4.98	2.42	4.96	4.30	4.96	2.34	4.86
	$P < 0.0001$		$P < 0.0001$		$P < 0.0001$		$P < 0.0001$		$P < 0.0001$	
Reader 2	3.66	4.98	4.54	4.98	2.80	5.00	4.18	4.92	2.62	4.92
	$P < 0.0001$		$P < 0.0001$		$P < 0.0001$		$P < 0.0001$		$P < 0.0001$	

Table 6 Differences in inter-reader (reader 1 and reader 2) quality scores

	Cecum/ascending colon	Transverse colon	Descending colon	Sigmoid colon	Rectum
PEG preparation	$P = 0.065$	$P = 0.540$	$P = 0.140$	$P = 0.359$	$P = 0.236$
PEG-C preparation	$P = 0.863$	$P > 0.999$	$P = 0.730$	$P = 0.615$	$P = 0.842$

colonoscopy, the integration of CT data with a CT colonography imaging system would most likely enhance the accuracy of preoperative diagnosis.

The common accepted technique of CT scans for preoperative clinical staging is single positioning. By contrast, dual positioning is the commonly acknowledged technique of CT colonography. Many studies have reported that dual positioning helps to distend the colon, thereby facilitating the detection of polyps [21–25]. There were several limitations of this study because dual positioning was not performed. We cannot compare which techniques were better for CT colonography but warrant examination. However, there were some reasons for not using dual positioning at CT scans in our study. The DCCTE with single positioning could visualize nearly the entire large intestine because the colon was distended enough not only by air but also much amount of tagged fluid of PEG-C preparation. Another advantage is decreased exposure to diagnostic radiation. Radiation dose is an important consideration [26]. The intrinsic high contrast between the colonic wall and the air insufflated to distend the colon allows low-radiation dose protocols [27, 28]. Such low-radiation dose protocols provide adequate colonic detail for colorectal polyp screening but result in very limited views of extracolonic organs. Low-radiation dose protocols are intuitively attractive for screening but may not be appropriate for preoperative staging of patients with colorectal cancer in whom extra colonic findings assume a high degree of importance [29].

Conclusion

In conclusion, DCCTE after PEG-C preparation produces much superior images to that of air-contrast CT enema after PEG preparation. Our results show that DCCTE and conventional colonoscopy after PEG-C preparation are feasible and safe procedures that can be used for preoperative evaluation in patients with colorectal cancer. Because DCCTE is useful for tumor localization and can visualize the course and length of the colon without additional preoperative examinations, we feel that it will ultimately help in contributing to the optimal use of MDCT data for preoperative evaluation. The question whether it might have effects on tumor staging and post-surgical outcome remains opens and warrants further examinations.

Further studies for single or dual positioning, radiation dose, and related costs have to be needed if DCCTE after PEG-C preparation will have a more impact on preoperative staging for colorectal tumor.

Acknowledgements We wish to thank Mia Takahashi R.T., Keishi Watanabe R.T., Eiji Hidaka M.D., and Kishiko Tatsukawa M.D. for their technical cooperation, and Ms. Masako Kitatani for help in preparing the manuscript. This paper was presented in part at the 12th International Congress of the European Association for Endoscopic Surgery (EAES), Barcelona, Spain, June 9 to 12, 2004.

Table 7 Distribution of Hounsfield unit values of residual fluid

	HU values		*P* value
	PEG preparation	PEG-C preparation	
Cecum/ascending colon			
Mean±SD	19.7±9.1[a]	433.2±176.9[b]	<0.0001
Range	8–65	170–890	
Rectum			
Mean±SD	20.6±9.1[a]	328.6±137.5[b]	<0.0001
Range	10–62	130–717	

SD Standard deviation
[a] *P* value=0.555 on comparison of the cecum/ascending colon with the rectum in PEG preparation, Mann–Whitney *U* test
[b] *P* value=0.0005 on comparison of the cecum/ascending colon with the rectum in PEG-C preparation, Mann–Whitney *U* test

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特集

機能温存を念頭に置いた直腸癌治療

下部直腸・肛門管癌に対する究極の肛門救済手術
—新たなる発想と新展開—

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An Ultimate Anus-Salvaging Operation for the Lower Rectal or Anal Canal Cancer —New Idea and New Development—: Shirouzu K, Ogata Y, Akagi Y, Ogou S, Ishibashi S and Mori S (Dept of Surgery, Kurume Univ Faculty of Med)

For the advanced cancer of the lower rectum or anal canal which is extremely near to an anus, abdominoperineal resection which creates a stoma is common. To avoid a stoma as much as possible, we perform an ultimate anus-preserving operation, and this operation is based on a new idea that anal preservation is possible if we widely remove both internal and external sphincter muscles.

