which were not stained even on IRL (non-SNs) for five patients. Of these five cases, all the tumors were of pT3 stage. Successful SN mappings on IRL without false negatives were achieved in 42 patients (Table I).

The number of patients in each pT category (histological extent of the primary tumor) of the TNM classification (10) is shown in Table I. The tumor site and differentiation were unrelated to the feasibility of SN mapping. The overall false-negative rate was 46.2% (66.7% in T3 disease) by IRL. There were no false-negative cases in T1 and T2 disease by IRL. In patients with stage pT3 CRC, laparoscopic SN mapping was not difficult, but resulted in a high number of false-negative (Table I) responses.

IRL detected additional SNs not identified on CL in 44 out of the 47 patients (93.6%). The average number of SNs identified on IRL was 3.5 per patient. From the resected specimens, the average number of lymph nodes was 21.0±11.4 [SD] per patient (range 6-58). The total number of SNs identified was only 32 (0.68±0.86 [SD] nodes/patient, range 0 - 3) on CL, as compared to 169 (3.5±1.7 [SD] nodes/patient, range 0 - 7) on IRL (Table II). IRL detected SN, even in a patient with a BMI of 30. In this obese patient, seven SNs were detected on IRL as compared with none on CL.

Four out of the 29 patients with stage T1 and T2 CRC were found to have lymph node metastasis on histopathological examination (Table III). CL could not detect SNs that contained metastasis. Four metastatic lymph nodes were included among 17 lymph nodes identified by IRL to be SNs (positive). No metastatic lymph node was included among 53 lymph nodes identified by IRL as non-SNs (negative).

Table III. *Identification of lymph node metastasis on conventional laparoscopy and infrared ray laparoscopy (T1-T2).*

		Proportion of nodes with metastasis			
		CL		IRL	
Patient	No.	Positive[a]	Negative[b]	Positive[a]	Negative[b]
1	15	0/1	1/14	1/5	0/10
2	13	0/0	1/13	1/2	0/11
3	16	0/2	1/14	1/6	0/10
4	26	0/1	1/25	1/4	0/22
Total	70	0/4	4/66	4/17	0/53

No. = number of resected lymph nodes, CL = conventional laparoscopy, IRL = infrared ray laparoscopy.
[a]Number of histologically confirmed lymph nodes as a proportion of number of resected lymph nodes stained on either CL or IRL. [b]Number of histologically confirmed lymph nodes as a proportion of number of resected lymph nodes not stained on CL or not stained on IRL.

Discussion

Recent studies have indicated that LAC is a safe and feasible procedure for the treatment of CRC (11-13). Increasing evidence suggests that SN mapping is useful for the evaluation of CRC (3-6). Intra-operative SN mapping and SN biopsy can potentially be combined with minimally invasive surgery for CRC.

Our study led to three major findings. First, the observation of the ICG dye stain in SNs by IRL was far superior to that by CL. The identification of SNs on IRL was approximately five times better than that on CL (Table II). SN mapping on IRL might be useful in obese patients with large amounts of mesenteric adipose tissue and warrants further examination.

Second, the technique of saline injection before dye injection facilitated easy and precise SN mapping for CRC during LAC. In a previous study, most unsuccessful mappings in patients with CRC were due to incorrect dye injection technique (5). The technique of saline injection before dye injection resolves this technical problem and is not operator-dependent. The technique we developed uses readily available dye capable of being used in a wide range of patients, without interfering with surgical procedures or pathological diagnosis.

Our third major finding was that SN mapping on IRL might be feasible for stage T1 and T2 CRC (Table I, III). When obvious nodal metastases are present, the lymph flow through these nodes may be obstructed by tumor, leading to lymph drainage through alternative pathways (14). The route of lymph flow may also be affected by tumor growth into the bowel wall (5). A recent report has reported that locally advanced tumors and palpable nodes may partially account for a high false-negative rate (15). In our study, the overall false-negative rate was 46.2% (66.7% in T3 disease) by IRL. There were no false-negative cases in T1 and T2 disease by IRL. Therefore, SN mapping might be feasible for the evaluation of T1 and T2 stage CRC. This means that preoperative T-staging should be done before SN mapping.

Our procedure was easy to perform and had a high success rate. However, more experience is necessary before SN mapping can be routinely used during LAC in patients with CRC.

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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

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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.

