Endoluminal CT Colonography After an Incomplete Endoscopic Colonoscopy

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OBJECTIVE. We evaluated the clinical usefulness of endoluminal CT colonography after an incomplete colonoscopy.

SUBJECTS AND METHODS. We prospectively studied 40 patients in whom the cecum could not be reached endoscopically despite adequate bowel preparation. Endoluminal CT colonography (120 kVp, 120 mA, 3-mm collimation, pitch of 2, 1.5-mm interval reconstruction) was performed within 2 hr of incomplete colonoscopy. Two-dimensional multiplanar reformatted images and three-dimensional endoluminal images were analyzed. Twenty-six patients (65%) underwent barium enema immediately after endoluminal CT colonography. We analyzed colonic distention; duration of endoluminal CT colonography; patient tolerance; number of colonic segments seen at colonoscopy, endoluminal CT colonography, and barium enema; and reasons for incomplete colonoscopy as well as colonic and extracolonic findings.

RESULTS. Duration of endoluminal CT colonography was 14.2 ± 4.6 min (mean ± SD). Endoluminal CT colonography was better tolerated than colonoscopy or barium enema ($p <$ .001). Probable causes for incomplete colonoscopy were identified at endoluminal CT colonography in 74% of 40 patients. Baseline colonic distention in the region of the transverse and right colon was considered adequate before additional air insufflation; however, the addition of air significantly enhanced colonic distention throughout the entire colon ($p <$ .001). Endoluminal CT colonography adequately revealed 96% of all colonic segments; in comparison, barium enema adequately revealed 91% of all segments ($p < .05$).

CONCLUSION. In patients with incomplete colonoscopy, endoluminal CT colonography successfully showed the previously unrevealed colon in more than 90% of patients. Endoluminal CT colonography is a rapid, well-tolerated technique that provides clinically useful colonic and extracolonic information and should be considered for all patients who undergo incomplete colonoscopy.

Endoscopic colonoscopy is currently the investigation of choice for the screening, diagnosis, and treatment of colorectal polyps, the precursors of colorectal carcinoma. However, in 5–15% of patients, the entire colon is not visualized during endoscopic colonoscopy [1]. Accepted practice in these patients is to obtain a barium enema to complete the diagnostic workup. Barium enema is associated with considerable patient discomfort and may not be tolerated on the same day as colonoscopy [2–4]. In addition, a high-quality double contrast study cannot be performed on the same day as polypectomy or ablation with a "hot-biopsy" forceps because of the inherent risk of colonic perforation.

Recent studies have shown a promising role for helical endoluminal CT colonography when screening for intraluminal colonic abnormalities such as tumors and polyps. Preliminary results report sensitivity for detection of polyps larger than 1 cm is 100%, with a sensitivity of 71–90% for 5- to 9-mm polyps [5–9]. If these numbers are confirmed, the technique would be more sensitive than barium enema, which fails to reveal 5–20% of polyps larger than 1 cm and 20–40% of polyps smaller than 1 cm [10–19]. Endoluminal CT colonography involves viewing a combination of magnified multiplanar reformatted images of the air-distended colon, as well as three-dimensional volume-rendered or shaded-surface endoluminal images, permitting ante- and retrograde navigation through the colonic lumen [7, 8, 20].

Endoluminal CT colonography may offer the potential for a rapid, comfortable, and accurate test that can depict the entire colon, especially regions not seen during colonoscopy. This study was designed to evaluate the clinical usefulness of endoluminal CT colonography in patients af-

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ter an incomplete colonoscopy, specifically to document whether all segments of the colon not seen during endoscopy could be evaluated with endoluminal CT colonography. Comparison with barium enema was also performed.

Subjects and Methods

Patients

The study protocol was approved by our Institutional Review Board, and written informed consent was obtained from all patients. We prospectively studied 40 patients (12 men, 28 women) who underwent incomplete endoscopic colonoscopy over a 10-month period. The mean age of the patient group was 62 ± 17 (years ± SD) (range, 22–96 years). Indications for colonoscopy included passage of blood via the rectum (n = 17), family history of colon cancer (n = 7), positive fecal occult blood tests (n = 7), history of colonic polyps (n = 5), and altered bowel habits (n = 4). The colonoscopist was unable to pass the endoscope beyond the sigmoid colon (n = 15), the descending colon (n = 2), the splenic flexure (n = 7), the transverse colon (n = 5), the hepatic flexure (n = 6), or the ascending colon (n = 4). In one additional patient, the rectum could not be intubated because of severe anal spasm associated with an anal fissure, which also precluded barium enema examination.