We reviewed the possibility from the pathologic findings and described the postoperative recurrence and survival, and the anal functional evaluation.

Key words: Anus-preserving operation, Anus-salvaging operation, Intersphincteric resection, Rectal cancer, Anal canal cancer

Jpn J Cancer Clin **52**(5): 411〜416, 2006

はじめに

肛門にきわめて近い下部直腸や肛門管の進行癌では，人工肛門を造設する直腸切断術が一般的である．われわれは，可能な限りこれを回避するために，広範囲に内外括約筋を切除すれば，肛門温存が可能という新たなる発想に基づき，究極の肛門救済手術を試みている．術式の可能性を病理学的所見から検討し，また，実際の臨床例における術後再発や生存率，肛門機能評価について述べる．

1. 病理学的検索

過去の腹会陰式直腸切断術211例について，既に報告したように[1]，全割階段切片法，スケッチ診断法により肛門管周囲組織への癌の浸潤・転移を詳細に検討すると，腫瘍の下縁が歯状線を超えない176例の下部直腸・肛門管癌（Pa癌）では，肛門管を構成する肛門挙筋，外肛門括約筋，括約筋間溝，坐骨直腸窩脂肪組織への癌の浸潤・転移はきわめてまれであった．腫瘍の下縁が歯状線を超える35例の下部直腸・肛門管癌（Pb癌）では，肛門挙筋，深・浅外括約筋，括約筋間溝への癌の浸潤・転移は約30%と高率であった．

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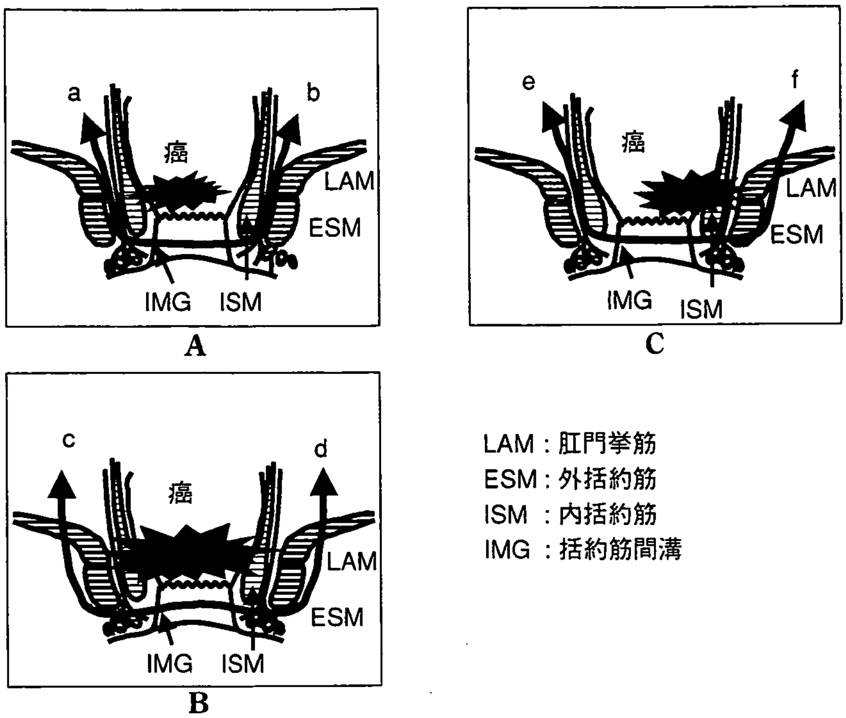

LAM：肛門挙筋
ESM：外括約筋
ISM：内括約筋
IMG：括約筋間溝

図1　切除線のシェーマ

A：Pa 癌における ISR の切除線を示す．切除線は a-b の線となる．
B：Pb 癌における ESR の切除線を示す．切除線は c-d の線となる．
C：腫瘍が片側に存在する場合には，腫瘍側では ESR，反対側では ISR の切除線を示す．