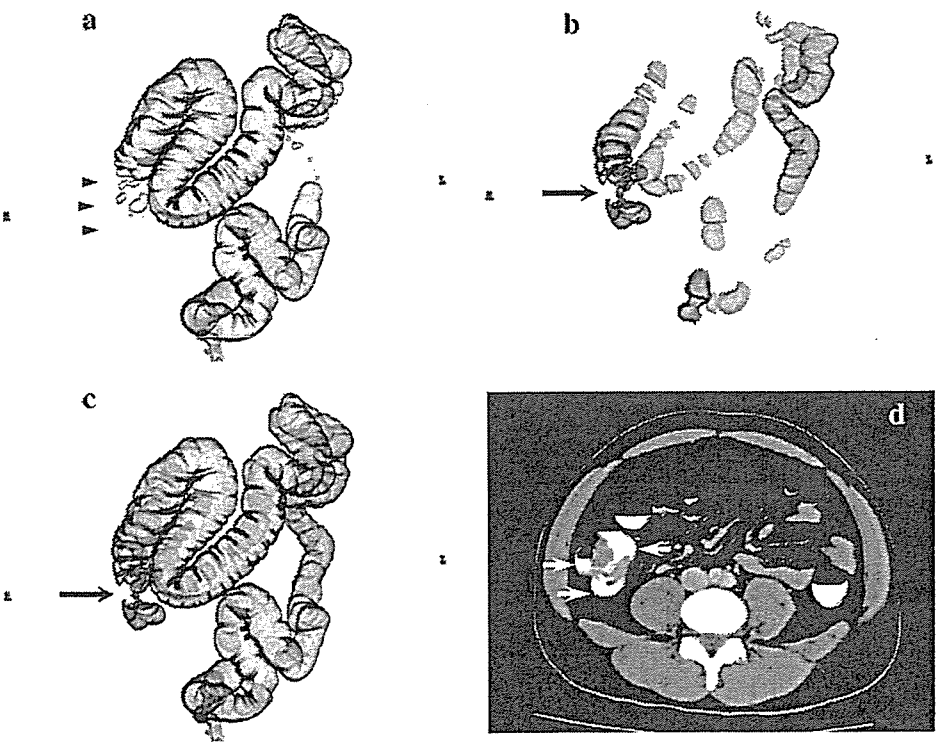

Fig. 1 Dual-contrast CT enema in PEG-C preparation group: **a** Air image (air-contrast CT enema) shows blind spots in the cecum and proximal descending colon. Air images cannot detect the lesion because it is concealed by residual fluid in the cecum (*arrowheads*). **b** Contrast-medium image can detect 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

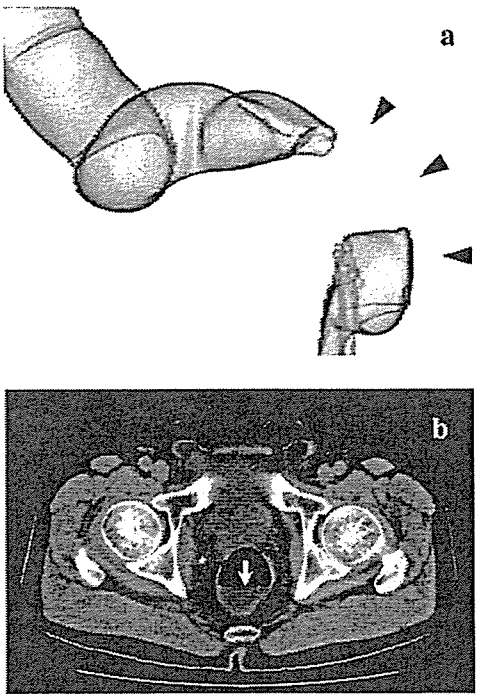

Fig. 2 Air-contrast CT enema in PEG preparation group: **a** Air-contrast CT enema shows a blind spot in the rectum. The ulcerated lesion (*pT2*) in the rectum was not detected (*arrowheads*). **b** In the transverse two-dimensional CT image, the tumor was concealed by residual fluid in the rectum (*arrow*).

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.

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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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ORIGINAL ARTICLE

Real-time in vivo virtual histology of colorectal lesions when using the endocytoscopy system

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Background: The histological findings of GI lesions are based on light-microscopic examination of H&E-stained thin-slice specimens. Recently, a concept of optical biopsy has been advocated. A study of the observation of colorectal lesions using endocytoscopy to obtain real-time histological images in vivo during endoscopy was performed.

Design: Prospective study.

Aim: To evaluate the usefulness of optical biopsy of colorectal lesions with the endocytoscopy (E-C) system.

Patients: The subjects were 113 consecutive patients who underwent a complete colonic examination, from April 2003 to March 2004, performed by a single colonoscopist.

Setting: Digestive Disease Center of Showa University Northern Yokohama Hospital.

Results: With E-C, it was possible to observe lesions at the cellular level and evaluate cellular atypia in addition to structural atypia in vivo. The correlation was statistically significant between the endocytoscopic diagnosis and the histological diagnosis.

Limitations: The endocytoscope had to be touched to the target colonic glands.

Conclusions: It was possible to distinguish neoplastic from non-neoplastic lesions, and also possible to distinguish invasive cancer from adenoma. 'Ultra-high' magnifying endoscopy, the E-C system, provides real-time histological images in vivo, which correspond well with those of H&E-stained microscopic images. (Gastrointest Endosc 2006;63:1010-7.)

With recent advances in endoscopic instruments and techniques, various new methods have been developed in addition to conventional endoscopy. Chromoendoscopy and magnifying endoscopy are now regarded as essential for diagnosing early colorectal lesions.[1] Our group has reported on pit-pattern diagnosis with magnifying endoscopy, describing the correlation between the pit-pattern findings and histologic diagnoses.[2,3] The pit-pattern analysis makes it possible to predict a histologic diagnosis of early colorectal lesions before resection.

There have been reports on laser-scanning confocal microscopy (LCM) imaging of untreated specimens from the GI tract, including the esophagus, the stomach, and the colon.[4,5] Sakashita et al[6] reported on virtual histology of colorectal lesions when using LCM and showed that LCM images corresponded well with H&E-stained microscopic images. Observation of the rectal mucosa in vivo was also performed by using a probe-type LCM endomicroscope, but the images obtained were not as clear as those provided by the in vitro LCM system.

The theory of contact endoscopy was applied to the endocytoscopy (E-C) system. Contact endoscopy was first described by Hamou[7,8] as microhysteroscopy to examine the surface of the genital tract at high magnification. Since 1979, the application of contact endoscopy has been extended to larynx, nose, and other sites. For the GI tract, Tada et al[9] first reported on ultrahigh magnifying endoscopy for colorectal lesions. Ooue,[10] Kumagai et al,[11,12] and Inoue et al,[13,14] independently reported on the experience of using prototype contact endoscopy for the digestive tract. The E-C system is a novel ultrahigh magnifying endoscopy, which enables microscopic observation at the cellular level and can be applied clinically.

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In the present study, we investigated the relation between real-time images by E-C in vivo and histologic images of colorectal lesions. The E-C system is a novel method of noninvasive imaging that is able to provide real-time microscopic images from colorectal lesions in vivo.