Patient Preparation

All patients underwent standard bowel preparation 24 hr before colonoscopy using either an oral cathartic polyethylene glycol preparation (Golytely; Braintree Laboratories, Braintree, MA) (n = 23) or a standard barium enema preparation (Fleet Prep Kit 1; Fleet Pharmaceutical, Lynchburg, VA) (n = 17).

Endoluminal CT Colonography

Data acquisition.—All patients underwent endoluminal CT colonography within 2 hr of colonoscopy. CT scans were obtained using either a General Electric CT scanner (General Electric Medical Systems, Milwaukee, WI) (n = 35) or a Somatom Plus 4 Spiral CT scanner (Siemens Medical Systems, Iselin, NJ) (n = 5). Images were acquired using 3-mm collimation with a table speed of 6 mm/sec (pitch of 2), 120 mA, 120 kVp, and 512 × 512 matrix. Axial images were reconstructed at 1.5-mm intervals with a 1.5-mm slice overlap.

Scanning technique.—Patients were initially placed in a supine position, and a preliminary scout radiograph of the abdomen was obtained to assess the degree of colonic distention after colonoscopy (Fig. 1). If the entire colon was not distended with air, additional room air was manually insufflated through a 12-French balloon-tipped rectal tube, titrated to patient tolerance. A second scout radiograph was then obtained to confirm adequacy of distention and to plan the location for volumetric data acquisition (Fig. 2). A single breath-hold data acquisition was used to examine the entire colon. After data acquisition in the supine position, the patient was placed in a prone position. A third scout radiograph was then obtained in the prone position to confirm accurate positioning. A prone CT scan was then obtained to confirm abnormalities seen on the supine examination, to aid detection of abnormalities seen in the rectum and descending colon by increasing air distention, to limit artifacts arising from stool, and to displace excessive intraluminal fluid commonly present after cathartic-type bowel preparation. This dual-position imaging has also been shown to increase the sensitivity of the technique of endoluminal CT colonography (Fletcher JG et al., presented at the American Roentgen Ray Society meeting, May 1998).

Barium Enema

In 26 patients, double contrast barium enema was carried out within 2 hr of endoluminal CT colonographic examination. Results were correlated with findings of endoscopic colonoscopy and endoluminal CT colonography. The remaining 14 patients did not have a barium enema examination because of refusal on the day of colonoscopy or refusal to undergo bowel preparation again on an alternative day.

Image Postprocessing

All acquired data were transferred to an Advantage Windows work station (General Electric Medical Systems) equipped with Navigator software, which permits multiplanar reformations and shaded-surface navigation. Magnified two-dimensional mul-

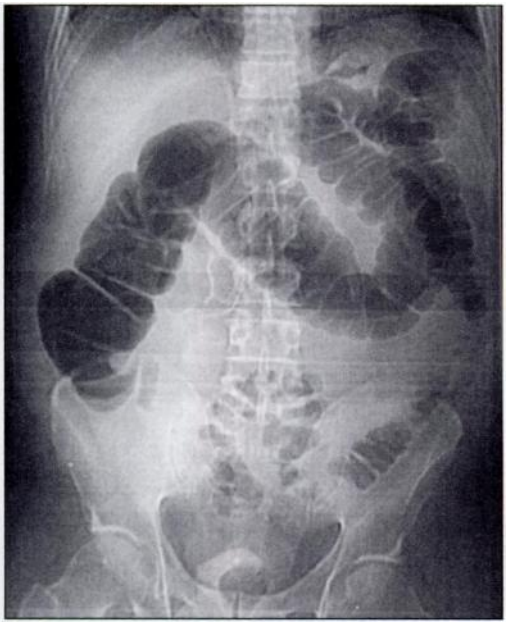

Fig. 1.—67-year-old woman who had incomplete colonoscopy to descending colon because of excessive colonic spasm. Scout radiograph obtained after colonoscopy shows adequate distention of cecum, ascending colon, and transverse colon. Image was obtained before additional air insufflation at endoluminal CT colonography (not shown).