2. 理論的に考えられる術式

病理学的所見より2つの術式が理論的に考えられた．すなわち，図 **1A** に示すように，Pa 癌では外括約筋を温存して内括約筋を切除する ISR (Internal Sphincter Resection) が可能である．Pb 癌では，図 **1B** に示すように内括約筋とともに深・浅外括約筋を合併切除する ESR (External Sphincter Resection) が適応となる．ただし，Pa 癌でも深・浅外括約筋に浸潤があれば，ESR の適応であり，また逆に，Pb 癌でも深達度が SM や，MP の場合には，ISR でよいと思われる．また，図 **1C** に示すように，腫瘍の占居部位が左側あるいは右側に偏在している場合には，占居している側を ESR とし，反対側を ISR とすることも可能である．括約筋間溝に癌の浸潤・転移があれば，この手術の適応はない．

3. 術　式

1）恥骨直腸筋の切離

直腸前壁の腹膜翻転部を切開し，男性では精嚢・前立腺の後壁を，女性では膣後壁を十分に露出する．直腸後壁は Waldeyer 筋膜を穿破して左右の肛門挙筋を腹腔内から十分に露出した後，恥骨直腸筋を直腸より 1〜2 cm 程度離れた部位で電気メスにて切離する．恥骨直腸筋が完全に離断されると，坐骨直腸窩の脂肪組織が露出するのが確認できる．この切離線を尾骨に向かって延長し尾骨直腸靱帯を切離する．対側の恥骨直腸筋も同様に切離する．この時点で恥骨直腸筋の左右側壁，後壁が完全に切離されるが，前壁側の恥骨直腸筋は切離せず，後述する“肛門外直腸引き出し法”の際に経肛門的に切除する．

2）経肛門的直腸切除

肛門指診にて括約筋間溝を確認し，これを電気メスにて坐骨直腸窩脂肪組織に達するまで垂直に切り込む．左右の側壁も同様に切除した後，癌細

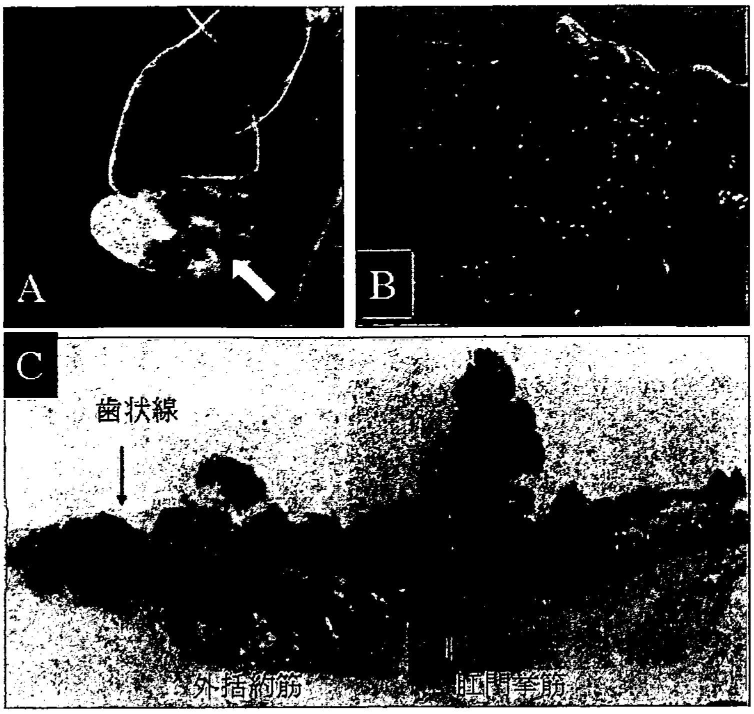

図2　ESRの症例
A：注腸造影所見で，下部直腸癌を示す．
B：切除標本で，歯状線に一部浸潤する2型の癌を示す．
C：病理所見で，外括約筋，歯状線に浸潤する深達度aiの癌で，外科的剥離面は陰性である．

胞の散布を防止する目的で肛門管の断端を縫合閉鎖する．パークスの肛門鏡を仙骨前に挿入し，直腸の口側断端を腹会陰式直腸切断術のように肛門外に引き出す(肛門外直腸引き出し法)．次いで，腹会陰式直腸切断術の要領で前壁側の恥骨直腸筋を切離する．男性では前立腺後壁を，女性では膣後壁を切離すると直腸を完全に摘出できる．

