Colorectal Cancer: Role of CT Colonography in Preoperative Evaluation after Incomplete Colonoscopy[1]

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Abbreviations:
NPV = negative predictive value
PPV = positive predictive value

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PURPOSE: To evaluate computed tomographic (CT) colonography in patients with clinical suspicion of colorectal cancer and in whom colonoscopy was incomplete.

MATERIALS AND METHODS: After incomplete colonoscopy, 34 patients underwent CT colonography before and after intravenous injection of iodinated contrast agent, in supine and prone positions. Twenty patients with no evidence of colon cancer after complete colonoscopy were included as a control group. Sensitivity and specificity of CT colonography were determined for detection of cancers, polyps, and metastases to liver.

RESULTS: In 29 patients, surgery revealed 30 colorectal cancers (three synchronous cancers) and two ischemic lesions of the descending colon. Colonoscopy missed 10 colorectal cancers and three synchronous cancers; all were detected with CT colonography. Sensitivity and specificity for detection of colorectal cancer were 56% and 92%, respectively, for incomplete colonoscopy and 100% and 96%, respectively, for CT colonography ($P < .01$). Sensitivity and specificity of CT colonography in detection of polyps were 86% and 70%, respectively, for diameters of 5 mm or less; 100% and 80%, respectively, for 5–10-mm diameters; and 100% for diameters greater than 10 mm. Spiral CT of the liver revealed four metastases (2–5 cm); sensitivity and specificity were 100% and 43% for nonenhanced scans and 100% for contrast-enhanced scans ($P < .01$).

CONCLUSION: In this selected group of patients, CT colonography provided complete information to properly address surgery of colorectal cancer and treatment of liver metastases.

Colorectal cancer is the second cause of cancer-related death in the United States and Europe (1). There are large differences in survival related to the stage of disease; patient survival rate at 5 years is significantly reduced, from 90%–100% (Duke stage A) to less than 5% when distant metastases are documented (Duke stage D) (2). Liver in 20%–40% of cases and lungs in 20% are the most frequent target organs of metastases, whereas adrenal glands, bone, kidneys, pancreas, spleen, and central nervous system are less commonly involved (3). About 60%–80% of patients who die of metastatic colorectal cancer have hepatic metastases at autopsy (3).

Another important issue regarding patients with colorectal cancer is the occurrence of synchronous malignant lesions, which are estimated to manifest in 1.5%–9.0% of cases (4,5). This condition changes the surgical approach from circumscribed resection to wider resection of the involved segments (6).

Accurate preoperative study of the entire colon and target organs for metastases is therefore mandatory in view of the possible benefits that could be obtained from a specific surgical approach or from adjuvant therapies (chemotherapy and radiation therapy).

Conventional colonoscopy potentially permits total colon evaluation but fails to show the entire colon in about 5% of cases owing to difficulties in reaching the right side; moreover, it does not allow evaluation of the liver and other organs outside the colon (7–10).

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Computed tomographic (CT) colonography has been proposed as an alternative procedure for the examination of these patients because it is not limited to endoluminal exploration of the colon (11); it reaches the cecum, even in cases of obstructive lesions, and combines study of the colon with evaluation of target organs for metastases, in particular the liver (12–16).

Our experience with CT colonography has been essentially motivated by the need for evaluation of the colon in patients who have had incomplete colonoscopy although there is a clinical suspicion of colorectal cancer. The purpose of our study, therefore, was to evaluate CT colonography in patients with a clinical suspicion of colorectal cancer and in whom colonoscopy was incomplete.

MATERIALS AND METHODS

Patients

From September 1996 through January 2001, a total of 34 patients (18 men, 16 women; mean age, 63 years; age range, 35–76 years) with clinical suspicion of colorectal cancer (bright red blood per rectum, positive fecal occult blood test, altered bowel habits, anemia of unknown cause, and pain in the right lower quadrant) underwent conventional colonoscopy, which was incomplete.