Fig. 2.—58-year-old woman who had incomplete colonoscopy to splenic flexure because of redundant, tortuous colon loops. Scout radiograph obtained after additional air insufflation shows adequate distention of cecum, ascending colon, and transverse colon.

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tiplanar images were viewed in rapid cine sequence, and the three-dimensional shaded-surface endoluminal images were reviewed on a 17-inch Advantage Windows monitor (General Electric Medical Systems) by two gastrointestinal radiologists who were unaware of the endoscopic and barium enema results at the time of endoluminal CT colonographic interpretation. Inconsistencies in interpretation were resolved by consensus. Images were viewed using both soft-tissue (level, 70 H; width, 500 H) and lung windows (level, –750 H; width, 500 H) [5]. Subsequent endoluminal navigation was performed using the multiplanar images to plan a course through the colon. Both supine and prone images were viewed in an antegrade (cecum to rectum) and retrograde (rectum to cecum) manner to permit visualization of both sides of haustral folds.

Data Analysis

The time to navigate the entire colon and the time to navigate the parts of the colon not seen during colonoscopy were assessed. The 26 patients who had undergone all three procedures (colonoscopy, endoluminal CT colonography, and barium enema) were asked to grade the degree of discomfort for all procedures immediately after each procedure on an interval scale (0–10), 10 representing the most severe discomfort ever experienced. Causes for incomplete colonoscopy; number, location and size of polyps; and identification of additional clinically relevant extracolonic abnormalities were noted. The degree of colonic distention of five defined segments of the colon (rectum, sigmoid colon, descending colon including splenic flexure, transverse colon including hepatic flexure, and ascending colon including cecum) was scored using a 5-point scale: 1 = collapsed; 2 = poorly visualized; 3 = entire segment visualized but underdistended; 4 = entire segment visualized and well distended; and 5 = overdistended. For this study, a distention score of 3 or higher represented adequate distention. We also compared the number of colonic segments adequately visualized on endoluminal CT colonography, barium enema, and incomplete colonoscopy. The total number of colonic segments that potentially could be visualized by colonoscopy or endoluminal CT colonography (n = 40) was 200, and the total number of potentially visualized segments at barium enema (n = 26) was 130. The results were expressed in terms of the percentage of total segments potentially visualized.

Statistical Analysis

Statistical analysis was performed by a statistician at our institution. As degrees of colonic distention and patient tolerance among the various groups were skewed, paired data was analyzed using the Wilcoxon's signed rank test. Unpaired data was compared using the unpaired t test. The mean length of time to perform the endoluminal CT colonography was analyzed using the paired t test. Significance was reached at the level of 5%.

Results

The degree of segmental colonic distention revealed on scout radiographs obtained before and after air insufflation is summarized in Figure 3. Baseline colonic distention in the region of the transverse colon, ascending colon, and cecum was considered adequate before additional air insufflation. However, the addition of air after incomplete colonoscopy significantly enhanced colonic distention throughout the entire colon. On the initial scout view, 87% of the 21 patients in whom colonoscopy did not progress beyond the splenic flexure had adequate distention of the transverse and right colon after colonoscopy. Conversely, only 33% of 40 patients had adequate distention distal to the splenic flexure because of evacuation of air after colonoscopy, and thus baseline distention in the left colon—including rectum, sigmoid colon, and descending colon to splenic flexure—was inadequate and significantly aided by air insufflation. Overall, after air insufflation, supine scout images showed that 88% of 40 patients had an adequate examination of the rectum; sigmoid colon, 91%; descending colon, 91%; transverse colon, 97%; and cecum, 97%. Subsequent prone positioning made no significant difference in terms of aiding distention.

The mean length of time required to perform the entire endoluminal CT colonographic examination from the time the patient was placed on the CT table to completion of the examination was 14 ± 5 min. The mean time required to navigate the colonic segments proximal to the sigmoid colon was significantly shorter compared with the time taken to navigate all colonic segments (20 ± 7 min versus 41 ± 11 min; paired t test, $p < .0001$). When patient tolerance for the three procedures was compared, endoluminal CT colonography was significantly better tolerated (3.3 ± 1.1, mean ± SD) than either incomplete colonoscopy (5.6 ± 2.0; Wilcoxon's signed rank test, $p < .001$) or double contrast barium enema (7.0 ± 1.5; $p < .001$).