3）経肛門的結腸肛門吻合

S状結腸を肛門側に引き出し，まず3時，6時，9時，12時方向の4点で肛門皮膚粘膜，皮下外肛門括約筋，結腸全層の順で3-0 Vicryl糸をかけ，折り返し結腸粘膜と肛門皮膚粘膜のマットレス縫合を行う．その後，4点縫合部の両隣を順次縫合結紮し合計16～20針程度で吻合が完了する．最後に一時的回腸人工肛門を造設し手術を終了する．人工肛門閉鎖は6～10カ月後を目安とする．術式の詳細については既に報告しているので参照されたい[6~8]．

4. 臨床結果

2001～2005年半ばまでに，本術式を32例（Pa癌：29例，Pb癌：3例），（ISR：12例，ESR+ISR：10例，ESR：10例）に施行した．

ESRの症例を図2に提示する．術前の注腸造影は下部直腸癌（Rb-P）の症例である（図2A）．切除標本は腫瘍の肉眼型は2型で腫瘍下縁の一部は歯状線を越えているが，肛門側断端の距離は十分に確保されている（図2B）．病理所見では，腫瘍は外括約筋に浸潤する深達度aiの癌で，深・浅外括約筋が十分切除され，外科的剥離面に問題はなかった（図2C）．

この期間中に本術式が不可能であった症例は10例で，肛門周囲皮膚に浸潤する肛門管癌，Pagetoid病変を伴う肛門腺由来の肛門管癌，前立腺浸潤例等であった．術後合併症は，縫合不全が2例で，その他重篤な合併症は無かった．術後再発は5例に発症し，その詳細を表1に示す．ISRの2例のうち1例が側方リンパ節転

表1　再発例の内訳

年齢	性	stage	術式	再発部位	治療	再々発部位	転　帰
1.　45歳	F	3a	ISR	No 216, 282, 272	op	肺	27カ月死亡
2.　64歳	F	3a	ISR	骨盤内，腹膜	op	骨盤内	39カ月死亡
3.　60歳	M	3a	ESR	肝（同時性）	op	肺（op）	50カ月生存
4.　48歳	F	2	ESR＋ISR	No 262	op		30カ月生存
5.　75歳	M	2	ESR	肝	op		36カ月生存

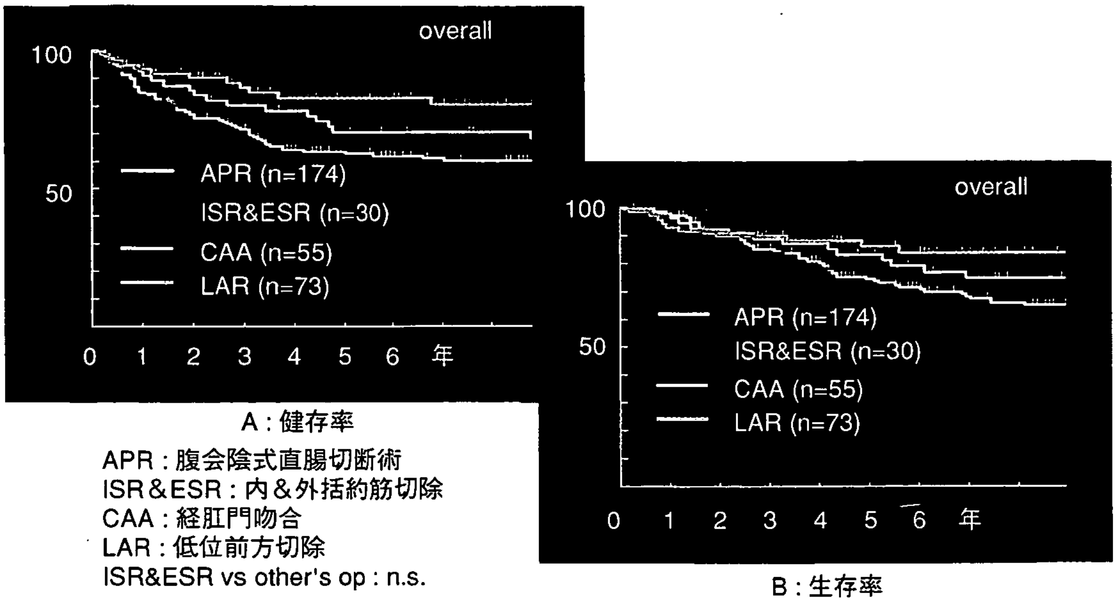

図3　健存率，生存率（治癒切除例）
A：健存率を示す．ISRとESRの4年健存率は81.3％であった．
B：生存率を示す．ISRとESRの4年生存率は78.6％であった．過去の術式と比較しても，いずれも有意な差は認められなかった．