PATIENTS AND METHODS

Patients

The subjects are 113 consecutive patients who underwent a complete colonic examination, from April 2003 to March 2004, performed by a single colonoscopist (K.S.). Written informed consent was obtained from all the patients before the examination. The first conventional colonic examination was performed. Patients without any localized colorectal lesions or with lesions larger than 40 mm in diameter were excluded from the study, thus 60 patients were enrolled for the E-C examination. Of 60 patients, 43 were men and 17 were women, and the mean age was 57.4 ± 8.3 years. All the patients had their lesions treated endoscopically or surgically at the Digestive Disease Center of Showa University Northern Yokohama Hospital. Ethical approval was granted by the ethics review committee of our hospital, and informed consents for colonoscopy and clinical trial were obtained.

Instruments

A colonoscope, CF-Q240ZI (with a magnifying power of ×100 at maximum), CF-Q240AI, or CF-XT240I (Olympus Optical Co, Ltd, Tokyo, Japan) and newly developed endocytoscopes, prototypes I and II (Olympus) were used in the study.

E-C system

An endocytoscope is a soft-catheter–type endoscope, with an outside diameter of 3.4 mm at the distal end and 3.2 mm at the shaft, and with a working length of 250 cm and a total length of 380 cm, which uses a lens system for magnification (Fig. 1A). The prototype I endocytoscope (low-resolution type) has a magnification capability of ×450, the depth of field is 50 μm, the field of view is 300 × 300 μm, and the spatial resolution is 1.7 μm. The prototype II endocytoscope (high-resolution type) has a magnification capability of ×1125; the depth of field is 5 μm, the field of view is 120 × 120 μm, and the spatial resolution is 4.2 μm. Both prototype endocytoscopes were set up with a fixed focus. The E-C system can be passed through the working channel of the colonoscope (Fig. 1B).

Methods

After detection with a conventional colonoscope, the lesion was stained with 1% methylene blue.[15] The excessive stain was washed off to avoid overstaining the cells.

Capsule Summary

What is already known on this topic

- A pit-pattern diagnosis correlates with histology, making it possible to assess early colorectal lesions before endoscopic resection or surgery.
- The E-C system applies contact endoscopy in a novel ultrahigh magnifying endoscope, which enables microscopic observation at the cellular level.

What this study adds to our knowledge

- In a blinded study of 75 lesions detected by colonoscopy, the real-time histologic images obtained by the E-C system closely correlated with histology.
- The E-C system allows viewing of lesions at the cellular level and evaluation of cellular and structural atypia in vivo.

Then, the E-C scope was passed through the working channel of the colonoscope. To obtain real-time images of the lesions at the cellular level in vivo, the tip of the instrument had to be touched to the target colonic glands. After a magnifying endoscopic examination, we observed most of the surface of the lesion by the E-C system if the lesions were 20 mm or less. For those more than 20 mm, the E-C system was used at the important part of the lesions that had been detected by magnifying endoscopy. It takes a few minutes to perform dye staining, and approximately 10 to 20 minutes to observe the surface of the lesion with the E-C system. The prototype I endocytoscope, low-resolution type, was used in all the lesions. However, the prototype II endocytoscope, high-resolution type, was required in cases where such colonic glands were not clearly observed with the prototype I endocytoscope. A pathologist, who was blinded to the conventional colonoscopic views and to the final histologic diagnosis, made a diagnosis of the E-C images by reviewing the digital files of the images. The criteria for the diagnosis is almost the same as for the histologic diagnosis[16] except that the E-C images are views obtained from the surface and are not the vertical section of the lesions. The factors that were considered included (1) pattern of the cellular arrangement; (2) size, shape, and arrangements of colonic glands (pits); (3) size and shape of the cells; (4) size and shape of the nuclei; and (5) nuclear-cytoplasmic ratio. The E-C diagnosis of high-grade adenoma was made according to the following criteria: (1) disorder of polarity, (2) deformity of nuclei, (3) enlargement of nuclei, (4) various shapes of cells, (5) higher cellular density, (6) increased nuclear:cytoplasmic ratio, and (7) irregular colonic glands. In other words, we could evaluate these 7 points of criteria of high-grade adenoma from the E-C images. All the E-C images were reviewed by a single pathologist.

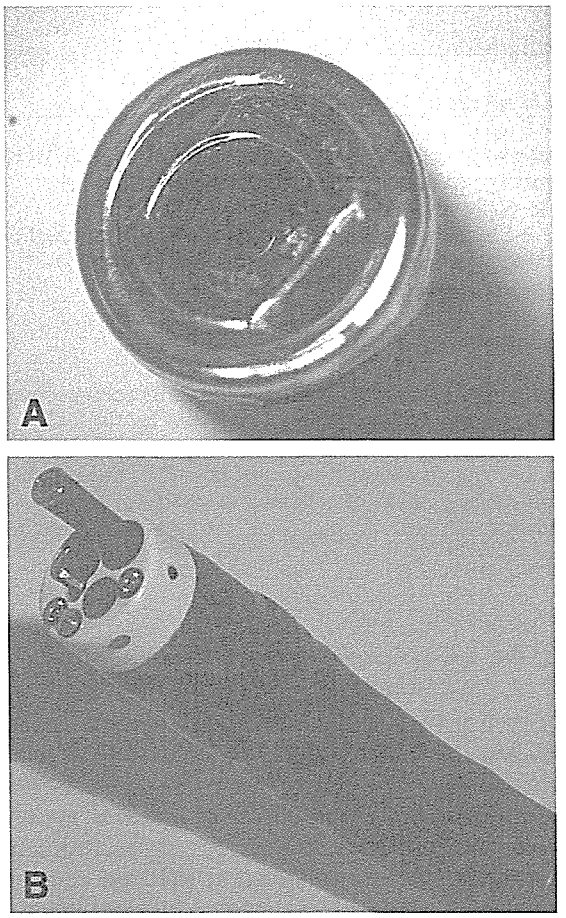

Figure 1. Endocytoscope. **A,** Endocytoscope is a soft-catheter–type endoscope with an outside diameter of 3.4 mm at the distal end. **B,** Endocytoscope can be passed through the working channel of endoscope.