Endoluminal CT colonography adequately revealed 192 (96%) of a possible 200 colonic segments, compared with only 82

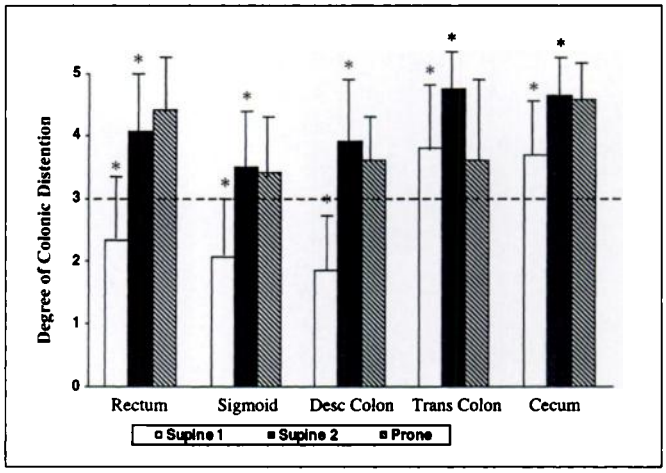

Fig. 3.—Degree of segmental colonic distention revealed by scout radiographs obtained before and after air insufflation. Bar and whisker graph depicts median colonic distention on supine scout radiographs before insufflation (Supine 1), supine after air insufflation (Supine 2), and prone after air insufflation (Prone). Whiskers represent 75th percentile. Comparisons are based on 5-point scale (1 = collapsed colon, 5 = overdistention). Adequate distention for endoluminal CT colonographic interpretation was defined as 3 or higher (above dotted line). Desc = descending, Trans = transverse. Addition of air after incomplete colonoscopy significantly enhanced colonic distention throughout entire colon on supine radiographs. Asterisks indicate $p < .0001$, Wilcoxon's signed rank test.

TABLE 1 Number and Percentage of Colon Segments Visualized on Three Tests

Colon Segment	Colonoscopy (n = 40)	CT Colonography (n = 40)	Barium Enema (n = 26)
Rectum	39 (98%)	39 (98%)	26 (100%)
Sigmoid colon	24 (60%)	34 (85%)	23 (88%)
Descending colon	22 (55%)	39 (98%)	23 (88%)
Transverse colon	10 (25%)	40 (100%)	23 (88%)
Ascending colon including cecum	4 (10%)	40 (100%)	23 (88%)
All	82 (41%)	192 (96%)[a]	118 (91%)[a]

Note.—All patients had initially undergone incomplete colonoscopy.

[a] $p < .05$.

(41%) segments visualized at incomplete colonoscopy in 40 patients. In three patients who had obstructing sigmoid tumors, barium could not be passed beyond the sigmoid colon. As a result, in the 26 patients who had double contrast barium enemas, a total of 118 (90.8%) of a possible 130 segments of colon were adequately revealed. For the percentages of the various colonic segments visualized at colonoscopy, endoluminal CT colonography, and double contrast barium enema, see Table 1.

Endoluminal CT colonography revealed a cause for incomplete colonoscopy in 73% of patients; these causes included redundant, tortuous colon loops (n = 17), severe diverticular disease (n = 4) (Fig. 4), obstructing sigmoid masses (n = 3), radiation stricture (n = 1), pelvic adhesions (n = 1), malrotation (n = 1), extrinsic compression by fibroids (n = 1), and partial bowel obstruction caused by a ventral hernia (n = 1). Other causes included excessive colonic spasm in 10 (25%) incomplete endoscopic colonoscopies; in one case, the colonoscope wheels broke during the procedure. Barium enema revealed a cause for incomplete colonoscopy in 65% of 26 patients. Although the difference was not statistically significant, barium enema did not identify extraluminal processes such as uterine fibroids.

Nine polypoid lesions were identified in seven patients on endoluminal CT colonography in the endoscopically nonvisualized segments of colon. Of these lesions, seven measured 5 mm, one measured 6 mm, and one measured 8 mm in diameter. The lesions were distributed in the sigmoid colon (n = 5), descending colon (n = 1, 8 mm), and one each in the transverse colon, ascending colon, and cecum. The 6-mm sigmoid polyp was seen on subsequent colonoscopy (Fig. 5). None of the 5-mm lesions were visualized on subsequent barium enema examination. In the patient with the 8-mm polypoid lesion visualized in the descending colon, this lesion was not seen on subsequent colonoscopy performed after dilatation of a radiation-induced stricture.