移，大動脈周囲リンパ節転移根治術後，肺転移で死亡．他の1例は骨盤内再発，大網転移根治術後，再々発で死亡した．ESR＋ISRの再発の1例は，No262転移根治術後，再発なく生存中である．ESRの2例は，いずれも肝転移再発で根治切除後，再発なく生存中である．治癒切除症例の4年健存率，生存率は図3に示すように，それぞれ81.3％，78.6％で，過去の術式と比較しても有意な差は認められず，根治性に問題は無かったと思われる．

5.　肛門機能評価

肛門内圧を経時的に測定した．肛門管静止圧は図4Aに示すように，術後早期にはいずれの術式とも減弱した．ISRでは回復が良好であったが，ESRでは回復が悪かった．随意収縮圧は図4Bに示すように，改善傾向が著明であった．ESRはISRよりも回復が悪かったが，かなりの回復がみられた．また，肛門内圧検査と臨床症状は必ずしも一致せず，内圧検査が悪くても便漏れが改善した．

6.　考　察

下部直腸癌や肛門管癌は，坐骨直腸窩や肛門挙筋に沿ってのリンパ節転移の可能性が存在すること，肛門を温存することが技術的にきわめて困難なこと，さらに括約筋切除による肛門機能の廃絶などのために，肛門を救済することは不可能と考えられ腹会陰式直腸切断術が一般的に施行されてきた．しかし最近，肛門にきわめて近い下部直腸

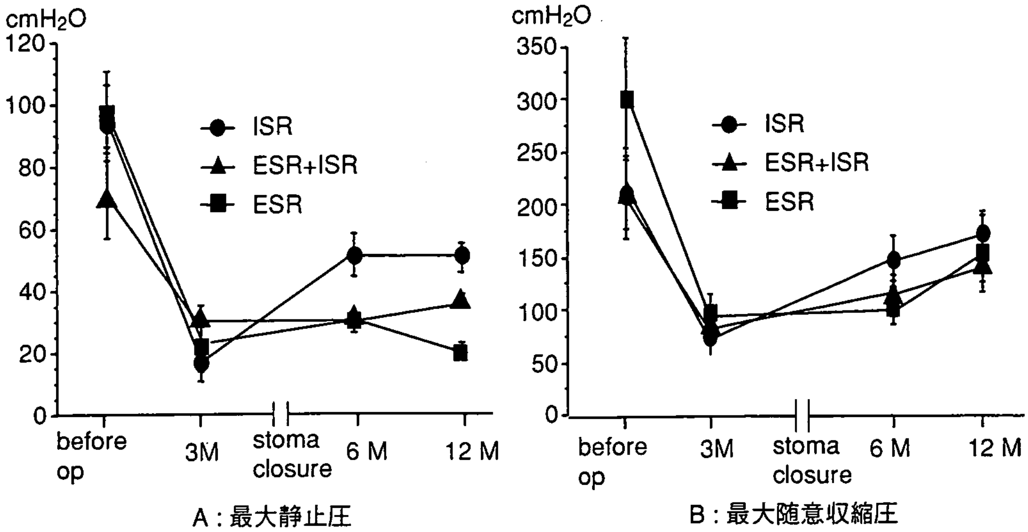

図4　肛門機能検査

A：最大静止圧を示す．ISRでは良好な回復が認められたが，ESRでは回復は悪かった．

B：最大随意収縮圧を示す．ISRでは著明な回復を示した．ESRでもかなりの回復がみられた．

癌に対して，外肛門括約筋（外括約筋）を温存して内肛門括約筋（内括約筋）を切除し肛門機能を温存しようとする試みがなされている[2~6]．このような新しい時代の流れの中で，われわれはさらに一歩前進し，肛門管内に腫瘍下縁がある下部直腸癌癌や肛門管癌に対しても，恥骨直腸筋を切離しながら深・浅外括約筋を合併切除して肛門を温存する新しい肛門救済手術を施行している[7,8]．本術式の問題点は，腫瘍学的な根治性，肛門機能評価などが重要である．根治性の面から言えば，諸外国の著者らが報告しているように[4,9~11]，再発率や生存率に従来の手術法に比べて有意な差は認められない．ESRを施行した症例の術後の病理標本においても，外科的切離面には全く問題はなく，根治術が可能であることが証明された．

