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**Abbreviation:**

DCBE = double-contrast barium  
 enema examination

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# Colorectal Cancer Screening with CT Colonography, Colonoscopy, and Double-Contrast Barium Enema Examination: Prospective Assessment of Patient Perceptions and Preferences<sup>1</sup>

**PURPOSE:** To prospectively assess and compare perceptions of and preferences for computed tomographic (CT) colonography, colonoscopy, and double-contrast barium enema examination (DCBE) by asymptomatic patients undergoing colorectal cancer screening.

**MATERIALS AND METHODS:** A total of 696 asymptomatic patients at higher-than-average risk undergoing colorectal cancer screening were consecutively recruited to undergo both CT colonography and colonoscopy (group 1), and a like group of 617 patients was separately recruited to undergo both CT colonography and DCBE (group 2). Standard bowel preparations were different between the groups undergoing colonoscopy and DCBE. Each patient completed a questionnaire that assessed preparation inconvenience and discomfort, examination discomfort, willingness to repeat examinations, and examination preference. Survey results were compared for significance by using the Wilcoxon rank sum or  $\chi^2$  test.

**RESULTS:** The majority of patients considered the preparation to be uncomfortable (group 1, 460 of 515 [89%]; group 2, 482 of 538 [90%]) and inconvenient (group 1, 393 of 502 [78%]; group 2, 427 of 527 [81%]). Reported discomfort was similar at CT colonography and colonoscopy ( $P = .63$ ) but was less at CT colonography than at DCBE ( $P < .001$ ). Patients experienced significantly less discomfort than expected at both CT colonography and colonoscopy but not at DCBE. Patients' willingness to undergo frequent rescreening was significantly greater for CT colonography than for either colonoscopy or DCBE. The acceptable time interval between screenings was significantly shorter for all examinations if the bowel preparation could be avoided. Overall, patients preferred CT colonography to colonoscopy (group 1, 72.3% vs 5.1%;  $P < .001$ ) or to DCBE (group 2, 97.0% vs 0.4%;  $P < .001$ ).

**CONCLUSION:** Patients undergoing colorectal cancer screening prefer CT colonography to both colonoscopy and DCBE. The majority of patients experience discomfort and inconvenience with cathartic bowel preparation.

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Colorectal cancer has become the second leading cause of cancer-related deaths in industrialized countries, accounting for approximately 11% of all cancer mortality (1). Screening is advocated as the best strategy for control of colorectal cancer, and national organizations have established screening guidelines that involve a number of choices in screening tools (2). Because of the limited sensitivities of fecal occult blood testing and

sigmoidoscopy (3,4), many organizations now recommend full structural examinations of the colorectum, especially with use of colonoscopy (5). Despite widespread promotion of colorectal cancer screening, only a small minority of Americans currently undergoes screening with any approach. In one survey, fewer than 10% of respondents complied with current screening guidelines (6). The extent to which perceived discomfort and inconvenience from the screening interventions contribute to these low participation rates remains poorly understood.

Computed tomographic (CT) colonography has emerged as a potentially more comfortable alternative for patients undergoing full structural screening of the colorectum (7–12). Several large studies suggest that CT colonography depicts colorectal neoplasms larger than 1 cm in diameter with a sensitivity greater than or equal to 85% while maintaining high specificity (8–10).

Effective neoplasm detection is a function of both test sensitivity and user rate (13), and both must be critically considered in selecting implementation strategies. However, a direct determination of user rates for CT colonography and conventional structural screening examinations would require widespread and equal availability of these tools, which would be improbable or complicated in the near future. Accordingly, assessment of a sample of patient perceptions and preferences may provide insight into the likelihood of use. To date, few data are available concerning patient attitudes toward and preferences for CT colonography in comparison to other screening approaches (14–20). However, these studies have been either preliminary or small in size, or they have not involved direct comparisons. The aim of our study was to prospectively assess and compare the perceptions of and preferences for CT colonography, colonoscopy, and double-contrast barium enema examination (DCBE) by asymptomatic patients undergoing colorectal cancer screening.