Clinically significant extracolonic abnormalities were identified in five patients (13%). These included mesenteric and pericolic lymphadenopathy in a patient with a sigmoid tumor, a 6-cm suprarenal aortic aneurysm (n = 1), a complex ovarian cyst (n = 1), a partially obstructing ventral hernia (n = 1), and a large fibroid with bowel compression (n = 1) (Fig. 6).

Discussion

Endoluminal CT colonography provides multiplanar and endoluminal reformatted images of a well-distended cleansed colon [5–8]. Helical data acquisition, coupled with several commercially and readily available software packages, have now made this technique available to many institutions. Several recent studies have determined that acceptable sensitivity (>90%) of endoluminal CT colonography can be achieved compared with conventional colonoscopy and have explored the possible future role of endoluminal CT colonography as a screening test for colon cancer [5–7]. In this study, we evaluated the feasibility and explored the potential

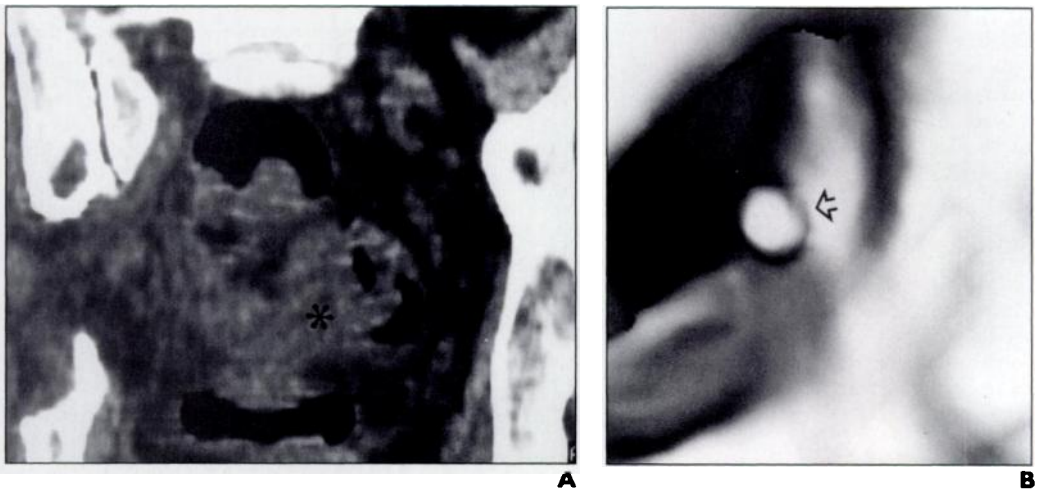

Fig. 4.—45-year-old man who had incomplete colonoscopy to sigmoid colon because of obstructing sigmoid carcinoma.
A, Coronal reformatted CT image illustrates large obstructing sigmoid tumor (*asterisk*).
B, Endoluminal CT colonographic image shows 6-mm polyp (*arrow*) in sigmoid colon proximal to obstructing sigmoid carcinoma, which was confirmed by subsequent endoscopic colonoscopy.

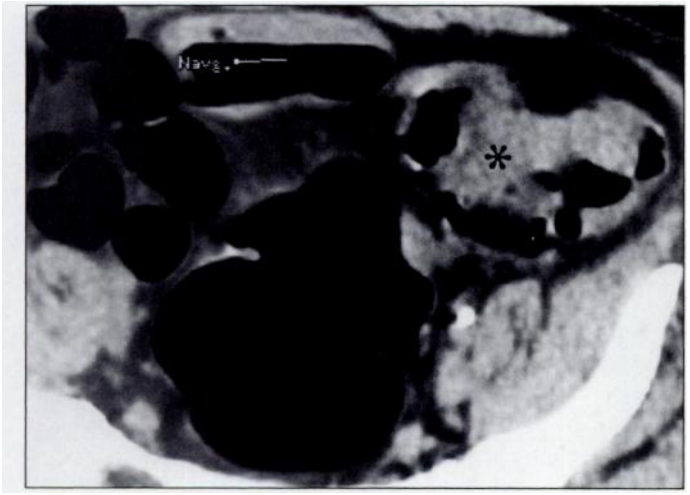

Fig. 5.—58-year-old man who had incomplete colonoscopy to sigmoid colon because of severe diverticular disease complicated by mucosal prolapse. Axial CT image illustrates multiple diverticula in sigmoid colon with associated marked wall thickening (*asterisk*) beyond which colonoscope could not be passed.