ESR術後の肛門機能の評価については，肛門管最大静止圧はあまり改善が認められなかったが，最大随意収縮圧は改善傾向が認められた．Sciessel[9]やSaito[12]らは，ISRの症例では外括約筋による随意収縮圧が改善したことを報告している．ESRでは，ISRに比較して改善傾向は低いが，皮下外括約筋の収縮機能がわずかではあるが温存され，これが肛門機能の改善につながっているものと思われる．その要因として，肛門機能の自己訓練やバイオフィードバックなどが一役を担っているものと考えている．肛門に極端に近い下部直腸癌や肛門管癌は，頻度的にはそれ程多くはないが，このような症例に対し腹会陰式直腸切断術を第一選択とする前に，肛門救済という面から本術式の可能性を考慮することも重要であろう．また，長期的な予後や肛門機能の評価が今後の課題である．

まとめ

下部直腸癌，肛門管癌に対する本術式は，深・浅外括約筋合併切除を施行する新しい肛門温存手術で，言わば究極の肛門救済手術である．本術式が腹会陰式直腸切断術に代わる術式として，許容される時代がくることを期待している．

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手術手技

下部直腸・肛門管癌に対する肛門救済手術

Anus-salvaging operation for lower rectal or anal canal cancer

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下部直腸・肛門管癌に対する究極の肛門救済手術について述べた．まず，理論的背景として過去の腹会陰式直腸切断術の症例について肛門管周囲組織への浸潤・転移の有無を病理学的に検討し，これらの癌に対しても肛門救済が可能であることを示した．次に実際の手術手技について，そのポイントを解説した．

はじめに

下部直腸癌や肛門管癌は，坐骨直腸窩や肛門挙筋に沿ってのリンパ節転移の可能性が存在すること，肛門を温存することが技術的にきわめて困難なこと，さらに括約筋切除による肛門機能の廃絶などのために，肛門を救済することは不可能と考えられ腹会陰式直腸切断術が一般的に施行されてきた．しかし最近，肛門にきわめて近い下部直腸癌に対して，外肛門括約筋(外括約筋)を温存して内肛門括約筋(内括約筋)を切除し肛門機能を温存しようとする試みがなされている[1)-5)]．このような新しい時代の流れの中で，われわれはさらに一歩前進し，肛門管内に腫瘍下縁がある下部直腸癌や肛門管癌に対しても，恥骨直腸筋を切離しながら深・浅外括約筋を合併切除して肛門を温存する新しい肛門救済手術を施行しているので[6)7)]，その理論的背景と手術手技の実際を紹介したい．

I．肛門管の局所解剖

肛門管の局所解剖については，すでに報告しているので[6)7)]，ここでは簡単に述べることにする．直腸の輪状筋は，肛門管の中では豊富な弾性繊維を有する厚い内括約筋に変化し，歯状線より約1～2 cm下端で終末となる．直腸の縦走筋は恥骨直腸筋，深・浅外括約筋の内側を走り，皮下外括約筋を貫き，皮下組織で終末となる．深外括約筋は恥骨直腸筋と連続しているが，筋繊維の走行はお互いに異なる．浅外括約筋は深外括約筋と連続性を保ち筋繊維の走行も同じある．皮下外括約筋は，肛門を取り巻く最下端の輪状の筋組織である．外括約筋にも豊富な弾性繊維が存在する．括約筋間溝は，肛門縁より約1 cm程度の部位に存在する輪状に陥凹する溝である．この溝は内括約筋の終末部と皮下外括約筋の内側上縁の境界に相当し，直腸指診で抵抗の弱い溝として触知できる．この手術のキーポイントとなる重要な部分である．

II．病理学的理論的背景

1．内・外肛門括約筋切除

1982～2004年までに当科にて腹会陰式直腸切断術を施行された直腸癌215例(肛門癌を除く)に

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Key words：直腸癌／肛門温存術／肛門救済手術／内肛門括約筋切除／外肛門括約筋切除

