Computed Tomographic Colonography Without Cathartic Preparation for the Detection of Colorectal Polyps

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Background & Aims: **We prospectively compared the performance of low-dose multidetector computed tomographic colonography (CTC) without cathartic preparation with that of colonoscopy for the detection of colorectal polyps.** ***Methods:*** **A total of 203 patients underwent low-dose CTC without cathartic preparation followed by colonoscopy. Before CTC, fecal tagging was achieved by adding diatrizoate meglumine and diatrizoate sodium to regular meals. No subtraction of tagged feces was performed. Colonoscopy was performed 3–7 days after CTC. Three readers interpreted the CTC examinations separately and independently using a primary 2-dimensional approach using multiplanar reconstructions and 3-dimensional images for further characterization. Colonoscopy with segmental unblinding was used as reference standard. The sensitivity of CTC was calculated both on a per-polyp and a per-patient basis. For the latter, specificity, positive predictive values, and negative predictive values were also calculated.** ***Results:*** **CTC had an average sensitivity of 95.5% (95% confidence interval [CI], 92.1%–99%) for the identification of colorectal polyps ≥8 mm. With regard to per-patient analysis, CTC yielded an average sensitivity of 89.9% (95% CI, 86%–93.7%), an average specificity of 92.2% (95% CI, 89.5%–94.9%), an average positive predictive value of 88% (95% CI, 83.3%–91.5%), and an average negative predictive value of 93.5% (95% CI, 90.9%–96%). Interobserver agreement was high on a per-polyp basis (κ statistic range, .61–.74) and high to excellent on a per-patient basis (κ statistic range, .79–.91).** ***Conclusions:*** **Low-dose multidetector CTC without cathartic preparation compares favorably with colonoscopy for the detection of colorectal polyps.**

Several studies have shown that screening for colorectal cancer (CRC) is effective in reducing the incidence rate and mortality from this disease.[1–3] However, despite this positive evidence and screening guidelines,[4–7] about one half of the average-risk population of the United States eligible for CRC screening do not pursue prevention tests.[8] The reasons for low participation in CRC screening programs are numerous and perhaps not yet completely understood.[9–15]

One of the barriers that may deter participation in CRC screening programs is the aversion of patients to bowel preparation.[12–15] It has therefore been suggested that the elimination of bowel preparation could enhance patient compliance and potentially increase the participation rate in CRC screening programs.[14,16,17]

Computed tomographic colonography (CTC), a recently developed imaging modality in which computed tomography (CT) data sets are used to generate 2-dimensional and 3-dimensional images of the colon,[18–20] can theoretically be performed without prior bowel preparation. However, without prior bowel cleansing, fecal material would either obscure or simulate the presence of colonic polyps because it has the same attenuation as colonic mucosa. In the attempt to differentiate fecal material from colonic mucosa, several recent reports on CTC have investigated the possibility of labeling the stool by adding contrast-modifying substances to regular meals (the so-called "fecal tagging" technique).[21–27] Some investigators have shown the feasibility of fecal tagging to completely eliminate bowel preparation be-

Abbreviations used in this paper: CI, confidence interval; CRC, colorectal cancer; CT, computed tomography; CTC, computed tomographic colonography.

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fore CTC.[21,22,25,26] However, these studies have been either preliminary or small in size; therefore, no reliable conclusion could be reached with regard to the performance of CTC without prior bowel cleansing. In addition, as of yet, no study has evaluated the expected improvement in patient acceptance. Notably, the American Gastroenterological Association has included the development of a "prep-less" CTC examination as one of the issues for future research on CRC screening.[7]

We therefore undertook this study to prospectively compare the performance of low-dose multidetector CTC without bowel cathartic preparation with that of optical colonoscopy for the detection of colorectal polyps.

Patients and Methods

The study was approved by our institutional review board. Written informed consent was obtained from all patients after the purpose and protocol of the study had been fully explained.

Patients 35 years of age or older scheduled to undergo optical colonoscopy were eligible. Indications for optical colonoscopy included average-risk CRC screening, a personal or family history of colorectal polyps, a family history of CRC, follow-up of an abnormal screening test (positive guaiac-based test of stool, sigmoidoscopy, or barium enema), and evaluation of iron deficiency anemia, hematochezia, change in bowel habits, abdominal pain, or weight loss. Exclusion criteria included history of familial adenomatous polyposis or hereditary nonpolyposis cancer syndromes; prior colorectal surgery; a suspected diagnosis of inflammatory bowel disease, bowel obstruction, or acute diverticulitis; a medical condition that precluded the use of bowel preparation; rejection for optical colonoscopy for any reason; contraindications to the ingestion of iodine-containing contrast agents (see following text); and pregnancy.

Fecal Tagging

For fecal tagging, an oral iodinated contrast agent (diatrizoate meglumine and diatrizoate sodium with an iodine concentration of 370 mg/mL, Gastrografin; Schering, Berlin, Germany) was administered in a total dose of 200 mL. Specifically, patients were asked to drink 20 mL of the contrast agent diluted in a glass of water at each of 5 principal meals beginning 48 hours before CTC (ie, 100 mL/day). During this period, patients were instructed to avoid intake of all fiber-rich food, including fruit, vegetables, whole-grain bread, and whole-grain cereals. Otherwise, all subjects were free to choose their diet, with no restrictions on fluid intake. No cathartic preparation was used before CTC.

CTC: Study Technique

CTC examinations were performed with a multidetector helical CT scanner (Somatom Plus 4 Volume Zoom; Siemens, Erlangen, Germany) with a tube rotation time of .5 seconds. In an attempt to minimize bowel peristalsis and reduce colonic spasm, a spasmolytic agent was administered intravenously before CTC. Hyoscine-*N*-butylbromide (20 mg, Buscopan; Boehringer Ingelheim, Ingelheim, Germany) was routinely prescribed (n = 189); if contraindicated (eg, for prostate hyperplasia, gastrointestinal obstruction, tachycardia, or glaucoma), glucagon hydrochloride (1 mg, Glucagen; Novo Nordisk, Malmo, Sweden) was administered (n = 14). With the patient in the left lateral decubitus position, the colon was gently insufflated with room air by a professional nurse using a lubricated Foley catheter placed in the rectum until the patient requested that air insufflation be discontinued or distention was believed to be adequate. The rectal tube was subsequently clamped and left in place during scanning. With the patient in the prone position, an anteroposterior CT scout image was obtained to assess the degree of colonic distention. If adequate colonic distention had not been achieved, air insufflation was administered again according to patient tolerance. Before scanning with the patient in the supine position, the colon was insufflated with additional air and colonic distention was checked with a second anteroposterior CT scout image.

CT images were acquired using a low-dose protocol optimized by Iannaccone et al[28] for the CT scanner used in the present study: slice collimation, 2.5 mm; slice thickness, 3.0 mm; reconstruction interval, 1.0 mm; table speed, 17.5 mm/s; acquisition time, 12–18 seconds; kVp, 140; and effective mAs, 10.

In addition, a senior resident who was not involved in the evaluation of CTC data recorded any complications associated with CTC. The same resident interviewed all patients concerning the presence of adverse effects related to the fecal regimen strategy; specifically, patients were asked about the occurrence of diarrhea, abdominal cramps, nausea, and vomiting.

CTC: Image Analysis

The CT data sets were postprocessed using commercially available software (Vitrea 2; Vital Images, Plymouth, MN). Three gastrointestinal radiologists separately and independently analyzed each case directly on a dedicated workstation. The readers had previously interpreted approximately 300, 200, and 100 CTC examinations with endoscopic correlation, respectively. All readers were blinded to the indications and results of optical colonoscopy.