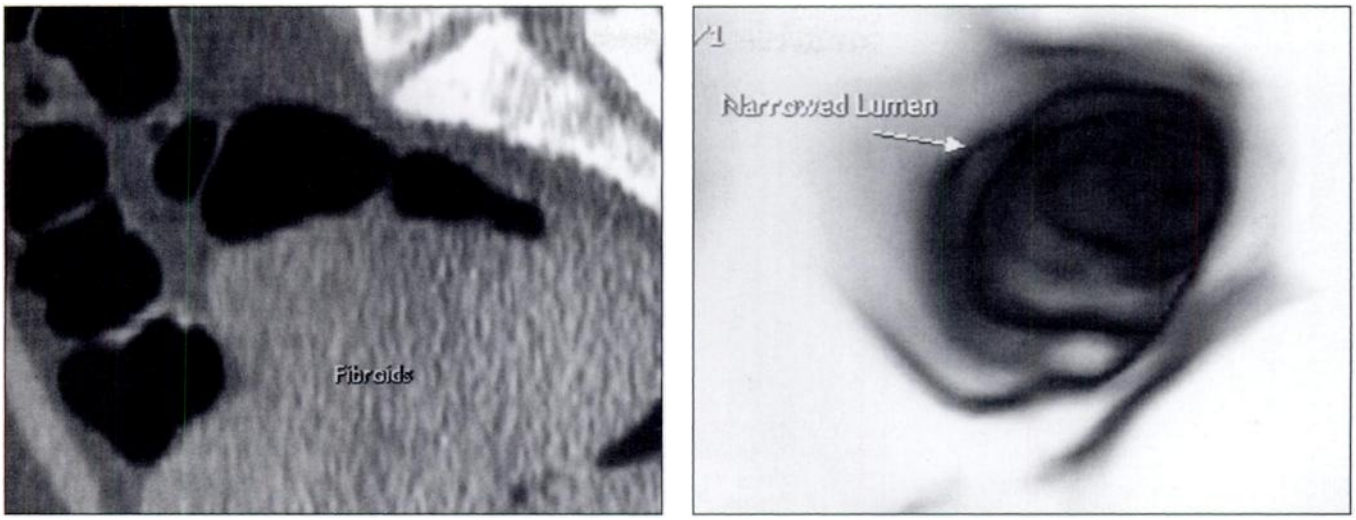

Fig. 6.—38-year-old woman who had incomplete colonoscopy to sigmoid colon because of extrinsic bowel compression caused by large uterine fibroids.
A, Sagittal reformatted CT scan shows bowel compression and uterine fibroids.
B, Endoluminal CT colonographic image illustrates narrowing of lumen of sigmoid colon associated with uterine fibroids.

clinical role of endoluminal CT colonography in a group of patients with risk factors for colorectal cancer in whom complete colonic evaluation was recommended but complete colonoscopy could not be performed. We found that endoluminal CT colonography can easily be performed in these patients immediately after incomplete colonoscopy, that it is readily tolerated, that it often only requires minimal additional air insufflation with no sedation required, and that it provides rapid images of all segments of the colon not seen during colonoscopy, in addition to revealing why colonoscopy could not be completed. Endoluminal CT colonography was also better tolerated than barium enema and revealed a greater number of descending colon, transverse colon, and cecal segments in this group of patients.