0433-2644/06/¥50/頁/JCLS

ついて，病理組織所見を見直してみた．表1に示すように，腫瘍の下縁が歯状線を越えないもの(Pa 癌)では，肛門挙筋，深・浅外括約筋への浸潤転移は11%であった．また，皮下外括約筋，括約筋間溝，坐骨直腸窩脂肪組織への浸潤転移もきわめて低率であった．一方，腫瘍下縁が歯状線を越えるもの(Pb 癌)では，それらへの浸潤転移が高率であった．したがって，腫瘍下縁が歯状線を越えないPa 癌の場合には，癌が深・浅外括約筋や肛門挙筋へ浸潤転移することは少ないために，図1a に示すように内括約筋を合併切除することによって根治性が得られる．しかし，腫瘍下縁が歯状線を越えるPb癌の場合には，深・浅外括約筋や肛門挙筋に浸潤転移する頻度が高率なために，内括約筋を合併切除しても外科的剝離面(EW)を確保できず，癌の遺残が生じ根治術にはなり得ない．この場合には図1bに示すように，恥骨直腸筋を切離し，深・浅外括約筋を合併切除してEW を確保することによって，完全な根治性を得ることができる．皮下外括約筋や坐骨直腸窩への浸潤・転移はきわめてまれであるため，これらを温存し結腸と皮下外括約筋，肛門皮膚粘膜を吻合すれば，肛門救済が可能となる．もちろん，Pb 癌でも浸潤が内括約筋にとどまる場合には，内括約筋切除でよいと思われる．

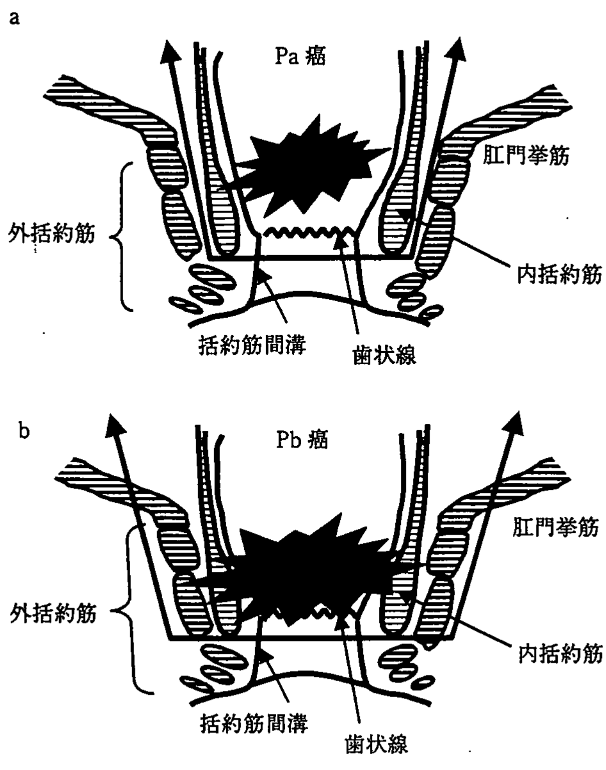

図1 切除線のシェーマ
Pa 癌ではa に示すように，内括約筋切除で十分に根治性が得られる．Pb 癌ではb に示すように，外括約筋切除によって根治性が得られることが多い．

2．肛門側切除断端の距離

肛門側切除断端の距離については，最近では1〜2 cm で十分であるとする意見が多い．私どもの検討でも Dukes A では肛門側進展は存在せず，Dukes B，C でも1.2%，9.7%と低率で，しかも進展距離が2 cm を越えるものはきわめて少なかった[10]．したがって肛門側切除断端の距離は

表1 肛門管周囲組織への癌浸潤・転移の有無
1982〜2004年

肛門管周囲組織	Pa 癌(n=177) 有り	無し	Pb 癌(n=38) 有り	無し	p-value
肛門挙筋 深・浅外括約筋	20 (11)	157	13 (34)	25	p<0.001
皮下外括約筋	2 (1)	175	3 (8)	35	p<0.05
括約筋間溝	4 (2)	173	10 (26)	28	p<0.0001
坐骨直腸窩 脂肪組織	0	177	4 (11)	34	p<0.001