Final histologic diagnosis on the resected specimens was made according to World Health Organization classification,[16] independently by the second pathologist, who was blinded to the conventional colonoscopic and E-C diagnoses. A pit-pattern diagnosis obtained from magnified endoscopic images was made on the basis of Kudo's classification.

After the diagnosis was determined and fixed, the E-C images for each lesion were compared with the H&E-stained slides, not only of the vertical section of specimens but also of the horizontal section of specimens.

Statistical analysis

The statistical analysis was performed by using computer software (SPSS for Windows, version 13.0; SPSS Japan Inc, Tokyo, Japan). The kappa value was used for statistical analysis to assess the differences between histologic and E-C diagnoses. The χ^2 calculation was used for statistical analysis to evaluate the ability of the E-C system for the differential diagnosis. A P value $<.05$ was considered statistically significant.

RESULTS

Seventy-five lesions were detected and endoscopically or surgically resected. In 8 randomly selected cases, the adjacent mucosa of the lesions that looked normal by conventional endoscopy was also subject to analysis as a control when using the E-C system.

Diagnosis of normal colonic mucosa

The criteria for the E-C system for the diagnosis of normal colonic mucosa were as follows: uniform glands were arranged regularly and nuclei along the basement membrane were visualized. As shown in Table 1, the diagnosis of normal colonic mucosa with the E-C system was histologically confirmed in all 8 cases studied. A representative case is shown in Figure 2A and B. The result with the magnifying endoscopy of the same lesion, which showed round pits and also classified as type I in the Kudo's classification, is also shown as a reference in Figure 2C.

Diagnosis of hyperplastic polyps

The criteria of E-C system for the diagnosis of hyperplastic polyps were as follows: serrated glands that were clearly observed and small vacuole that appeared to correspond to foamy change of cytoplasm of hyperplastic epithelia. As shown in Table 1, the diagnosis of hyperplastic polyp with the E-C system was histologically confirmed in all 8 cases studied. A representative case is shown in Figure 3A and B. The result with the magnifying endoscopy of the same lesion, which showed star-like pits and also was classified as type II in Kudo's classification, is also shown as a reference in Figure 3C.

Diagnosis of low-grade adenomas

The criteria of the E-C system for the diagnosis of low-grade adenomas were as follows: tubular glands were homogeneous in size, nuclei were fusiform and regularly arranged along the basement membrane, there was only a slight disorder of polarity, and cellular density was low. As shown in Table 1, the diagnosis of low-grade adenomas with the E-C system was histologically confirmed in 14 of 15 cases studied. A representative case is shown in Figure 4A and B. The result with the magnifying endoscopy of the same lesion, which showed long tubular pits and also classified as type IIIL in Kudo's classification, is also shown as a reference in Figure 4C.

Diagnosis of high-grade adenomas

The criteria of the E-C system for the diagnosis of high-grade adenomas were as follows: nuclei were arranged in the luminal side for the gland; the glands branched out irregularly; disorder of polarity, deformity, and enlargement of nuclei; and various shapes of cells from the viewpoint of cellular atypia were there. As shown in Table 1, the diagnosis of high-grade adenomas with the E-C system was histologically confirmed in 28 of 31 cases studied.

TABLE 1. Accuracy of E-C diagnosis in colorectal lesions

	Histologic diagnosis				
E-C diagnosis	**Normal mucosa**	**Hyperplastic polyp**	**Low-grade dysplasia**	**High-grade dysplasia**	**Invasive cancer**
Normal mucosa	8				
Hyperplastic polyp		8			
Low-grade dysplasia			14	3	
High-grade dysplasia			1	28	1
Invasive cancer					12

Kappa value 0.910.

A representative case is shown in Figure 5A and B. The result with the magnifying endoscopy of the same lesion, which showed that the fine structure of the surface was slightly irregular, is also shown as a reference in Figure 5C.

Diagnosis of invasive cancers

The criteria of the E-C system for the diagnosis of invasive cancers were as follows: there were marked deformities and enlargement of nuclei; colonic gland structure was hardly recognized, because of ulceration and exposure of the desmoplastic reaction at the surface; the nuclei were swollen and round; and vesicular and coarse chromatin were recognizable only by prototype II endocytoscope, high-resolution type. As shown in Table 1, the diagnosis of invasive cancers with the E-C system was histologically confirmed in 12 of 13 cases studied. A representative case is shown in Figure 6A. The result with the magnifying endoscopy of the same lesion, which showed fine structure of the surface, was destroyed and looked nonstructural, and is also shown as a reference in Figure 6B.

A comparison between E-C and histologic diagnoses is shown in Table 1. The overall accuracy was 93.3%. The kappa value between the E-C diagnosis and the histologic diagnosis was 0.910; therefore, the correlation was statistically significant. As for differential diagnosis between neoplastic and non-neoplastic lesions, the P value was $<.01$ (Table 2). Concerning the differential diagnosis between adenoma and invasive cancer, the P value was $<.01$ (Table 3). The differential diagnostic ability of E-C system was statistically confirmed by the χ^2 test.

DISCUSSION

Conventional histology with light microscopy has been based upon a consecutive management of specimens involving formalin fixation, paraffin embedding, thin slicing of the specimen with a microtome, dye staining, and finally mounting the specimen on a glass slide. It usually takes several days to obtain the histologic diagnosis because of involvement of many processes before microscopic examination. In comparison with biopsy, the E-C system provides real-time microscopic images in vivo during endoscopy. Moreover, there is no assurance that you are taking a biopsy specimen from the appropriate parts of the lesion, and the histologic diagnosis made on the biopsy specimens may not be representative of the lesion as a whole. In E-C, however, we are able to observe the entire surface of the lesion. We cannot perform a biopsy in patients with thrombocytopenia or in those who are taking anticoagulant medicine, because it may cause hemorrhage. In contrast, E-C is a safe method of examination even in such risky patients.