At examination of 19 patients, a distal occlusion (located in the rectum, sigmoid colon, or descending colon) was found, but colonoscopy failed to enable exploration of the colon segments proximal to the site of occlusion; these patients were designated group A. In the remaining 15 patients, colonoscopy enabled exploration of the colon lumen up to the sigmoid (n = 2) and descending (n = 5) colon, splenic flexure (n = 2), transverse colon (n = 3), and hepatic flexure (n = 3). The cause of incomplete colonoscopy in these patients was patient intolerance of the examination, strictures of the large bowel from diverticulitis, or pericolic fibrotic residual after surgery of the pelvic floor; these patients were designated group B. All patients underwent single–detector row spiral CT performed with air in the colon within 1 week after colonoscopy.

To evaluate the specificity of CT colonography in detecting colorectal cancer, a control group of 20 patients who underwent both complete colonoscopy and CT colonography for screening purposes was included in the study. These patients were matched to the 34 patients with colorectal cancer with respect to age and sex. However, the main reason for selecting this control group was that they had been examined with the same imaging protocol used in the patients with colorectal cancer (ie, nonenhanced and enhanced phases, prone and supine positions); in this control group, malignant disease was excluded on the basis of clinical parameters and imaging techniques.

The institutional review board approved the study, and informed consent was obtained from all patients.

Pneumocolon Procedure

Twenty-four hours before examination, each patient received a standard bowel preparation in the form of polyethylene glycol solution (Isocolan; Giuliani, Milan, Italy). Before CT scanning, the patients were placed in the left lateral decubitus position on the CT table for the introduction of a rectal enema tube. They were then turned supine, and room air was insufflated through the tube into the colon. To reduce bowel peristalsis and colonic spasm, at least 20 mg of joscine N-bromuro (Buscopan; Boehringer Ingelheim, Florence, Italy) was administered intravenously immediately before air insufflation. The patient's tolerance was monitored regarding the volume of insufflated air (range, 1,500–2,000 mL). Air was insufflated from a bag containing room air that was connected to the enema tube and had a 2,000-mL maximum capacity.

CT Image Acquisition

A standard scout view of the abdomen and pelvis was acquired to evaluate the degree of colonic distention, and more air was insufflated if required. All examinations were performed with a single–detector row spiral CT scanner (HiSpeed; GE Medical Systems, Milwaukee, Wis). Images were obtained by using 3-mm collimation with a pitch of 2 (120 kV, 180 mAs), and data were reconstructed at 2-mm intervals. A single-breath-hold acquisition was used to encompass the entire colon; all studies were performed with the patient in supine and prone positions. The abdominal CT study was performed before and after intravenous injection of iodinated contrast agent, iodixanol (Visipaque 320; Nycomed Amersham, Oslo, Norway); 140 mL of contrast agent was administered at 3 mL/sec. The nonenhanced images were acquired in the supine position, whereas contrast material–enhanced acquisitions were obtained first in the supine and then in the prone position. This scanning protocol allowed a three-phase study of the liver (nonenhanced phase plus contrast-enhanced portal and later phases).