Image analysis was performed in a previously validated "time-efficient" fashion.[29] In brief, image analysis consisted of review of magnified 2-dimensional transverse images. When a suspected polyp was detected, coronal and sagittal multiplanar reconstructions as well as 3-dimensional images were also analyzed to confirm the finding and increase diagnostic confidence. If no suspected polyp was detected after review of the transverse scans, no further image analysis was performed. The number, location, and size of all suspected polyps were recorded. The maximum diameter of all polyps was measured using an electronic ruler on the CT images. To specify the location of each lesion, the colon was divided into 6 segments: cecum, ascending colon and hepatic flexure, transverse colon

and splenic flexure, descending colon, sigmoid colon, and rectum. All polyps seen at CTC were photographed and stored in digital format. Extracolonic findings on CT were also documented and categorized as representing a condition of low, moderate, or high clinical importance.[30,31] Findings in each patient were prospectively recorded by the 3 readers on the same day that the CTC examination was performed. Image interpretation time for each CTC examination was also noted.

The effectiveness of fecal tagging was jointly assessed by 2 senior residents not involved in the evaluation of the CT data sets for lesion detection. Because the fecal tagging agent used in the present study was believed to opacify both solid and liquid fecal material, no separate assessment of tagging effectiveness was made for solid and liquid feces. Specifically, to quantify the effectiveness of tagging, fecal material was considered either labeled or not labeled on a per-segment basis. The colon was divided into 6 segments based on the same classification system described for lesion localization. Therefore, 1218 total colonic segments were evaluated (6 segments in each of the 203 patients). Each segment of the colon was given a visual subjective score of 0%, 25%, 50%, 75%, or 100% for the effectiveness of fecal tagging, with a score of 0% assigned in the case of unlabeled stool and a score of 100% assigned for complete homogeneous labeling of stool.[21,23] For long or tortuous colonic segments, the grade was assigned based on the area within the segment with the worst label. In addition to this per-segment analysis, the effectiveness of tagging was also assessed on a per-patient basis. In brief, the total colon of each patient was judged as having poor tagging (inadequate labeling of stool with severe difficulties in image interpretation), sufficient tagging (adequate labeling of stool with minor difficulties in image interpretation), and excellent tagging (homogeneous labeling of stool with clear differentiation between fecal material and colonic mucosa).

Optical Colonoscopy

Optical colonoscopy was performed in all patients 3–7 days after CTC (average, 4.2 days). Bowel preparation before optical colonoscopy comprised 2 L of polyethylene glycol electrolyte solution (Isocolan; Bracco, Milan, Italy) to be initiated on the afternoon of the day before the examination. Once the oral lavage solution was administered, each patient was instructed to ingest 10 mg of bisacodyl (Dulcolax; Boehringer Ingelheim, Ingelheim, Germany) on the evening before the examination. Bisacodyl was added to reduce the amount of fluid ingested by the patient because a high amount of fluid can reduce patient compliance.[32]

A single experienced colonoscopist, who was initially blinded to the results of CTC, performed these examinations using a standard video colonoscope (Olympus C240; Olympus Optical Co, Tokyo, Japan). The colonoscopist had performed more than 5000 colonoscopic examinations before this study. The instrument was inserted into the cecum and sequentially withdrawn segment by segment for the detection of polyps. Cecal intubation was verified by identification of the appendix orifice, triradiate cecal fold, ileocecal valve, and small bowel biopsy at terminal ileal intubation. The location and size of all colorectal polyps were documented. Polyps were photographed and size was estimated with the use of a fully open biopsy forceps (4 mm) pushed against the polyp or by direct comparison with the resected specimen before formalin fixation when the polyp was retrieved in toto. All of the examinations were performed while the patients were under moderate sedation with intravenous administration of midazolam hydrochloride (Versed; Hoffmann-La Roche Inc, Nutley, NJ).

Table 1. Questionnaire

Since you had both the preparation with "Gastrografin" prior to CT colonography and the preparation with "Isocolan and Dulcolax" prior to colonoscopy: which preparation did you prefer?
☐ "Gastrografin" (prior to CT colonography)
☐ "Isocolan and Dulcolax" (prior to colonoscopy)
☐ No preference
Since you had both CT colonography and colonoscopy: which exam would you repeat in the future?
☐ CT colonography
☐ Colonoscopy
☐ No preference

After the colonoscopist completed the evaluation of a given colonic segment, a senior resident who was not involved in the evaluation of CTC data revealed the results of CTC for the previously examined segment. If a polyp was identified at CTC but not on optical colonoscopy, the endoscopist carefully reexamined that segment. This "segmental unblinding" has been previously adopted[33–35] to minimize the possibility that false negatives from optical colonoscopy would be recorded as false positives on CTC. When CTC results were negative, a second look was not performed. All polyps were retrieved or a biopsy was performed for subsequent histologic evaluation. The same pathologist examined all specimens. Polyps were histologically classified as non-neoplastic (including hyperplastic, inflammatory, and juvenile polyps) or neoplastic (including tubular, villous, tubulovillous, serrated, and microtubular adenomas; carcinoma in situ; and invasive carcinoma).[36]

At discharge, all patients were given a questionnaire to complete at home and return by mail. The questionnaire evaluated the levels of acceptance of fecal tagging before CTC and bowel preparation before optical colonoscopy as well as the preference for the use of CTC or optical colonoscopy in the future (Table 1). To avoid the effects of sedation, patients were instructed to complete the questionnaire no sooner than 24 hours after optical colonoscopy.

Data Analysis

Results were calculated in 2 ways: (1) individual polyp detection (per-polyp analysis) and (2) patient detection (per-patient analysis). As elucidated by Pineau et al,[33,34] the per-polyp analysis is important to understand which polyps CTC is most likely to identify or miss. However, from a clinical point of view, the per-patient analysis is of pivotal importance because it determines which patients should undergo optical colonoscopy in case of a positive CTC examination.[33,34]

With regard to per-polyp analysis, results of optical colonoscopy for location and size were considered the reference standard in all cases. When CTC detected a polyp missed on initial optical colonoscopy, results of the second-look optical colonoscopy after unblinding were used as a reference standard. In these cases, the location and size of the polyp documented by the second-look optical colonoscopy were considered the reference standard.[33,34] For a given polyp to be considered a true-positive match between CTC and optical colonoscopy, both the location and the size of the polyp were considered. Endoscopic localization of colonic segments can be inaccurate due to the lack of clear landmarks separating the different segments.[37] Therefore, with respect to location, a polyp identified on CTC was considered concordant with one found on optical colonoscopy if it was located in the same or adjacent colonic segment, except for cecal polyps, in which no margin of error was allowed due to the presence of clear demarcating borders within the cecum.[33,34] Correlation of polyps by size criteria would rarely be possible because of the known measurement error associated with endoscopic measurement and the unknown measurement error associated with CTC.[33,34] Therefore, for a given polyp to match the size criteria, the size measured on CTC had to be within a 50% margin of error from the size determined by optical colonoscopy.[33–35] After completion of the comparison, a retrospective review of all false-negative and false-positive lesions at CTC was jointly performed by the 3 readers, together with a study supervisor, to determine the reasons for diagnostic errors. In addition, because of a potential range of size measurements for a given polyp among the 3 readers, a consensus reading was performed to establish the CT size of each polyp. Therefore, the average results given throughout this report refer to the size of polyps as derived from this consensus reading.

With regard to per-patient analysis, the overall CTC examination results were compared with the overall optical colonoscopic examination results for each patient. A case was considered true positive if CTC detected at least one polyp seen on optical colonoscopy based on the location and size criteria described previously.

Statistical Analysis

With regard to per-polyp analysis, the sensitivities with confidence intervals (CIs) of CTC were calculated for both total polyps (neoplastic and non-neoplastic polyps combined) and for neoplastic polyps alone. Because a total number of true-negative polyps cannot be assessed, specificity for individual polyps cannot be calculated.[34]

With regard to per-patient analysis, the sensitivity, specificity, positive predictive value, negative predictive value, and 95% CIs were calculated.

Interobserver variabilities for both per-polyp and per-patient detection at CTC were evaluated by calculating the κ statistic for multiple readers with the nonweighted binary κ statistic. A κ value between .01 and .20 was judged as minor agreement, between .21 and .40 as fair; between .41 and .60 as moderate, between .61 and .80 as high, and between .81 and 1.00 as excellent.