We believe this report is the first of a kind to evaluate the usefulness of E-C system for colorectal lesions. The E-C system can provide real-time images in vivo, corresponding well to the light microscopic images of the H&E-stained horizontal cross-section of the resected specimens. It is a catheter-type endoscope, which uses a magnifying lens system for magnification.

Chromoendoscopy and magnifying endoscopy are often used now, in addition to conventional endoscopy.[1] Magnifying endoscopy has been established as a clinically useful method, especially for the diagnosis of early colorectal lesions. Our group has reported on the pit-pattern diagnosis when using magnifying endoscopy, describing the correlation between the pit-pattern findings and pathologic diagnoses.[2,3] This pit-pattern diagnosis makes it possible to differentiate between neoplastic and non-neoplastic lesions, and to predict the depth of cancers before endoscopic resection or surgery.[2,3] However, with magnifying endoscopes, we can observe the structural atypia of the lesions but cannot evaluate the cellular atypia.

There were reports on virtual histology of colorectal lesions when using LCM and a probe-type LCM endomicroscope. The images could be obtained by using E-C without dye staining. But it was difficult to obtain clear images from the target in the proximal colon. The probe-type LCM images were not as clear as the images in vivo, which were provided by the E-C system.

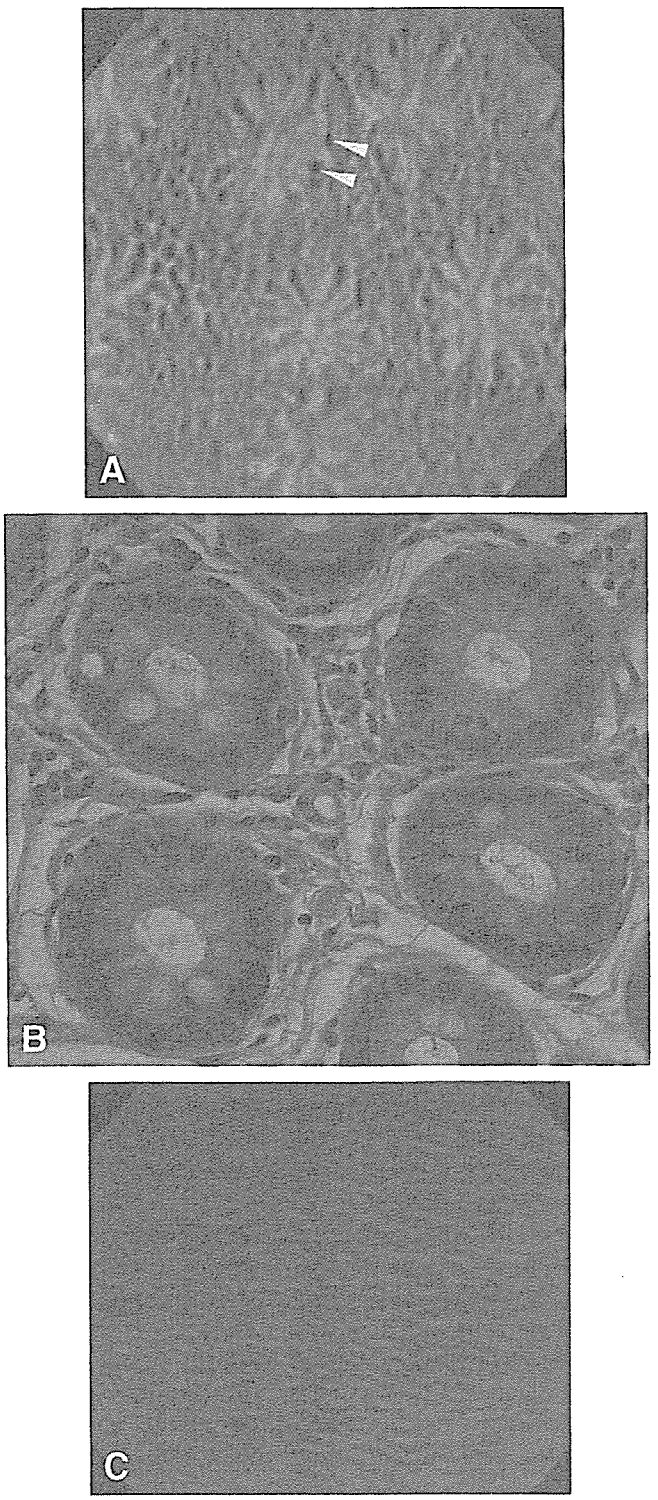

Figure 2. Normal mucosa. **A,** Endocytoscopic image. Nuclei (*yellow arrowhead*) along the basement membrane were visualized (orig. mag. ×450). **B,** Horizontal cross-section of tissue (H&E, orig. mag. ×400). **C,** Magnified endoscopic view after crystal violet dye staining.