( )：%

2 cm で十分であるが，癌が歯状線を越えている場合にはやむを得ず 1 cm でも良いと思われる．

III．内・外肛門括約筋合併切除の適応

腫瘍下縁が肛門縁から 1 ～ 4 cm に存在する下部直腸・肛門管癌で，括約筋間溝に癌の浸潤転移が認められない症例を適応としている．

深達度に関しては，術前に MP 以浅であることが確実であれば，内括約筋切除でよいと思われるが，診断が不確実であれば，癌遺残の危険性が高い内括約筋切除よりも内・外括約筋合併切除の方が安全と考えている．ただし，腫瘍が比較的小さい場合には，腫瘍側では内・外括約筋切除を行い，腫瘍の反対側は内括約筋切除を行うという選択もあり得る．このように種々のオプションがあり得るので，個々の症例に応じた術式を考えていかなければならない．

IV．手術術式

1．恥骨直腸筋の切離

直腸の剝離は通常の低位前方切除術に準じて行う．ここでは直腸前壁の剝離と恥骨直腸筋切離の要点を述べる．直腸前壁の腹膜翻転部を切開し，男性では精嚢・前立腺の後壁を，女性では腟後壁を露出しながら Denonvilliers 筋膜を切除する．この操作は腹腔側からでは見え難い位置であるが，十分に剝離をしておいた方がよい．この方が後述する“肛門外直腸引き出し法”を容易に施行できる．直腸後壁は仙骨前面の静脈叢を損傷しないように注意深く行い，Waldeyer 筋膜を穿破して左右の肛門挙筋を腹腔内から十分に露出する．肛門挙筋の最内側に位置する恥骨直腸筋を直腸より 1 ～ 2 cm 程度離れた部位で電気メスにて切離する．恥骨直腸筋が完全に離断されると，坐骨直腸窩の脂肪組織が露出するのが確認できる(図 2)．この切離線を尾骨に向かって延長し尾骨直腸靱帯を切離する．その後，対側の恥骨直腸筋を同様に切離し，坐骨直腸窩の脂肪組織を露出させながら切離線を連続させる．この時点で恥骨直腸筋の左右側壁，後壁が完全に切離されるが，前壁側の恥骨直腸筋は切離せず，後述する“肛門外直腸引き出し法”の際に経肛門的に切除する．

2．経肛門的直腸切除

肛門指診にて肛門縁を取巻く皮下外括約筋を触

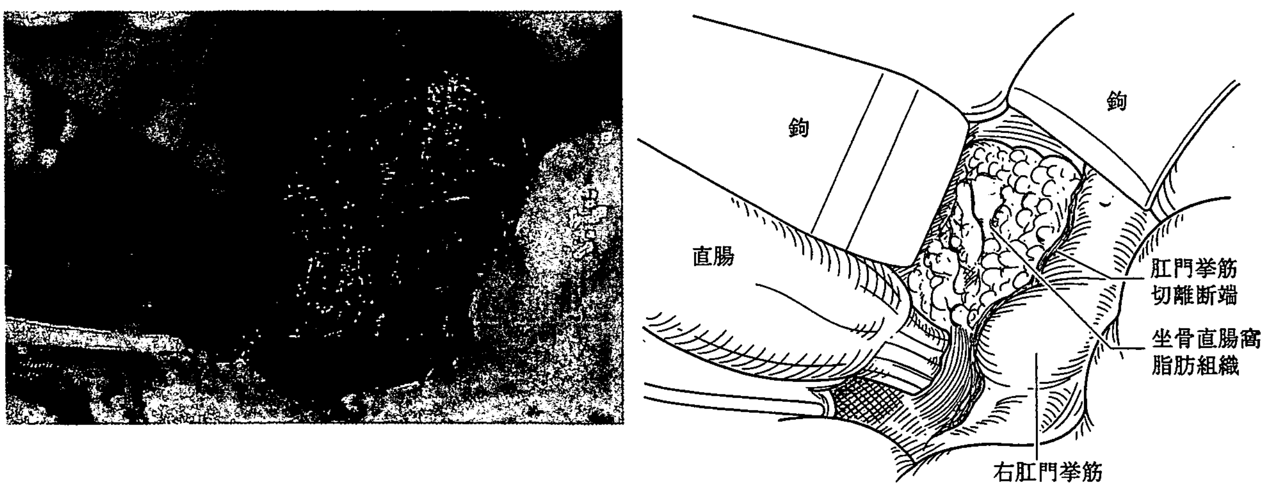

図 2　肛門挙筋切離
右肛門挙筋を切離すると，坐骨直腸窩の脂肪組織が露出される．