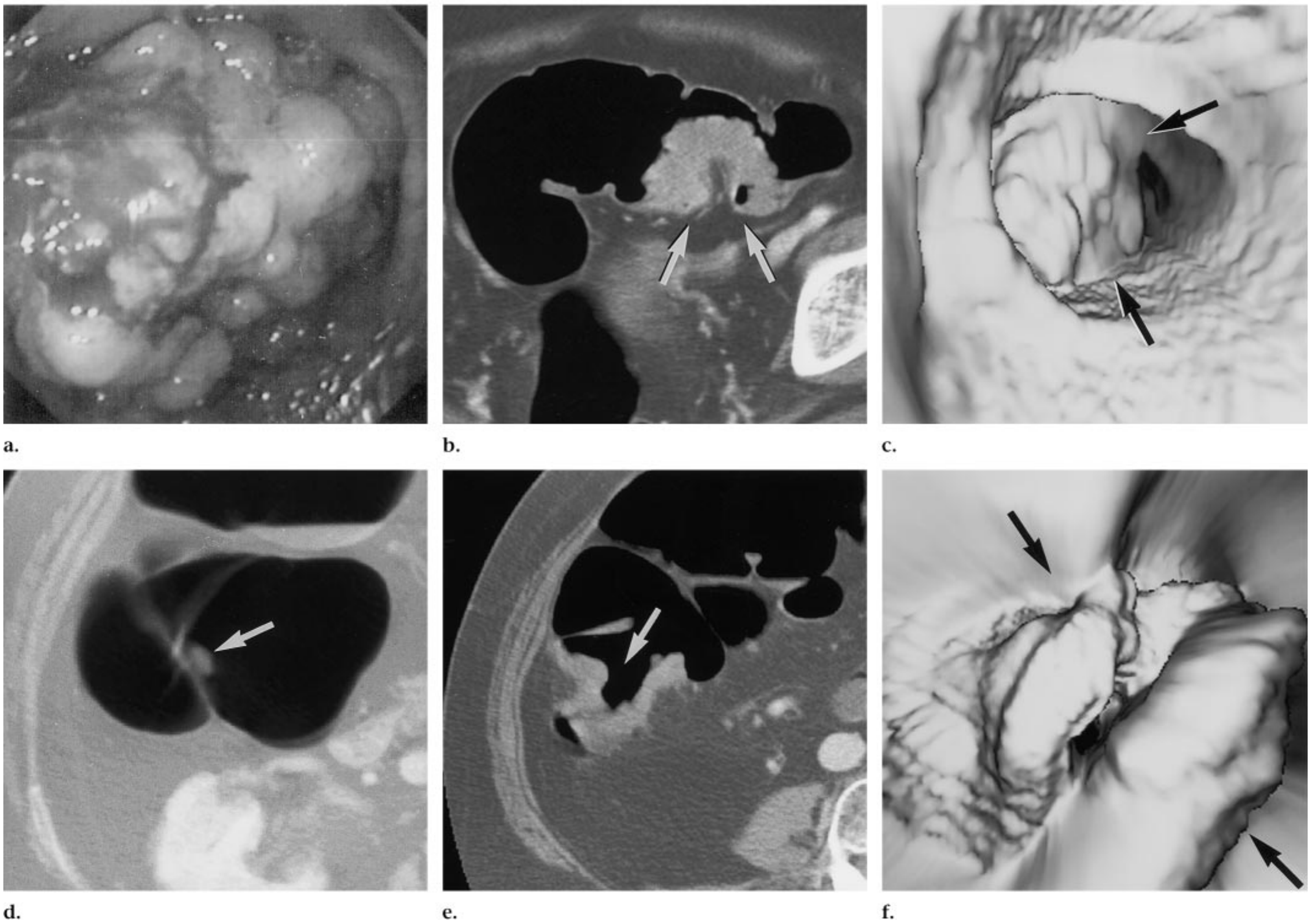
CT Colonography

CT images were transferred to an independent workstation (Advantage Windows 3.1; GE Medical Systems). From native CT images, the software can generate a three-dimensional endoluminal view of the colon with surface rendering or volume renderings of the colonic surface that simulate the double-contrast barium enema examination.

CT colonographic analysis was performed in consensus by two observers (E.N., P.B.) together. Each observer has at least 5 years experience in interpreting CT colonographic studies and spiral CT images of the abdomen. Both were blinded to the results of colonoscopy. Evaluation included that of the endoluminal and extracolonic compartments of the abdomen and pelvis. Colonic evaluation included that for the presence of wall thickening, cancers, polyps, and wall discontinuity (as in cases of fistulas or diverticula). The liver was evaluated in an attempt to detect metastases.

Each study was analyzed directly at the workstation monitor (20-inch) with a real-time navigation through the colon. Endoluminal views were presented with regard to transverse, coronal, and sagittal reconstructions crossing through each navigation step. The observer could also indicate a point on the surface of the colon and directly obtain the multiplanar reconstructions crossing through it; this function allowed the simultaneous display of the intra- and extraluminal aspects of the colon. Real-time navigation was performed in each patient four times—two antegradely (cecum to rectum) for the supine position and two retrogradely (rectum to cecum) for the prone position—and thus enabled visualization of both sides of the haustral folds.