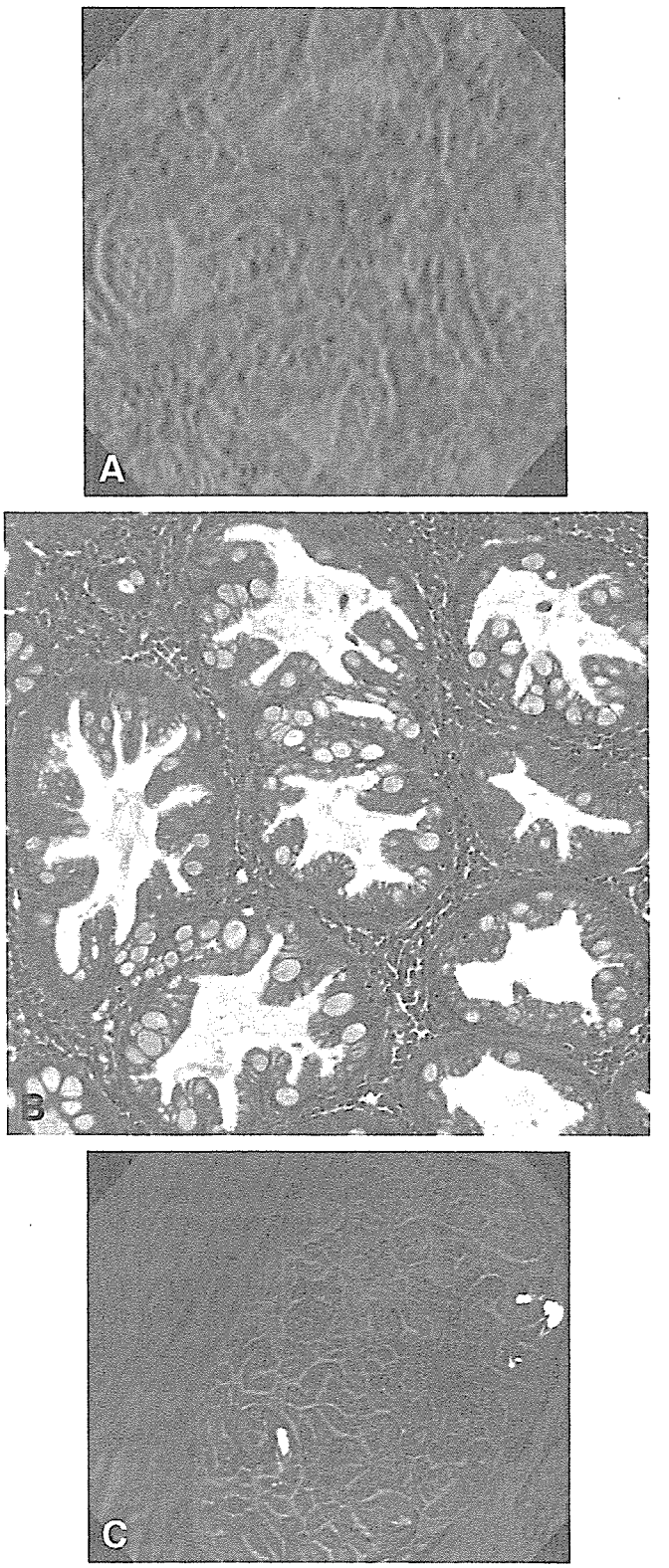

Figure 3. Hyperplastic polyp. **A,** Endocytoscopic image (orig. mag. ×450). **B,** Image (H&E, orig. mag. ×400). **C,** Magnified endoscopic view after crystal violet dye stain.

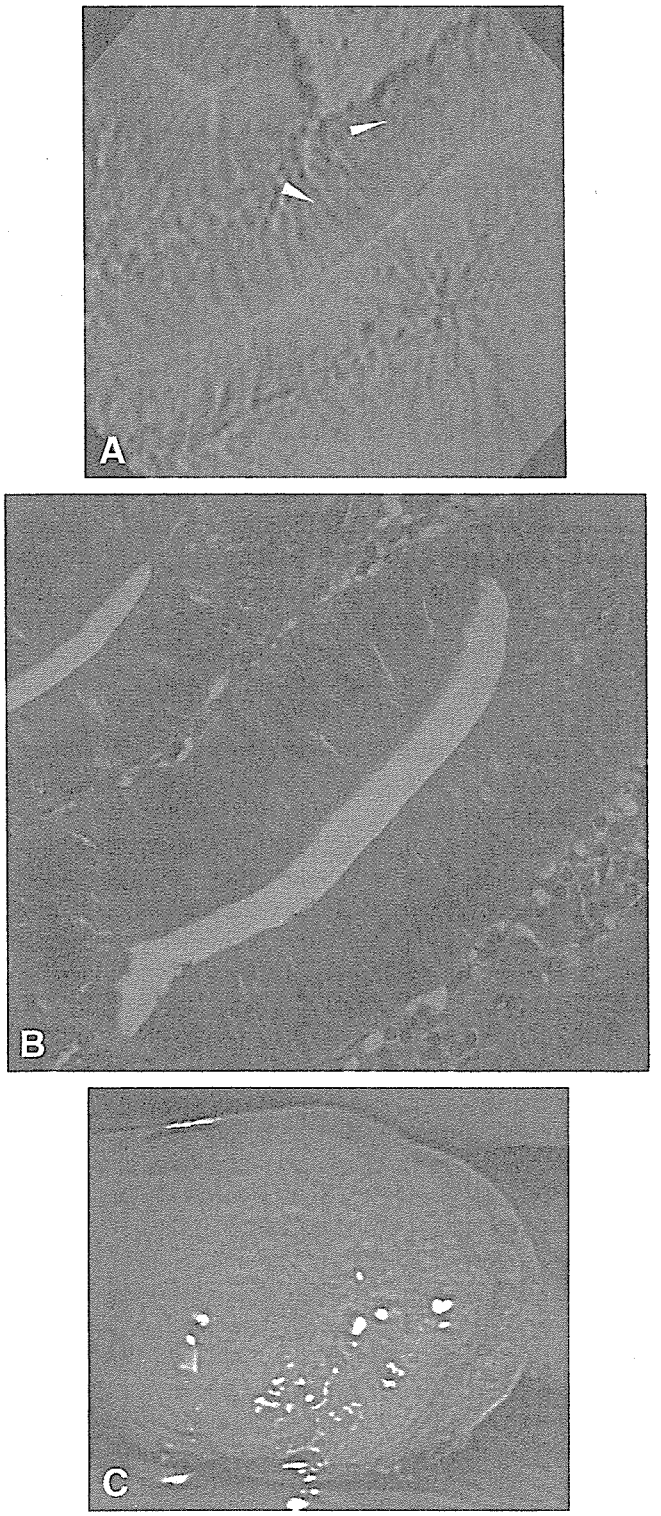

Figure 4. Low-grade dysplasia. **A,** Endocytoscopic image. Nuclei (*yellow arrowhead*) were fusiform and regularly arranged along the basement membrane (orig. mag. ×450). **B,** Image (H&E, orig. mag. ×400). **C,** Magnified endoscopic view after indigo carmine dye spraying.