Commercially available software (SPSS for Windows version 11.0.0; SPSS Inc, Chicago, IL) was used to perform all statistical analyses.

Table 2. Demographic Characteristics and Indications for Optical Colonoscopy of the Study Population

No. of male patients (%)	141 (69.4)
Age (*y*)	
Mean	60.5
Range	36–80
Ethnicity (%)	
White	100
Indication for optical colonoscopy, n (%)	
Asymptomatic patients	105 (51.7)
Screening	46 (22.6)
Family history of colorectal cancer	32 (15.8)
Personal history of polyps	19 (9.3)
Abnormal screening test[a]	8 (3.9)
Symptomatic patients	98 (48.3)
Hematochezia	38 (18.7)
Change in bowel habits	23 (11.3)
Iron deficiency anemia	15 (7.4)
Abdominal pain	12 (5.9)
Weight loss	10 (2.1)

NOTE. n = 203.
[a]Includes positive guaiac-based test of stool (n = 4), sigmoidoscopy (n = 2), or barium enema (n = 2).

Results

From April 2002 to September 2003, a total of 426 patients referred for optical colonoscopy met the criteria for enrollment in the study. Of these, 204 declined to participate. Of the 222 remaining patients, 9 patients were excluded because of incomplete optical colonoscopy (for a completion rate of 96%) and 10 patients were excluded because of failure of the CT scanner on the day of the scheduled CTC examination. The remaining 203 patients underwent complete CTC and optical colonoscopic examinations and thus constituted the final study population. Demographic characteristics and indications for optical colonoscopy of the study population are shown in Table 2. Overall, 98 patients (48.3%) were scheduled to undergo optical colonoscopy for the evaluation of symptoms. The remaining 105 patients (51.7%) were asymptomatic.

Optical Colonoscopy

Only one patient (.5%) had a complication associated with optical colonoscopy (ie, gastrointestinal bleeding that required hospitalization). A negative optical colonoscopy examination was observed in 124 patients (61%). A total of 162 polyps were detected in the remaining 79 patients; of these, 40 had a single polyp,

Table 3. Distribution of Polyps According to Size, Location, and Histology

No. of polyps	Polyp size			
	≤5 mm	6–9 mm	≥10 mm	Any size
Rectum				
Neoplastic	3	3	2	8
Non-neoplastic	15	5	1	21
Total	18	8	3	29
Sigmoid colon				
Neoplastic	11	8	6	25
Non-neoplastic	18	7	3	28
Total	29	15	9	53
Descending colon				
Neoplastic	4	4	4	12
Non-neoplastic	7	4	2	13
Total	11	8	6	25
Transverse colon/splenic flexure				
Neoplastic	3	2	2	7
Non-neoplastic	5	3	0	8
Total	8	5	2	15
Ascending colon/hepatic flexure				
Neoplastic	4	7	2	13
Non-neoplastic	9	2	1	12
Total	13	9	3	25
Cecum				
Neoplastic	1	8	1	10
Non-neoplastic	3	2	0	5
Total	4	10	1	15
All colonic segments				
Neoplastic	26	32	17	75
Non-neoplastic	57	23	7	87
Total	83	55	24	162

18 had 2 polyps, and 21 had 3 or more polyps. Table 3 summarizes the distribution of polyps according to size, segmental location, and histology; these are the final results based on the unblinded optical colonoscopy. Of the 162 polyps, 83 (51.2%) were 1–5 mm in diameter, 55 (33.9%) were 6–9 mm in diameter, and 24 (14.8%) were ≥10 mm in diameter.

All polyps were successfully classified histologically. Non-neoplastic histology was reported in 75 of 162 polyps (46.3%); all of these polyps proved to be hyperplastic. The remaining 87 polyps were categorized as neoplastic and included 67 tubular adenomas (41.3%), 9 tubulovillous adenomas (5.5%), 2 serrated adenomas (1.2%), 3 carcinomas in situ (1.8%), and 6 invasive carcinomas (3.7%).

A total of 5 polyps (3.1%) in 3 patients were missed by optical colonoscopy and were only found by the second-look optical colonoscopy after unblinding to the results of CTC. All of these polyps were tubular adenomas (diameter range, 4–8 mm) situated behind a colonic fold.

CTC

Twenty-three of 203 patients (10.3%) reported adverse reactions during the fecal tagging regimen (diarrhea, n = 13; abdominal cramps, n = 6; nausea, n = 3; vomiting, n = 1). No complication was associated with the CTC examination. Average CT image interpretation time was 9.8 minutes (range, 8–15 minutes). With regard to labeling of fecal material on a per-segment basis, fecal tagging yielded an average labeling score of 82% for the cecum, 85% for the ascending colon, 80% for the transverse colon, 82% for the descending colon, 84% for the sigmoid colon, and 84% for the rectum. On a per-patient basis, fecal material was judged to have excellent tagging (ie, homogeneous labeling with clear differentiation between fecal material and colonic mucosa) in 200 of 203 patients (98.5%). Due to a less homogeneous tagging of the fecal material, the remaining 3 patients (1.5%) were judged to have sufficient tagging (ie, adequate labeling of stool with minor difficulties in image interpretation).

Extracolonic findings were present in 28 of 203 patients (13.7%). Of these, 4 were categorized as of high clinical importance, 7 as of moderate clinical importance, and 17 as of low clinical importance. Overall, further diagnostic imaging was recommended in 8 patients (3.9%).

Per-Polyp Analysis

The κ values among the 3 observers showed high agreement regarding the presence or absence of individual colorectal polyps (Table 4). Table 5 shows the results of the 3 observers for individual polyp detection according to polyp size. CTC had an average per-polyp sensitivity of 64.4% (95% CI, 60.2%–68.7%; average sensitivity, 72% for neoplastic polyps) (Figure 1*A–C* and Figure 2*A* and *B*). If the analysis was focused on polyps ≥8 mm, CTC had an average sensitivity of 95.5% (95% CI, 92.1%–99%; average sensitivity, 100% for neoplastic polyps). If the cutoff size was reduced to polyps ≥6 mm, CTC had an average sensitivity of 86% (95% CI, 81.7%–90.5%; average sensitivity, 90.5% for neoplastic polyps).

The causes for false-positive and false-negative findings in individual polyp detection at CTC are shown in Table 6. CTC yielded 16, 16, and 21 false positives for readers 1, 2, and 3, respectively. At retrospective analy-

Table 4. Agreement Between Readers Regarding the Presence or Absence of Individual Colorectal Polyps (Per Polyp) and Regarding the Identification of Patients With Colorectal Polyps (Per Patient)

	Readers		
	1 vs 2	2 vs 3	1 vs 3
Per polyp	.64	.74	.61
Per patient	.91	.79	.87

Table 5. Sensitivity of the 3 Readers for Individual Polyp Detection According to Polyp Size

	Polyp size (*mm*)						
	≤5	≥6	≥7	≥8	≥9	≥10	Total
Reader 1	45/83	68/79	57/61	44/45	30/30	24/24	108/162
Sensitivity for all polyps (%)	54.2 (42.9–65.2)	86 (76.5–92.8)	93.4 (84–98.2)	97.7 (88.2–99.9)	100 (88.4–100)	100 (85.8–100)	66.6 (59.4–73.9)
Reader 1	13/26	44/49	35/37	28/28	21/21	17/17	55/75
Sensitivity for neoplastic polyps (%)	50 (29.9–70.1)	89.8 (77.9–96.6)	94.6 (81.8–99.3)	100 (87.8–100)	100 (83.9–100)	100 (80.5–100)	73.3 (61.9–82.9)
Reader 2	43/83	69/79	56/61	43/45	30/30	24/24	105/162
Sensitivity for all polyps (%)	51.8 (39.4–61.8)	87.3 (78–93.8)	91.8 (81.9–97.3)	95.5 (84.9–99.5)	100 (88.4–100)	100 (85.8–100)	64.8 (57.5–72.2)
Reader 2	13/26	45/49	34/37	28/28	21/21	17/17	55/75
Sensitivity for neoplastic polyps (%)	50 (29.9–70.1)	91.8 (80.4–97.7)	91.9 (78.1–98.3)	100 (87.7–100)	100 (83.9–100)	100 (80.5–100)	73.3 (61.9–82.9)
Reader 3	42/83	67/79	55/61	42/45	30/30	24/24	100/162
Sensitivity for all polyps (%)	50.6 (39.4–61.8)	84.8 (75–91.9)	90.2 (79.8–96.3)	93.3 (81.7–98.6)	100 (88.4–100)	100 (85.8–100)	61.7 (54.2–69.2)
Reader 3	11/26	44/49	34/37	28/28	21/21	17/17	52/75
Sensitivity for neoplastic polyps (%)	42.3 (23.4–63.1)	89.8 (77.8–96.6)	91.9 (78.1–98.3)	100 (87.8–100)	100 (83.9–100)	100 (80.5–100)	69.3 (57.6–79.5)