Total colon distention was assumed to be the situation in which room air reached the cecum, even in those cases in which the patient's position could determine the collapse of one or more segments. For evaluation of segmental colonic distention, eight colonic segments were considered as follows: rectum; sigmoid, descending, transverse, and ascending colons; splenic and hepatic flexures; and cecum. The degree of distention was ranked by using the following four-point scale: 1, segment totally collapsed (ie, bowel wall not visible); 2, segment partially collapsed (ie, bowel wall poorly visible); 3,



Polypoid occlusive carcinoma in the sigmoid colon. **(a)** Colonoscopic image shows a large bleeding mass that caused obstruction of the sigmoid colon and could not be crossed by the colonoscope. **(b)** Transverse CT colonographic image obtained with the patient in the prone position and **(c)** corresponding three-dimensional endoluminal view reveal a mass (arrows) obstructing the colonic lumen. **(d)** Transverse CT colonographic image obtained with the patient in the supine position shows a 1-cm polyp of the hepatic flexure (arrow). **(e)** Transverse CT colonographic image obtained with the patient in the supine position and **(f)** corresponding endoluminal view show also a synchronous stenosing carcinoma (arrows in **e** and **f**) of the ascending colon.

segment distended (ie, bowel wall visible enough); and 4, segment overdistended (ie, bowel wall clearly visible).

For evaluation of patient preparation, the proportion of colonic segments containing residual fecal matter or fluid was recorded for each patient. (No specific attempt was made to rank the amount of fluid or stool.)

The total number of segments evaluated was 432 in 54 patients, first in supine and then in prone decubitus positions. On average, the total CT room time for CT colonography was 20 minutes, whereas the time for image processing and interpretation was 30–90 minutes.

Statistical Analysis

Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of CT colonography were determined for detection of cancers, polyps, and metastases to liver. Specific attention was paid to the liver by comparing sensitivity and specificity of nonenhanced and contrast-enhanced CT scans for detection of focal lesions. Maximum diameters of cancers, polyps, and focal liver lesions were measured on transverse images and multiplanar reconstructions and recorded.

From the observations, true-positive findings were defined as those cases in which CT colonography enabled correct detection of findings confirmed with surgery or colonoscopy; false-positive findings were the cases in which CT colonography enabled detection of findings not confirmed with surgery or colonoscopy; false-negative findings were the cases with no detection of findings that were identified with surgery or colonoscopy; and true-negative findings were the cases without pathologic findings at both CT colonography and surgery or colonoscopy.

With regard to colorectal cancer detection, the statistical difference between CT colonography and colonoscopy for the proportions of true-positive, false-positive, false-negative, and true-negative findings in groups A and B were determined with the χ^2 test. *P* values less than or equal to .01 were considered to indicate a statistically significant difference. The scores for bowel distention in prone and supine positions were compared by using the Wilcoxon signed rank test. *P* values of less than or equal to .05 indicated a statistically significant difference.

RESULTS

Diagnosis of Colorectal Cancer

All 19 patients in group A underwent surgery, and tumor was found in the rectum in seven patients, in the sigmoid colon in five, in the descending colon in three, and in the splenic flexure in two. Ischemic lesions of the entire descending colon were found in two patients. CT colonography enabled identification of all 20 colorectal cancers and correct diagnosis of ischemic lesions in these 19 patients. With colonoscopy, one synchronous cancer of the right colon (Figure) and two synchronous cancers in the descending colon and splenic flexure were missed, and ischemic lesions were mistakenly interpreted as malignant.