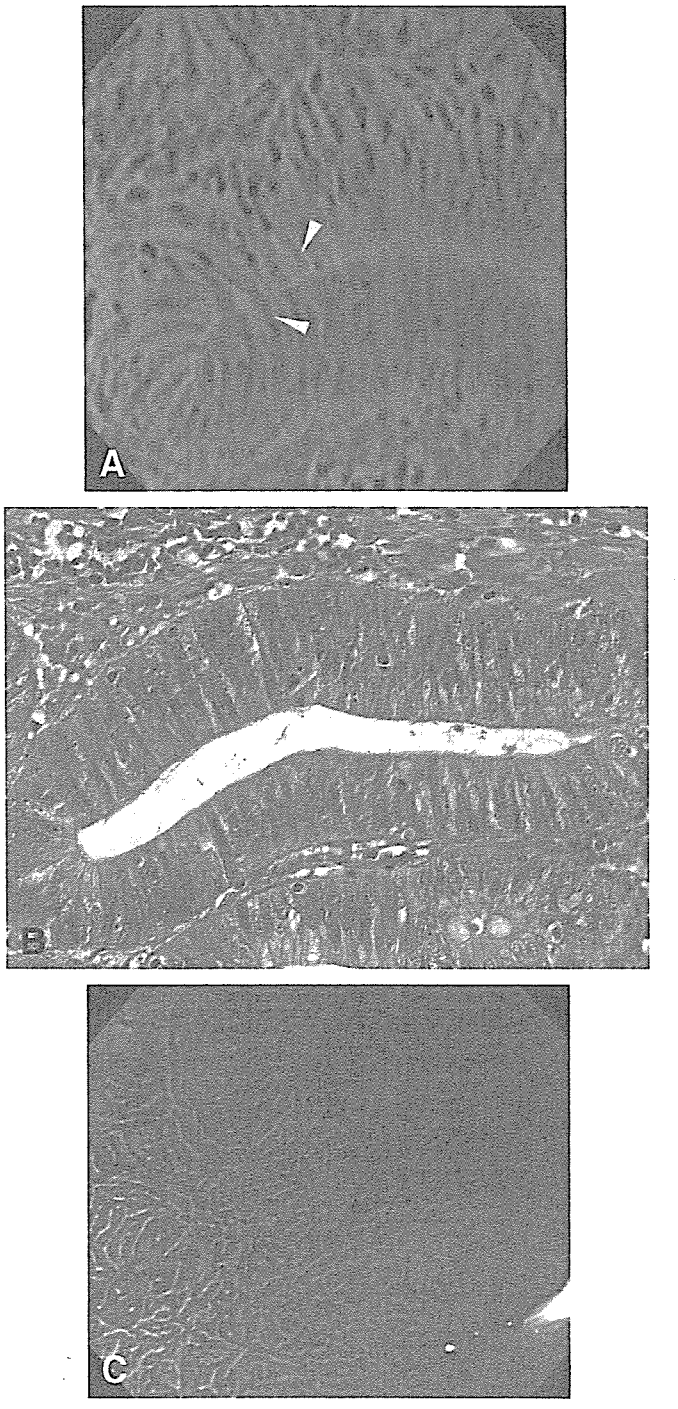

Figure 5. High-grade dysplasia. **A,** Endocytoscopic image. Disorder of polarity was recognized (orig. mag. ×450; *yellow arrowhead*). **B,** Image (H&E, orig. mag. ×400). **C,** Magnified endoscopic view after crystal violet dye stain. Fine structure of the surface was slightly irregular.

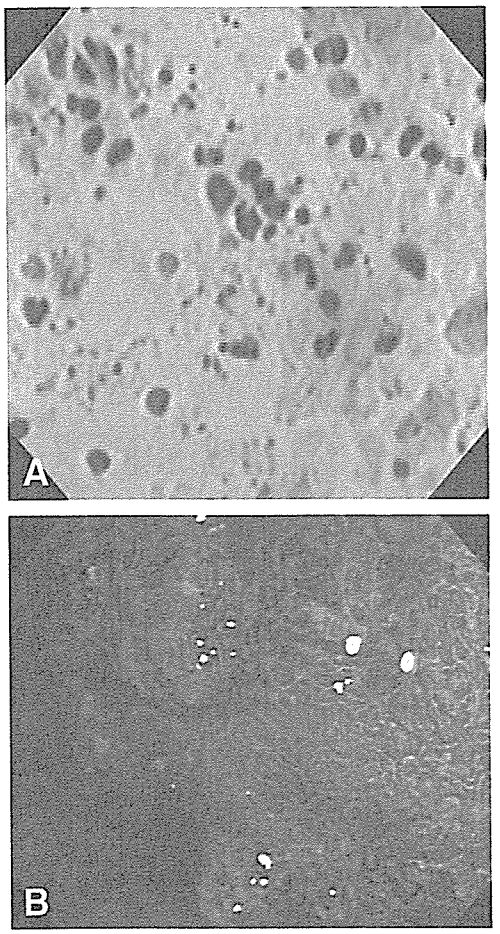

Figure 6. Invasive cancer. **A,** Endocytoscopic image (orig. mag. ×1125). **B,** Magnified endoscopic view after indigo carmine dye spraying. Fine structure of the surface was destroyed.