NOTE. Data are presented separately for all polyps (ie, neoplastic and non-neoplastic polyps combined) and for neoplastic polyps alone. 95% CIs are presented in parentheses.

sis, the most frequent cause of error was attributed to the presence of thickened, polypoid-like colonic folds. Interestingly, despite the absence of bowel cleansing, fecal material accounted for only 4, 4, and 5 false-positive findings for readers 1, 2, and 3, respectively.

Overall, CTC yielded 54, 57, and 62 false-negative findings for readers 1, 2, and 3, respectively. Despite careful retrospective analysis, no clear cause of error could be determined for 49, 51, and 53 of these false negatives. Notably, only 1, 2, and 2 false negatives for readers 1, 2, and 3, respectively, were related to the presence of fecal material (ie, unlabeled fecal material).

Per-Patient Analysis

The κ values among the 3 observers showed high to excellent agreement in the identification of patients with colorectal polyps (Table 4). With regard to the identification of patients with colorectal polyps, CTC yielded an average sensitivity of 89.9% (95% CI, 86%–93.7%), an average specificity of 92.2% (95% CI, 89.5%–94.9%), an average positive predictive value of 88% (95% CI, 83.3%–91.5%), and an average negative predictive value of 93.5% (95% CI, 90.9%–96%). Table 7 summarizes the results of the 3 observers for identification of patients with colorectal polyps according to polyp size.

Questionnaire

A total of 162 of the 203 patients (79.8%) returned their questionnaires. Overall, more patients preferred fecal tagging before CTC compared with cathartic bowel preparation before optical colonoscopy: 143 patients (88.3%) preferred fecal tagging, 12 patients (7.4%) preferred cathartic bowel preparation, and 7 patients (4.3%) had no preference. In addition, more patients indicated that they would prefer CTC to optical colonoscopy in the future: 99 patients (61.1%) preferred CTC, 57 patients (35.2%) preferred optical colonoscopy, and 6 patients (3.7%) had no preference.

Discussion

We prospectively compared the performance characteristics of low-dose multidetector CTC without cathartic bowel preparation with that of optical colonoscopy for the detection of colorectal polyps. Our results show that low-dose multidetector CTC without cathartic bowel preparation provides excellent results for the detection of colorectal polyps ≥8 mm (average sensitivity, 95.5%; average sensitivity for neoplastic polyps ≥8 mm, 100%). Even when the cutoff size is reduced to polyps ≥6 mm, CTC maintains an average sensitivity of 86%, a value that approaches that of optical colonoscopy and is in the upper range reported in the literature for CTC as performed with standard bowel cleansing.[19,38–40] This finding has important clinical implications, because polyps ≥6 mm have the highest probability of containing malignancy.[41]

By contrast, similar to what has been reported in previous studies,[19,38–40] the performance of CTC sub-

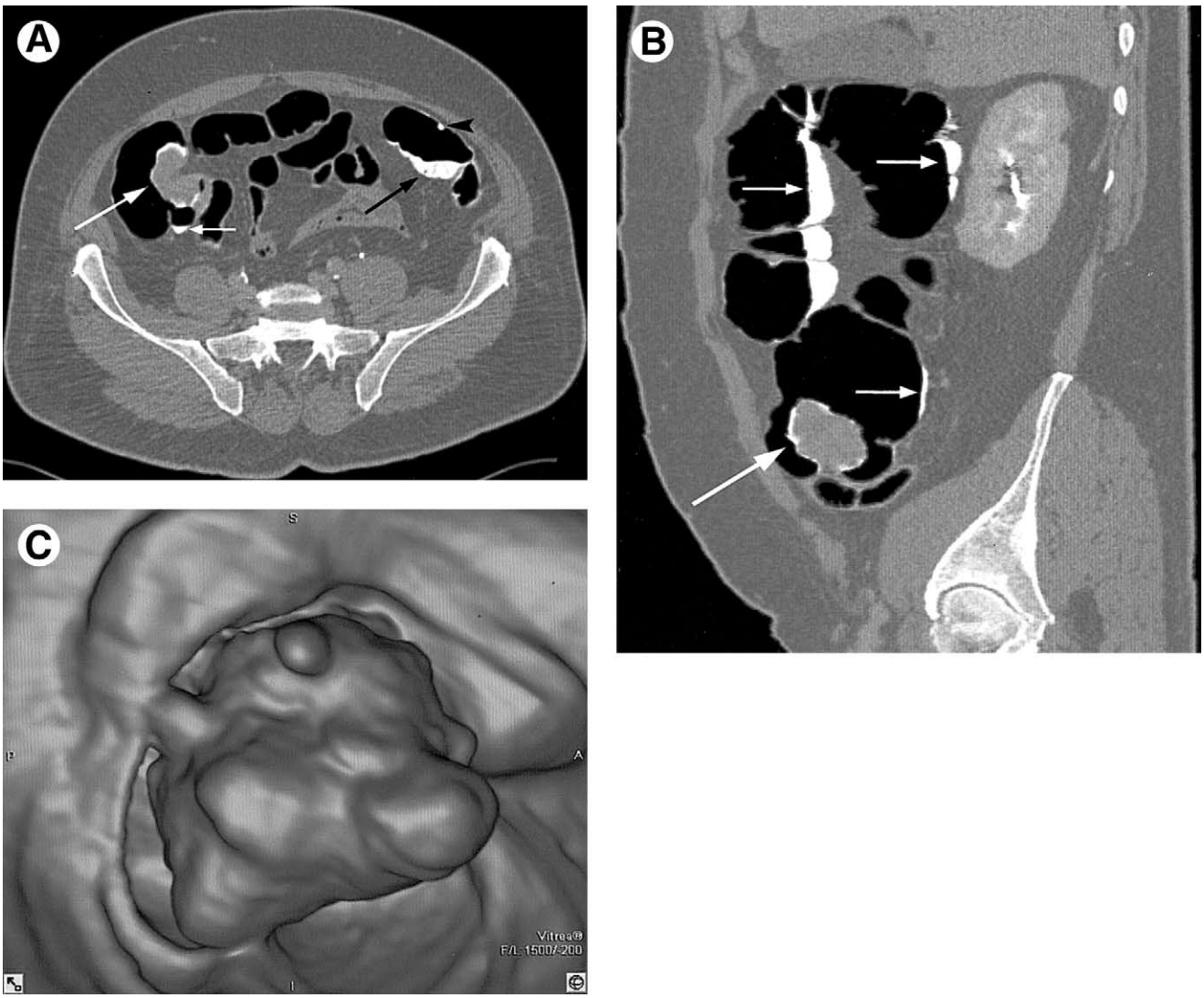

Figure 1. Carcinoma of the cecum. (*A*) Transverse CT colonographic image from supine acquisition shows a 4-cm mass within the cecum at the level of the ileocecal valve (*large white arrow*). The lesion, an invasive carcinoma at histologic examination, was correctly identified by the 3 readers. Notably, liquid fecal material within the cecum is homogeneously tagged (*small white arrow*). At the level of the descending colon, solid fecal material (*black arrow*) and a tiny fecal residue adherent to the colonic mucosa (*black arrowhead*) also are homogeneously tagged. (*B*) Multiplanar CTC reconstruction along the sagittal plane provides excellent depiction of the cecal mass (*large white arrow*). Fecal material (*small white arrows*) is homogeneously tagged throughout the colon. (*C*) The 3-dimensional endoluminal CTC image confirms the presence of the neoplasm within the cecum.