Ten (67%) of the 15 patients in group B underwent surgery, and tumor was found in the proximal sigmoid colon in three patients, in the descending colon in one patient, in the transverse colon in two, in the ascending colon in three, and in the cecum in one. Four patients (27%) were excluded from intervention with CT colonography; colonoscopy was repeated with these patients sedated and confirmed the CT colonographic diagnosis as follows: ulcerative colitis in one patient (biopsy and 2-year follow-up excluded malignancy) and no alterations indicative of colon cancer in three patients. In one patient (7%), CT colonography resulted in a false-positive diagnosis: A wall thickening with 3-cm-long stenosis that was visible both in the prone and supine positions and located at the junction of the descending and sigmoid colon was interpreted as a malignant stricture. Colonoscopy with the patient sedated was repeated within 1 week after CT colonography and did not reveal malignancy. Retrospective analysis of CT colonographic images resulted in reconsideration of the wall thickening as a consequence of repeated diverticular inflammations.

CT colonography enabled identification of all 10 colon cancers that were missed at incomplete colonoscopy.

Considering all 30 colorectal cancers, the largest lesion diameters measured 3.5–7.0 cm (mean size, 4 cm). The segmental locations of the cancers are reported in Table 1. Sensitivity, specificity, PPV, and NPV of CT colonography and colonoscopy for cancer detection are reported in Table 2. The difference between CT colonography and colonoscopy for colorectal cancer detection was statistically significant ($P < .01$) in group B and for the entire patient series, but the difference was not statistically significant in group A.

TABLE 1
Segmental Location of Colorectal Cancers

Location	No. of Cancers (n = 30)
Colonic segment	
Rectum	7 (23)
Sigmoid colon	8 (27)
Descending colon	5 (17)
Splenic flexure	2 (7)
Transverse colon	3 (10)
Hepatic flexure	0 (0)
Ascending colon	4 (13)
Cecum	1 (3)
Side	
Left	23 (77)
Right	7 (23)

Note.—Numbers in parentheses are percentages.

Polyps

Forty-nine polyps were found at surgery or colonoscopy among the entire patient series. Among these, nine polyps were found in the control subjects and did not show malignancy at histologic examination after endoscopic removal. Polyps were located in the rectum (n = 5), sigmoid colon (n = 7), descending colon (n = 13), splenic flexure (n = 5), transverse colon (n = 6), hepatic flexure (n = 5), ascending colon (n = 6), or cecum (n = 2). Polyp sizes ranged between 2.5 and 24.0 mm.

Sensitivity, specificity, PPV, and NPV of CT colonography for detection of polyps are reported in Table 3. Ten false-positive diagnoses (six for polyp size < 5 mm and four for polyp size 5–10 mm) were due to residual fecal material. Two false-negative diagnoses were represented by polyps smaller than 5 mm in diameter identified in the ascending colon at colonoscopy.

Liver Study

CT colonography revealed the presence of four hepatic lesions (diameter range, 2–5 cm) suspicious for metastases. Among these cases, in one patient surgery included resection of the liver metastasis (5 cm), and in two patients intraoperative thermal ablation performed with a 100-W radio-frequency generator (Model 500 L; RITA Medical System, Mountain View, Calif) was used to treat a single metastasis (3 cm) and double metastases (2.0 and 3.5 cm). Two liver hemangiomas (diameter range, 2–3 cm) and five cysts (diameter range, 1–4 cm) also were detected with CT. At both nonenhanced and contrast-enhanced phases, 11 of 11 hepatic lesions were detected (sensitivity, 100%), but at the nonenhanced phase, two metastases (2 and 3 cm in maximum diameter, respectively) and both hemangiomas were missed (specificity, 43%; PPV, 50%; NPV, 100%). In fact, the enhanced phase was required to demonstrate the presence of solid, enhancing tissue in metastases and the typical enhancement pattern of hemangiomas (specificity, PPV, NPV, 100% each).

Technical Results of CT Colonography

Total colon distention, considering both supine and prone evaluations, was achieved in all patients. On the supine images, the sigmoid lumen was totally collapsed in 25 (46%) of 54 patients. The prone images depicted inadequate distention of the transverse colon with partial lumen collapse in six (11%) of 54 patients. The mean overall bowel distention was ranked 3.38 (SD ± 0.7) for supine position and 3.50 (SD ± 0.3) for prone position, and the difference between ranks was not statistically significant (P = .93).