Endoscopic colonoscopy is currently the investigation of choice for the screening, diagnosis, and treatment of colorectal polyps, the precursors of colorectal carcinoma. However, visualizing the entire colon is technically challenging and time-consuming, with colonoscopy failing to visualize the entire colon in 5–15% of patients. Although the incidence of polyps is higher in the descending or sigmoid colon, 40% of polyps occur proximal to the splenic flexure [21–23]. Furthermore, synchronous adenomas are more common in the proximal colon of patients with left-sided polyps. In a recent prospective study of asymptomatic individuals at average risk for colorectal cancer, 31% of those found to have benign distal adenomas at screening flexible sigmoidoscopy had proximal synchronous neoplasms [24]. Our study corroborates these reports of increased prevalence of lesions because we identified eight polypoid lesions in the part of the proximal colon that was not endoscopically visualized. A 6-mm polyp in the proximal sigmoid colon was seen on colonoscopy in a patient with a large rectosigmoid carcinoma. There was one false-positive finding of an 8-mm polypoid lesion at the splenic flexure, which was not visualized on subsequent repeated colonoscopy after dilatation. In addition, none of the other seven polypoid lesions were seen on barium enema. Although we do not have proof of these polypoid lesions identified at endoluminal CT colonography, they do not necessarily represent false-positive findings because even in experienced hands, barium enema examination fails to visualize approximately 5–20% of polyps larger than 1 cm and 20–40% of polyps smaller than 1 cm [10–19]. Although we could not assess the accuracy of endoluminal CT colonography in our patient group, it is reasonable to assume that detection of lesions in the endoscopically unseen region of colon would parallel the high accuracy reported in the literature (sensitivity for detection of polyps larger than 1 cm, 100%; sensitivity for detection of 5- to 9-mm polyps, 71–90%) [5–9].

Although the current standard of care for patients with incomplete colonoscopy is double contrast barium enema, performing a diagnostic-quality barium examination on the same day as incomplete colonoscopy (to expedite care and prevent repeated full-bowel preparation) can occasionally be difficult and sometimes untenable because of excessive air in the bowel. In addition, the bowel cleansing preparation usually used is Golytely, an oral cathartic agent that frequently results in excessive residual intraluminal fluid, which may prevent adequate coating of the colon wall with barium. We did not encounter these problems in our study. Furthermore, barium enema may be refused by the patient or contraindicated on the same day as colonoscopy if a polypectomy has been performed. In these situations, repeated full-bowel preparation is considered intolerable by many patients.

Endoluminal CT colonography was significantly better tolerated by patients than were endoscopic colonoscopy or double contrast barium enema. Furthermore, most patients found the endoluminal CT colonography to be a much less degrading and unpleasant experience than either endoscopic colonoscopy or barium enema. Endoluminal CT colonography thus represents a feasible, well-tolerated, safe, noninvasive alternative to barium enema and may serve as an adjunct to endoscopic colonoscopy in patients who have undergone incomplete endoscopic colonoscopy. An additional benefit of endoluminal CT colonography is the potential to identify clinically relevant extracolonic abnormalities. In addition to imaging the liver and mesenteric drainage of three colonic tumors, our study also identified several other processes that required surgical attention. How-

ever, endoluminal CT colonography is usually performed using low amperage and without IV contrast material, and therefore, if significant incidental findings are encountered, a dedicated CT scan of the abdomen with standard technique should be performed.

The potential limitations of endoluminal CT colonography now include the length of time needed to process images and interpret the examination. Almost half of the time spent navigating the entire colon during endoluminal CT colonography was spent examining the sigmoid colon. On the other hand, navigation of the colonic segments not visualized proximal to the sigmoid colon ($n = 24$) was significantly faster, less than 20 min. Thus, if only nonvisualized proximal colonic segments are navigated, a significant reduction in the overall time for the endoluminal CT colonography would be achieved. An additional potential limitation with endoluminal CT colonography is the need for adequate air insufflation for accurate interpretation. However, in our study, almost all patients in whom colonoscopy did not progress beyond the splenic flexure had adequate distention of the remaining nonvisualized colon before air insufflation. This suggests that air insufflation after incomplete colonoscopy may be required only in a minority of patients. In our study, the sigmoid colon appeared to be the least well distended colonic segment visualized by endoluminal CT colonography, reflecting a preponderance of marked diverticular disease and strictures at this location.

In conclusion, endoluminal CT colonography is a rapid, well-tolerated technique that successfully imaged all nonvisualized portions of the colon in patients who had undergone incomplete colonoscopic examinations. It yields clinically useful colonic and extracolonic information, and if additional studies show endoluminal CT colonography to be an accurate technique, it could replace barium enema in patients who have an incomplete colonoscopy.

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