stantially decreased for the detection of polyps ≤5 mm (average sensitivity, 52.2%). In previous reports, some investigators have hypothesized that, because most such small polyps have hyperplastic histology (and, therefore, a soft consistency), polyps ≤5 mm have a tendency to be effaced when the colon is distended with air and therefore can be extremely difficult to detect at CTC.[19,39] In our study, with regard to polyps ≤5 mm, the sensitivity for the detection of neoplastic polyps (37 of 78; sensitivity, 47.4%) was slightly inferior to the sensitivity for nonneoplastic (hyperplastic) polyps (93 of 171; sensitivity, 54.3%). Thus, it is possible that polyps ≤5 mm, which generate only minimal alteration of the colonic surface, are inherently difficult to detect at CTC, regardless of histologic type. This consideration is corroborated by the retrospective analysis of diagnostic errors at CTC. Indeed, no clear cause of error could be found for the majority of false-negative findings at CTC (Table 6), which suggests that misdiagnosis of such polyps can most likely be attributed to the current limits of CT image spatial resolution. However, considering that only a minority of these small polyps are malignant[42] and that the adenoma-carcinoma transformation is estimated to take at least 10 years on average,[1,43] the identification of such diminutive polyps is of controversial clinical importance.

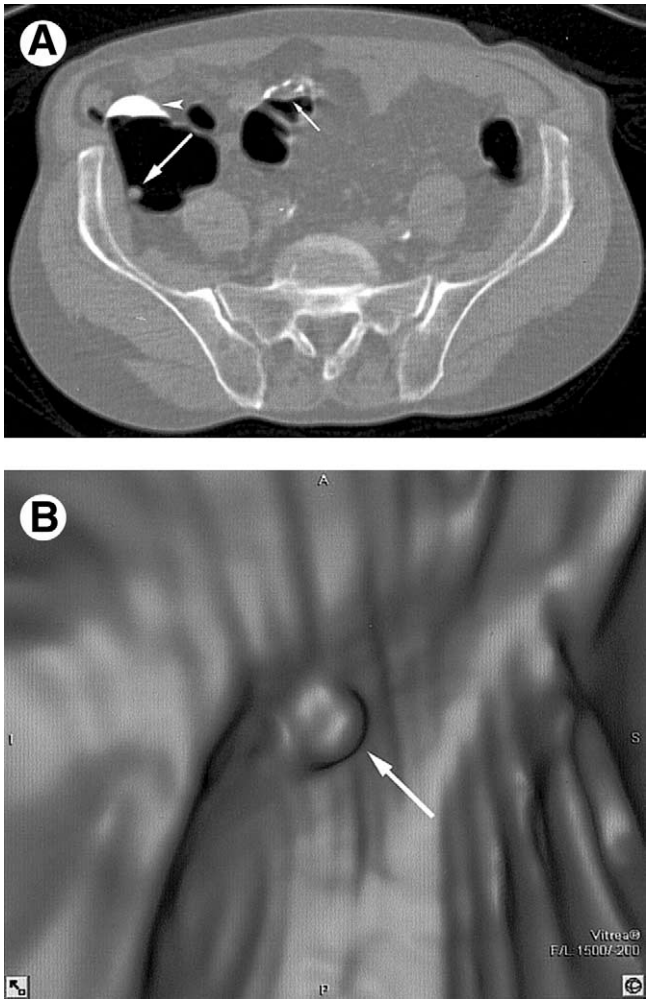

Figure 2. Polyp of the cecum and polyp of the sigmoid colon. (*A*) Transverse CTC image from prone acquisition shows an 8-mm polyp within the cecum (*large arrow*). Liquid fecal material is homogeneously tagged (*arrowhead*). Another 20-mm polyp is detected within the sigmoid colon (*small arrow*). Although this polyp is completely submerged by liquid fecal material, it can still be identified because of the excellent tagging of the feces. Both polyps were correctly depicted by the 3 readers. At histologic examination, the polyp within the cecum was proven to be a tubular adenoma, whereas the sigmoid polyp was proven to be a tubulovillous adenoma. (*B*) The 3-dimensional endoluminal CTC image confirms the presence of the 8-mm polyp within the cecum (*arrow*).

Although individual polyp detection (per-polyp analysis) is extremely important to assess the performance of CTC, the identification of patients with colorectal polyps (per-patient analysis) is, from a clinical point of view, far more important. In this regard, the most impressive result of our study is the high negative predictive value of CTC (average negative predictive value, 93.5%). Indeed, as noted by Pineau et al,[34] the negative predictive value of CTC represents the ability of this examination to correctly identify those patients who do not need to undergo optical colonoscopy. The clinical impact of this issue can easily be understood, considering that 46%–85% of screening colonoscopies identify no clinically significant pathology.[44,45]

Although Pickhardt et al[35] have proposed a threshold of 8 mm, the appropriate threshold of polyp size that should trigger a therapeutic optical colonoscopy is not yet known. Further studies are certainly warranted to evaluate this important issue.

A further advantage of our proposed fecal tagging strategy is the reduction of diagnostic errors (either false positives or false negatives) related to fecal material, with a consequent increase in specificity compared with previous reports. In fact, fecal material may often either obscure or mimic the presence of colorectal polyps and therefore remains a major source of false-negative and false-positive diagnoses at CTC.[46] In particular, tiny fecal debris is often indistinguishable from small polyps because it is adherent to the colonic mucosa (and consequently does not change position from the prone to the supine image) and is too small to contain gas bubbles (a finding consistent with fecal material). This leads to false-positive findings, which translate into unnecessary optical colonoscopies and therefore may represent a potential limitation of CTC.[47] It is noteworthy that, in our study, only a few false positives and false negatives were attributed to fecal material at retrospective analysis (Table 6). This result is correlated to the fact that the use of an effective fecal tagging strategy in our study helped the readers in the differentiation between fecal material and colonic polyps.

Moreover, our study shows that CTC images without cathartic bowel preparation are interpreted with high interobserver agreement on a per-polyp basis and with high to excellent interobserver agreement on a per-patient basis, thus suggesting the reproducibility of our results. This result correlates with the findings of other investigators[35,48] but is in contrast to the recent findings of Johnson et al.[49] Two possible factors, namely the use of fecal tagging strategy and thin-section multidetector CT acquisition, might have minimized interobserver variability in our study compared with the study from the Mayo Clinic.[49]

Notably, in our study, average image interpretation time was 9.8 minutes, which is substantially lower than the reading time reported by Pickhardt et al (average reading time, 19.6 minutes).[35] This difference can be explained with our primary 2-dimensional approach for the analysis of CTC examinations, in which coronal and sagittal multiplanar reconstructions as well as 3-dimensional images are used to confirm and better characterize suspected polyps. By contrast, Pickhardt et al[35] based image interpretation primarily on 3-dimensional images, which can be potentially more time consuming. Specific

Table 6. Causes for False-Positive and False-Negative Findings in Individual Polyp Detection at CTC

	Total no.	Perceptual error	Fecal material	Collapsed bowel	Thick fold	Motion artifact	No clear cause[a]
False positives							
Reader 1	16	0	4	0	8	3	1
Reader 2	16	0	4	0	9	2	1
Reader 3	21	0	5	0	9	4	3
False negatives							
Reader 1	54	2	1	2	0	0	49
Reader 2	57	3	2	1	0	0	51
Reader 3	62	5	2	2	0	0	53

[a]The polyp could not be seen retrospectively in a well-distended colonic segment with adequate labeling of the fecal material.

studies are needed to compare a primary 2-dimensional with a primary 3-dimensional reading to better understand the specific advantages and limitations of each methodology.