Concerning the presence of residual fecal material (stools and fluid) for both supine and prone acquisitions, CT colonography failed to depict six (1.4%) of 432 segments (cecum [n = 5] and descending colon [n = 1]).

DISCUSSION

In our opinion, the main benefit of using CT colonography in the present study was to couple the evaluation of the entire endoluminal colon, at completion of unsuccessful colonoscopy, with the study of the liver.

In our series, multiple reasons led to an incomplete colonoscopy. Fenlon et al (12) reported on a series of 29 patients who all had incomplete colonoscopy for distal occlusive carcinoma. In our study, 19 patients in group A underwent CT colonography for the same reason, but our study also included 15 patients in group B in whom unsuccessful colonoscopy was due to intolerance to the examination owing to pain, postinflammatory strictures of the large bowel, or pericolic fibrosis after surgery of the pelvic floor. In group A, all occlusive carcinomas were identified at both CT colonography and conventional colonoscopy, whereas synchronous lesions could be detected only with CT colonography. In contrast, a sta-

TABLE 2
Sensitivity and Specificity of CT Colonography versus Conventional Colonoscopy for Detection of Colorectal Cancer

		CT Colonography					Colonoscopy					
Group	No. of Cancers Found at Surgery	FP/FN*	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	FP/FN*	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	*P* Value
A (n = 19)	20	0/0	100	100	100	100	2/2	90	92	90	91	.42
B (n = 15)	10	1/0	100	96	90	100	0/10	0	100	0	71	<.01
A and B (n = 34)	30	1/0	100	96	96	100	2/12	56	92	88	66	<.01

* FP/FN = number of false-positive diagnoses/number of false-negative diagnoses.

TABLE 3
Sensitivity and Specificity of CT Colonography for Detection of Polyps

Polyp Size (mm)	No. of Polyps	FP/FN*	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
≤5	14	6/2	86	70	67	87
5–10	24	4/0	100	80	86	100
>10	11	0/0	100	100	100	100

* FP/FN = number of false-positive diagnoses/number of false-negative diagnoses.

tistically significant difference between CT colonography and colonoscopy was observed in group B; the presence of cancer in all patients could not be proved with the latter procedure.

In our experience, CT colonography was effective in evaluating the colon, despite a few exceptions in which residual fecal material in the descending colon and cecum obstructed complete endoluminal visualization. However, in all cases the combination of the three-dimensional endoscopic perspective, transverse views, and multiplanar images was helpful to distinguish residual fecal material from the colonic wall, and the enhancement achieved after administration of contrast material was helpful. Residual fecal material did not affect the diagnosis of colorectal cancer in our series, but we believe that it has potential influence. This issue was recently discussed by Morrin et al (17), who showed an increased diagnostic confidence in contrast-enhanced CT colonography with respect to the nonenhanced phase for both the assessment of bowel wall conspicuity and the detection of medium-sized polyps (diameter, 5–9 mm) in suboptimally prepared colons.

Although our study was not aimed at demonstrating the usefulness of contrast material administration in detecting colorectal cancer, although it was always used in CT colonography, the comparison between nonenhanced and contrast-enhanced acquisitions showed a difference between the two phases in the characterization of liver metastases. The nonenhanced phase allowed detection of liver lesions, but their hypoattenuation did not allow a diagnosis of metastatic disease; only the images enhanced with contrast material showed solid, enhancing tissue at the periphery of the lesion with consequent apparent reduction in size of the hypoattenuating portion (18). Another drawback of the nonenhanced phase was the incomplete characterization of hemangiomas, which are also hypoattenuating and frequently require delayed scans to demonstrate the characteristic centripetal enhancement.

Early detection of liver metastases, especially before surgery of the colon, is extremely important for patient survival because it enables one to plan a combined treatment of the primary and secondary diseases (19–21).

Our experience has shown that in a selected group of patients who underwent incomplete colonoscopy, CT colonography provided information necessary to properly address surgery of colorectal cancer and treatment of metastatic disease.

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