TABLE 2. Differential diagnosis between neoplastic and non-neoplastic lesions

	Histologic diagnosis	
E-C diagnosis	**Non-neoplastic**	**Neoplastic**
Non-neoplastic	16	0
Neoplastic	0	59

$P < .01$.

Cellular atypia is usually judged by variation in cell size, disorder of polarity, deformity of nuclei, hyperchromatin, and distinct nucleolus in the light microscopic images of an H&E-stained histologic specimen. E-C by using the prototype I endocytoscope made it possible to judge the degree of cellular atypia by visualizing variation in cell size, disorder of polarity, and deformity of nuclei. E-C images with the prototype II endocytoscope made it possible to observe hyperchromatin and distinct nucleolus in adenocarcinoma. In other words, we can evaluate not only the structural atypia but also cellular atypia in vivo with the E-C system. In this sense, E-C system is superior to the current magnifying endoscopy. E-C system provides real-time histologic images in vivo during endoscopy, corresponding to the H&E-stained microscopic images and allows us to make the correct diagnosis. The images obtained by the E-C system were almost comparable with the microscopic images, therefore, we believe that this method can be called "optical biopsy."

TABLE 3. Differential diagnosis between adenoma and invasive cancer

	Histologic diagnosis	
E-C diagnosis	**Adenoma**	**Invasive cancer**
Adenoma	46	1
Invasive cancer	0	12

$P < .01$.

The present E-C study of colorectal lesions included normal mucosa, hyperplastic polyps, adenomas, and invasive cancers. In E-C images of normal mucosa, glands were uniform and neatly arranged. In hyperplastic polyps, serrated glands were observed clearly and small vacuoles appeared to correspond to foamy change of cytoplasm of epithelial cells. In low-grade adenomas, tubular glands were almost homogeneous. Fusiform nuclei were clearly seen and regularly arranged along the basement membrane. In high-grade adenomas, nuclei were arranged in the luminal side of the gland. The glands branched out irregularly. There was disorder of polarity, deformity of nuclei, enlargement of nuclei, and various sizes of cells from the viewpoint of cellular atypia.

For the diagnosis of hyperplastic polyps and adenomas, the prototype I endocytoscope was usually enough. The prototype II endocytoscope could provide images corresponding well to cytology. The enlarged and round nuclei, vesicular, and coarse chromatin in invasive cancers were distinctly visualized by using the prototype II endocytoscope.

The correlation was significant between the E-C diagnosis and the histologic diagnosis. With the E-C system, it was possible to distinguish between neoplastic and non-neoplastic lesions, between adenomas and invasive cancers. This system would no doubt be useful for determining the treatment option, endoscopic or surgical.

In the near future, a pathologist at a distant site may be able to receive transmitted E-C images and to diagnose the histologic character of the lesion during endoscopy. The technologic innovation and improvement of E-C images would make it possible to reduce a good many biopsy specimens during endoscopic examination by providing real-time virtual histologic images.

There were some difficulties during the observation by using the E-C system in vivo. The presence of mucus or

bleeding made the visualization of the underlying cells more difficult. It was also difficult to obtain clear images from the target that was affected by respiratory or cardiac movements. The images could be obtained only by touching the object softly; therefore, we needed to attach a cap at the end of the colonoscope to fix the E-C scope onto the target site. Moreover, the device made it possible to obtain images in a distant location from the distal side, such as the cecum, and the ascending, transverse, and descending colon. Those images are just as clear as in the rectum.

In conclusion, E-C system provides real-time histologic images, which are almost as good as H&E-stained images during endoscopy.

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DISCLOSURE

None.

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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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石橋生哉*1　森　真二郎*1

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

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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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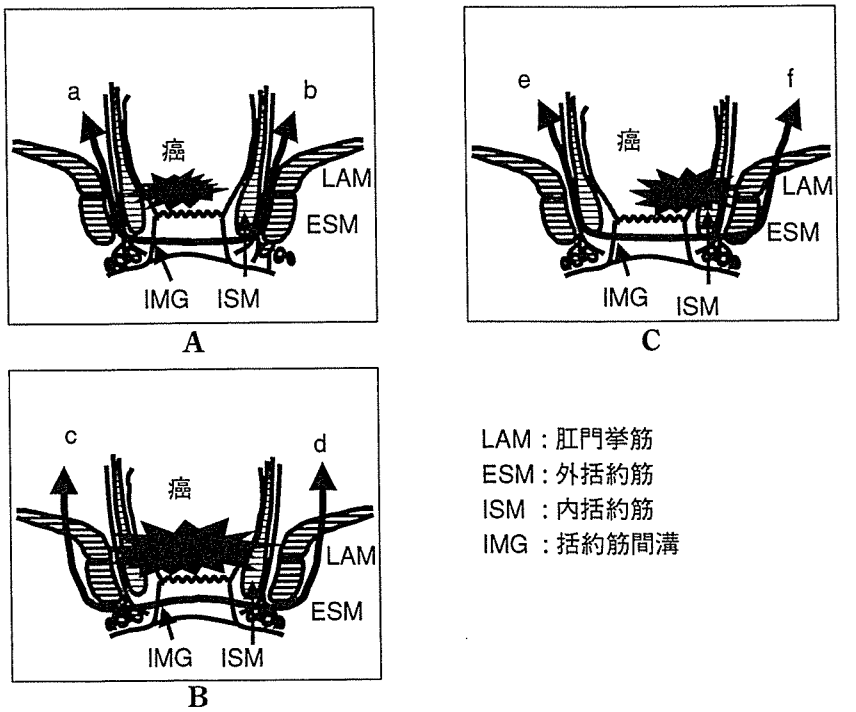

図1　切除線のシェーマ
A：Pa癌におけるISRの切除線を示す．切除線はa–bの線となる．
B：Pb癌におけるESRの切除線を示す．切除線はc–dの線となる．
C：腫瘍が片側に存在する場合には，腫瘍側ではESR，反対側ではISRの切除線を示す．

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