In our study, to obviate the need for cathartic bowel preparation, fecal material was labeled by adding an iodinated contrast agent (diatrizoate meglumine and diatrizoate sodium) to regular meals. Clearly, the ideal

Table 7. Results From the 3 Readers for Identification of Patients With Colorectal Polyps According to Lesion Size

	Polyp size (*mm*)						
	≤5	≥6	≥7	≥8	≥9	≥10	Total
Reader 1	27/31	44/48	35/37	27/28	23/23	17/17	71/79
Sensitivity (%)	87.1 (70.2–96.4)	91.6 (80–97.7)	94.6 (81.8–99.3)	96.4 (81.7–99.9)	100 (85.2–100)	100 (80.5–100)	89.9 (81–95.5)
Reader 2	27/31	45/48	35/36	28/28	23/23	17/17	72/79
Sensitivity (%)	87.1 (70.2–96.4)	93.7 (82.8–98.7)	97.2 (81.8–99.3)	100 (87.7–100)	100 (85.2–100)	100 (80.5–100)	91.1 (82.6–96.4)
Reader 3	27/31	43/48	35/37	27/28	23/23	17/17	70/79
Sensitivity (%)	87.1 (70.2–96.4)	89.6 (77.3–96.5)	94.6 (81.8–99.3)	96.4 (81.7–99.9)	100 (85.2–100)	100 (80.5–100)	88.6 (79.5–94.7)
Reader 1	172/172	129/138	144/149	155/158	161/163	186/186	115/124
Specificity (%)	100 (97.8–100)	93.5 (89.4–97.6)	96.6 (92.3–98.9)	98.1 (94.6–99.6)	98.8 (95.6–99.9)	100 (98–100)	92.7 (86.7–96.6)
Reader 2	172/172	130/138	144/149	155/158	162/163	186/186	116/124
Specificity (%)	100 (97.8–100)	94.2 (88.9–97.5)	96.6 (92.3–98.9)	98.1 (94.6–99.6)	99.4 (96.6–99.9)	100 (98–100)	93.5 (87.7–97.2)
Reader 3	172/172	126/138	143/149	155/158	161/163	186/186	112/124
Specificity (%)	100 (97.8–100)	91.3 (86.6–96)	96 (91.4–97.6)	98.1 (94.6–99.6)	98.8 (95.6–99.9)	100 (98–100)	90.3 (85.1–95.5)
Reader 1	27/27	44/53	35/40	27/30	23/25	17/17	71/80
Positive predictive value (%)	100 (87.2–100)	83 (70.2–91.9)	87.5 (73.2–95.8)	90 (73.5–97.9)	92 (74–99)	100 (80.5–100)	88.7 (79.7–94.7)
Reader 2	27/27	45/53	35/40	28/31	23/24	17/17	72/80
Positive predictive value (%)	100 (87.2–100)	84.9 (72.4–93.3)	87.5 (73.2–95.8)	90.3 (74.3–98)	95.8 (78.9–99.9)	100 (80.5–100)	90 (81.2–95.6)
Reader 3	27/27	43/55	35/41	27/30	23/25	17/17	70/82
Positive predictive value (%)	100 (87.2–100)	78.2 (65–88.2)	85.4 (70.8–94.4)	90 (73.5–97.9)	92 (74–99)	100 (80.5–100)	85.4 (75.8–92.2)
Reader 1	172/176	129/133	144/146	155/156	161/161	186/186	115/123
Negative predictive value (%)	97.7 (94.3–99.1)	97 (92.5–99.2)	98.6 (95.1–99.6)	99.3 (96.5–100)	100 (97.7–100)	100 (98–100)	93.5 (87.7–96.7)
Reader 2	172/176	130/133	144/145	155/155	162/162	186/186	116/123
Negative predictive value (%)	97.7 (94.3–99.1)	97.7 (93.6–99.2)	99.3 (96.2–99.9)	100 (97.6–100)	100 (97.7–100)	100 (98–100)	94.3 (88.6–97.7)
Reader 3	172/176	126/131	143/145	155/156	161/161	186/186	112/121
Negative predictive value (%)	97.7 (94.3–99.1)	96.2 (94.5–97.9)	98.6 (95.1–99.6)	99.3 (96.5–100)	100 (97.7–100)	100 (98–100)	92.6 (86.4–96.5)

NOTE. 95% CIs are presented in parentheses.

tagging agent should be well tolerated, not absorbable, readily available, and inexpensive. Diatrizoate meglumine and diatrizoate sodium meet the criteria for an ideal tagging agent. It is widely used to create an artificial contrast in the gastrointestinal tract in standard CT examinations and to treat small bowel obstruction.[50] Because of its iodine content, possible adverse reactions (10.3% of patients in our experience) can occur, including nausea, vomiting, skin reactions, and diarrhea. Moreover, in rare cases, delayed hypersensitivity reactions have been described,[51] although none occurred in our series. A further disadvantage of diatrizoate meglumine and diatrizoate sodium is that its iodine content precludes its use in patients allergic to iodine-containing contrast agents.

In several previous reports with[35] or without[22,25,26] cathartic bowel preparation, fecal tagging has been combined with electronic subtraction of the tagged fecal material. Although this technique can lead to artifacts at the level of the colonic mucosa,[26] it offers the advantage of preserving 3-dimensional navigation even when substantial fecal material is present in a given colonic segment. In our series, electronic subtraction of tagged fecal material could not be performed because this feature is not available on the software used in the present study. Further investigations are therefore needed to evaluate the potential improvement in performance of CTC without cathartic bowel preparation using subtraction of tagged fecal material.

A further difference between our study and many previous reports on CTC[19,34,35,38,39] is the use of hyoscine-*N*-butylbromide in the majority (93.1%) of our patients. This antiperistaltic drug is currently unavailable in the United States (where glucagon hydrochloride is often administered before CTC) but is widely used in Europe. Due to the fact that, at present, the effects of this drug on colonic distention are controversial[52,53] and the impact on patient tolerance is unknown, the reproducibility of our results in terms of quality of colonic distention and patient tolerance to CTC without cathartic bowel preparation needs confirmation in future studies using glucagon hydrochloride (or no premedication).

With regard to patient acceptance, more patients (79.8%) preferred fecal tagging before CTC compared with cathartic bowel preparation before optical colonoscopy. Although a formal assessment of the reasons for this result was not performed, a possible explanation might be attributed to the absence of laxative effects associated with the fecal tagging regimen (at least for the majority of our patients). In addition, more patients (61.1%) indicated that they would prefer CTC to optical colonoscopy in the future. However, it is noteworthy that a substantial proportion (35.2%) of patients still opted for optical colonoscopy, despite the need for cathartic bowel preparation. A possible explanation for this result could be attributed to the inherent therapeutic capabilities of optical colonoscopy (namely, patients could still opt for a test that allows for both detection and removal of polyps in a single session).[54]

Several potential limitations of our study merit consideration. First, a potential criticism of our study could be related to the use of a fixed total amount of 200 mL of fecal tagging agent (ie, diatrizoate meglumine and diatrizoate sodium). Notably, in our series, 13 of 203 patients (6.4%) reported episodes of diarrhea. Such laxative effects are probably related to the ingestion of an excessive amount of tagging agent. In addition, 3 of 203 patients (1.5%) were judged to have only sufficient tagging of the feces, which indicates the ingestion of an insufficient amount of tagging agent. Indeed, the use of 200 mL of tagging agent did not take into account several variables, including differences in bowel transit time, body weight, and eating behavior. Our current research is focused on the optimization of the fecal tagging regimen to individualize the total amount of tagging agent for each patient.

In addition, similarly to what has been reported for optical colonoscopy and the expertise of endoscopists,[55] the effectiveness of CTC depends on the expertise of the radiologist.[56] In our study, the 3 readers had higher-than-average experience in CTC data interpretation (approximately 300, 200, and 100 examinations with endoscopic correlation). Therefore, because CTC has a high learning curve,[57] the results of CTC without cathartic bowel preparation in the hands of less experienced readers may be different.

Furthermore, one potential criticism of our research could be related to the fact that 51.7% of the patients were symptomatic. Indeed, some authorities[58] have emphasized that the major limitation of the published results on CTC is that the performance of the examination was often evaluated in "polyp-enriched" populations. However, taking into consideration the definition of "advanced disease" (ie, adenoma $\geq$10 mm, or villous features, high-grade dysplasia, or invasive cancer),[44] the prevalence of advanced disease in our study was 8.3% (with a prevalence of polyps of any histologic type of 38.9%). Notably, this value is lower than that reported by Lieberman et al in the colonoscopic screening of asymptomatic patients (prevalence of advanced disease, 10.5%; prevalence of polyps of any histologic type, 48.9%).[44] Therefore, although further studies on larger series are needed to confirm our promising results before CTC without cathartic bowel preparation can be pro-

posed for screening purposes, we believe that the prevalence of disease in our patients cannot be construed as a major limitation to our research.

Finally, the questionnaire used for the assessment of patient acceptance was completed by patients no sooner than 24 hours after optical colonoscopy (which had to be performed after CTC to allow patients to undergo bowel cleansing). Therefore, the questionnaire was completed closer to the time when optical colonoscopy was performed rather than when CTC was performed. Thus, it is possible that, after a few days, the discomfort experienced during the fecal tagging regimen and CTC was less clearly remembered than the discomfort experienced during bowel cleansing and optical colonoscopy. Therefore, we are unable to rule out the possibility that there might have been a certain bias in favor of the fecal tagging regimen (versus bowel preparation) and the preference for CTC (versus optical colonoscopy).

In conclusion, our study shows that the performance of low-dose multidetector CTC without cathartic bowel preparation compares favorably with that of optical colonoscopy for the detection of colorectal polyps and that, given its high negative predictive value, this examination can be useful in identifying patients without colorectal polyps, thus potentially obviating the need for many unnecessary endoscopic examinations.

References

1. Winawer SJ, Zauber AG, Ho MN, O'Brien MJ, Gottlieb LS, Sternberg SS, Waye JD, Schapiro M, Bond JH, Panish JF, et al. Prevention of colorectal cancer by colonoscopic polypectomy. The National Polyp Study Workgroup. N Engl J Med 1993;329:1977–1981.
2. Mandel JS, Church TR, Bond JH, Ederer F, Geisser MS, Mongin SJ, Snover DC, Schuman LM. The effect of fecal occult-blood screening on the incidence of colorectal cancer. N Engl J Med 2000;343:1603–1607.
3. Pignone M, Rich M, Teutsch SM, Berg AO, Lohr KN. Screening for colorectal cancer in adults at average risk: a summary of the evidence for the U.S. Preventive Services Task Force. Ann Intern Med 2002;137:132–141.
4. Rex DK, Johnson DA, Lieberman DA, Burt RW, Sonnenberg A. Colorectal cancer prevention 2000: screening recommendations of the American College of Gastroenterology. American College of Gastroenterology. Am J Gastroenterol 2000;95:868–877.
5. Smith RA, von Eschenbach AC, Wender R, Levin B, Byers T, Rothenberger D, Brooks D, Creasman W, Cohen C, Runowicz C, Saslow D, Cokkinides V, Eyre H. ACS Prostate Cancer Advisory Committee, ACS Colorectal Cancer Advisory Committee, ACS Endometrial Cancer Advisory Committee. American Cancer Society guidelines for the early detection of cancer: update of early detection guidelines for prostate, colorectal, and endometrial cancers. Also: update 2001—testing for early lung cancer detection. (erratum in CA Cancer J Clin 2001;51:150) CA Cancer J Clin 2001;51:38–75.
6. U.S. Preventive Services Task Force. Screening for colorectal cancer: recommendation and rationale. Ann Intern Med 2002; 137:129–131.
7. Winawer S, Fletcher R, Rex D, Bond J, Burt R, Ferrucci J, Ganiats T, Levin T, Woolf S, Johnson D, Kirk L, Litin S, Simmang C. Gastrointestinal Consortium Panel. Colorectal cancer screening and surveillance: clinical guidelines and rationale—update based on new evidence. Gastroenterology 2003;124:544–560.
8. Seeff L, Nadel M, Blackman D. Colorectal cancer test use among persons aged ≥50 years—United States, 2001. MMWR Morb Mortal Wkly Rep 2003;52:193–196.
9. Vernon SW. Participation in colorectal cancer screening: a review. J Natl Cancer Inst 1997;89:1406–1422.
10. Nadel MR, Blackman DK, Shapiro JA, Seeff LC. Are people being screened for colorectal cancer as recommended? Results from the National Health Interview Survey. Prev Med 2002;35:199 206.
11. Janz NK, Wren PA, Schottenfeld D, Guire KE. Colorectal cancer screening attitudes and behavior: a population-based study. Prev Med 2003;37:627–634.
12. Harewood GC, Wiersema MJ, Melton LJ III. A prospective, controlled assessment of factors influencing acceptance of screening colonoscopy. Am J Gastroenterol 2002;97:3186–3194.
13. James AS, Campbell MK, Hudson MA. Perceived barriers and benefits to colon cancer screening among African Americans in North Carolina: how does perception relate to screening behavior? Cancer Epidemiol Biomarkers Prev 2002;11:529–534.
14. Gluecker TM, Johnson CD, Harmsen WS, Offord KP, Harris AM, Wilson LA, Ahlquist DA. Colorectal cancer screening with CT colonography, colonoscopy, and double-contrast barium enema examination: prospective assessment of patient perceptions and preferences. Radiology 2003;227:378–384.
15. Ristvedt SL, McFarland EG, Weinstock LB, Thyssen EP. Patient preferences for CT colonography, conventional colonoscopy, and bowel preparation. Am J Gastroenterol 2003;98:578–585.
16. Elwood JM, Ali G, Schlup MM, McNoe B, Barbezat GO, North F, Sutton K, Parry B, Chadwick VS. Flexible sigmoidoscopy or colonoscopy for colorectal screening: a randomized trial of performance and acceptability. Cancer Detect Prev 1995;19:337–347.
17. Rex DK. Current colorectal cancer screening strategies: overview and obstacles to implementation. Rev Gastroenterol Disord 2002;2(Suppl 1):S2–S11.
18. Hara AK, Johnson CD, Reed JE, Ahlquist DA, Nelson H, Ehman RL, McCollough CH, Ilstrup DM. Detection of colorectal polyps by computed tomographic colography: feasibility of a novel technique. Gastroenterology 1996;110:284–290.
19. Fenlon HM, Nunes DP, Schroy PC III, Barish MA, Clarke PD, Ferrucci JT. A comparison of virtual and conventional colonoscopy for the detection of colorectal polyps. N Engl J Med 1999;341: 1496–1503.
20. Morrin MM, Farrell RJ, Kruskal JB, LaMont JT. Virtual colonoscopy: a kinder, gentler colorectal cancer screening test? Lancet 1999;354:1048–1049.
21. Callstrom MR, Johnson CD, Fletcher JG, Reed JE, Ahlquist DA, Harmsen WS, Tait K, Wilson LA, Corcoran KE. CT colonography without cathartic preparation: feasibility study. Radiology 2001; 219:693–698.
22. Zalis ME, Hahn PF. Digital subtraction bowel cleansing in CT colonography. AJR Am J Roentgenol 2001;176:646–648.
23. Lefere PA, Gryspeerdt SS, Dewyspelaere J, Baekelandt M, Van Holsbeeck BG. Dietary fecal tagging as a cleansing method before CT colonography: initial results polyp detection and patient acceptance. Radiology 2002;224:393–403.
24. Thomeer M, Carbone I, Bosmans H, Kiss G, Bielen D, Vanbeckevoort D, Van Cutsem E, Rutgeerts P, Marchal G. Stool tagging applied in thin-slice multidetector computed tomography colonography. J Comput Assist Tomogr 2003;27:132–139.

25. Zalis ME, Perumpillichira J, Del Frate C, Hahn PF. CT colonography: digital subtraction bowel cleansing with mucosal reconstruction initial observations. Radiology 2003;226:911–917.
26. Bielen D, Thomeer M, Vanbeckevoort D, Kiss G, Maes F, Marchal G, Rutgeerts P. Dry preparation for virtual CT colonography with fecal tagging using water-soluble contrast medium: initial results. Eur Radiol 2003;13:453–458.
27. Chen D, Liang Z, Wax MR, Li L, Li B, Kaufman AE. A novel approach to extract colon lumen from CT images for virtual colonoscopy. IEEE Trans Med Imaging 2000;19:1220–1226.
28. Iannaccone R, Laghi A, Catalano C, Brink JA, Mangiapane F, Trenna S, Piacentini F, Passariello R. Detection of colorectal lesions: lower-dose multi-detector row helical CT colonography compared with conventional colonoscopy. Radiology 2003;229: 775–781.
29. Macari M, Milano A, Lavelle M, Berman P, Megibow AJ. Comparison of time-efficient CT colonography with two- and three-dimensional colonic evaluation for detecting colorectal polyps. AJR Am J Roentgenol 2000;174:1543–1549.
30. Hara AK, Johnson CD, MacCarty RL, Welch TJ. Incidental extracolonic findings at CT colonography. Radiology 2000;215:353–357.
31. Gluecker TM, Johnson CD, Wilson LA, MacCarty RL, Welch TJ, Vanness DJ, Ahlquist DA. Extracolonic findings at CT colonography: evaluation of prevalence and cost in a screening population. Gastroenterology 2003;124:911–916.
32. Adams WJ, Meagher AP, Lubowski DZ, King DW. Bisacodyl reduces the volume of polyethylene glycol solution required for bowel preparation. Dis Colon Rectum 1994;37:229–233.
33. Pineau BC, Paskett ED, Chen GJ, Durkalski VL, Espeland MA, Vining DJ. Validation of virtual colonoscopy in the detection of colorectal polyps and masses: rationale for proper study design. Int J Gastrointest Cancer 2001;30:133–140.
34. Pineau BC, Paskett ED, Chen GJ, Espeland MA, Phillips K, Han JP, Mikulaninec C, Vining DJ. Virtual colonoscopy using oral contrast compared with colonoscopy for the detection of patients with colorectal polyps. Gastroenterology 2003;125:304–310.
35. Pickhardt PJ, Choi JR, Hwang I, Butler JA, Puckett ML, Hildebrandt HA, Wong RK, Nugent PA, Mysliwiec PA, Schindler WR. Computed tomographic virtual colonoscopy to screen for colorectal neoplasia in asymptomatic adults. N Engl J Med 2003;349:2191–2200.
36. Rubio CA, Jaramillo E, Lindblom A, Fogt F. Classification of colorectal polyps: guidelines for the endoscopist. Endoscopy 2002; 34:226–236.
37. Shah SG, Saunders BP, Brooker JC, Williams CB. Magnetic imaging of colonoscopy: an audit of looping, accuracy and ancillary maneuvers. Gastrointest Endosc 2000;52:1–8.
38. Fletcher JG, Johnson CD, Welch TJ, MacCarty RL, Ahlquist DA, Reed JE, Harmsen WS, Wilson LA. Optimization of CT colonography technique: prospective trial in 180 patients. Radiology 2000; 216:704–711.
39. Yee J, Akerkar GA, Hung RK, Steinauer-Gebauer AM, Wall SD, McQuaid KR. Colorectal neoplasia: performance characteristics of CT colonography for detection in 300 patients. Radiology 2001;219:685–692.
40. Laghi A, Iannaccone R, Carbone I, Catalano C, Di Giulio E, Schillaci A, Passariello R. Detection of colorectal lesions with virtual computed tomographic colonography. Am J Surg 2002;183:124–131.
41. Rex DK. Virtual colonoscopy: time for some tough questions for radiologists and gastroenterologists. Endoscopy 2000;32:260–263.
42. Bond JH. Clinical relevance of the small colorectal polyp. Endoscopy 2001;33:454–457.
43. Hofstad B, Vatn N. Growth rate of colon polyps and cancer. Gastrintest Endosc Clin North Am 1997;7:345–363.
44. Lieberman DA, Weiss DG, Bond JH, Ahnen DJ, Garewal H, Chejfec G. Use of colonoscopy to screen asymptomatic adults for colorectal cancer. Veterans Affairs Cooperative Study Group 380. N Engl J Med 2000;343:162–168.
45. Imperiale TF, Wagner DR, Lin CY, Larkin GN, Rogge JD, Ransohoff DF. Risk of advanced proximal neoplasms in asymptomatic adults according to the distal colorectal findings. N Engl J Med 2000;343: 169–174.
46. Yee J, Kumar NN, Hung RK, Akerkar GA, Kumar PR, Wall SD. Comparison of supine and prone scanning separately and in combination at CT colonography. Radiology 2003;226:653–661.
47. Ferrucci JT. Colon cancer screening with virtual colonoscopy: promise, polyps, politics. AJR Am J Roentgenol 2001;177:975–988.
48. McFarland EG, Pilgram TK, Brink JA, McDermott RA, Santillan CV, Brady PW, Heiken JP, Balfe DM, Weinstock LB, Thyssen EP, Littenberg B. CT colonography: multiobserver diagnostic performance. Radiology 2002;225:380–390.
49. Johnson CD, Harmsen WS, Wilson LA, Maccarty RL, Welch TJ, Ilstrup DM, Ahlquist DA. Prospective blinded evaluation of computed tomographic colonography for screen detection of colorectal polyps. Gastroenterology 2003;125:311–319.
50. Choi HK, Chu KW, Law WL. Therapeutic value of Gastrografin in adhesive small bowel obstruction after unsuccessful conservative treatment: a prospective randomized trial. Ann Surg 2002; 236:1–6.
51. Miller SH. Anaphylactoid reaction after oral administration of diatrizoate meglumine and diatrizoate sodium solution. AJR Am J Roentgenol 1997;168:959–961.
52. Bruzzi JF, Moss AC, Brennan DD, MacMathuna P, Fenlon HM. Efficacy of IV Buscopan as a muscle relaxant in CT colonography. Eur Radiol 2003;13:2264–2270.
53. Taylor SA, Halligan S, Goh V, Morley S, Bassett P, Atkin W, Bartram CI. Optimizing colonic distention for multi-detector row CT colonography: effect of hyoscine butylbromide and rectal balloon catheter. Radiology 2003;229:99–108.
54. Morrin MM, LaMont JT. Screening virtual colonoscopy—ready for prime time? N Engl J Med 2003;349:2261–2264.
55. Rex DK, Rahmani EY, Haseman JH, Lemmel GT, Kaster S, Buckley JS. Relative sensitivity of colonoscopy and barium enema for detection of colorectal cancer in clinical practice. Gastroenterology 1997; 112:17–23.
56. Johnson CD, Toledano AY, Herman BA, Dachman AH, McFarland EG, Barish MA, Brink JA, Ernst RD, Fletcher JG, Halvorsen RA Jr, Hara AK, Hopper KD, Koehler RE, Lu DS, Macari M, Maccarty RL, Miller FH, Morrin M, Paulson EK, Yee J, Zalis M. American College of Radiology Imaging Network A6656. Computerized tomographic colonography: performance evaluation in a retrospective multicenter setting. Gastroenterology 2003;125:688–695.
57. Spinzi G, Belloni G, Martegani A, Sangiovanni A, Del Favero C, Minoli G. Computed tomographic colonography and conventional colonoscopy for colon diseases: a prospective, blinded study. Am J Gastroenterol 2001;96:394–400.
58. Rex DK. Barium studies/virtual colonoscopy: the gastroenterologist's perspective (erratum in Gastrointest Endosc 2002;56: 324). Gastrointest Endosc 2002;55(7 Suppl):S33–S36.

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