## MATERIALS AND METHODS

Asymptomatic patients who were already scheduled for colorectal cancer screening with either colonoscopy or DCBE were queried for study recruitment. The patients were referred to undergo either colonoscopy or DCBE by the referring physician; thus individuals were not randomized between colonoscopy or DCBE. Recruited subjects were asked addition-

ally to undergo CT colonography, and the two groups were studied. Group 1 included 696 patients who underwent CT colonography prior to the scheduled colonoscopy, and group 2 included 617 patients who underwent CT colonography prior to the scheduled DCBE. In each group, patients were more than 50 years of age and were at higher-than-average risk for colorectal cancer (first-degree relative with colorectal neoplasia, prior personal history of colorectal neoplasia, or new onset of asymptomatic anemia) except for three patients: one 41-year-old patient with a family history of colon cancer was investigated with use of CT colonography and colonoscopy for asymptomatic anemia, one 46-year-old patient who previously underwent polyp removal and who had a family history of colon cancer underwent both CT colonography and colonoscopy, and one 48-year-old patient with a family history of colon cancer underwent DCBE and colonoscopy. Exclusion criteria were presence of gastrointestinal symptoms, recent overt gastrointestinal bleeding, inflammatory bowel disease, familial adenomatous polyposis, and bowel resection or polyp removal within the prior 2 months. Patients underwent both CT colonography and the structural examination scheduled by their physicians on the same day. To avoid artifacts caused by removal of lesions or presence of barium, CT colonography necessarily preceded both colonoscopy and DCBE in all cases. The study was approved by our institutional review board, and all subjects provided signed informed consent. At the time of consent, patients were informed in both oral and written form that CT colonography involved radiation exposure.

### Cathartic Bowel Preparation

In preparation for colonoscopy, each patient was instructed to ingest 4 L of polyethylene glycol electrolyte solution (GoLytely; Braintree Laboratories, Braintree, Mass), to be initiated on the afternoon of the day prior to the examination. Patients were allowed only a clear liquid diet until after the preparation was completed. Once the oral lavage solution was administered, each patient was instructed to ingest 10 mg of bisacodyl on the evening prior to the examination.

In preparation for DCBE, each patient was allowed only a clear liquid diet beginning the afternoon prior to the examination. On the evening before examination, 300 mL of magnesium citrate and

20 mg of bisacodyl were to be taken orally by the patient. On the morning of the examination, a 300-mL tap water enema was administered. The tap water enema was either self-administered or performed for the patient in an enema preparation facility at the medical center. If the final effluents contained solid stool particles, the enema was repeated.

### CT Colonography

CT colonography was preceded with a subcutaneous injection of 1 mg of glucagon, which was administered 10 minutes prior to the study. Gentle rectal insufflation was performed by using CO<sub>2</sub> administered with the patients in the left lateral decubitus position. Air insufflation was performed until the patients stated they were full or until 2 L had been administered. The rectal tube was clamped and left in place. The adequacy of air insufflation was evaluated with a CT scout view. Distention was considered to be adequate when a continuous column of gas was visible at CT throughout the well-distended colorectum. If the amount of air was considered insufficient, additional CO<sub>2</sub> insufflation was performed. After scanning in the supine position was completed, the patient was positioned in the prone position. The air insufflation was again verified with a scout view, and if necessary, additional CO<sub>2</sub> was administered.

In all patients, CT was performed in helical mode on either a single-detector row HiSpeed Advantage ( $n = 189$ ) or multi-detector row Light Speed ( $n = 1,123$ ) scanner (GE Medical Systems, Milwaukee, Wis). Scanning parameters for the single-detector row scanner were 5-mm collimation, a pitch of 1.3, 3-mm reconstruction interval, 70 mAs, 120 kVp, a 512 × 512 matrix, and a standard reconstruction algorithm. The scanning procedures were performed in breath-hold periods of about 20 seconds with a 3-cm overlap. Three or four breath holds were usually required. Scanning parameters for the multi-detector row scanner were 5-mm collimation, a pitch of 6, 3-mm reconstruction interval, 40 mAs, 120 kVp, and a 512 × 512 matrix (11).

The average acquisition time with the single-detector row scanner was 2 minutes (three 20-second breath holds each for acquisition in the supine and prone positions) and 40 seconds with the multi-detector row scanner (one 20-second breath hold for each position). The patients spent on average 15 minutes in the CT facility; this time consisted of po-

| <b>PATIENT SURVEY: QUESTIONS AND OPTIONS</b><br>(CT COLONOGRAPHY, COLONOSCOPY, DOUBLE CONTRAST BARIUM ENEMA (DCBE))   |  |
|---|--|
| <b>Bowel Preparation</b>  |  |
| How would you rate the <b>physical discomfort</b> you experienced while preparing for computed tomographic colography and colonoscopy / double contrast barium enema?             | Extreme – Severe – Moderate – Mild – None            |
| How much of an inconvenience was the preparation in relation to your daily routine?   | Very – Somewhat – Not at all                         |
| <b>CT Colonography</b>  |  |
| Please rate the level of physical discomfort you <b>expected</b> to experience during the exam  | Extreme – Severe – Moderate – Mild – None            |
| Please rate the level of physical discomfort you <b>actually experienced</b> during the exam  | Extreme – Severe – Moderate – Mild – None            |
| How often would you be willing <b>to do the preparation and have the CTC</b> done as a screening for colon polyps or cancer?  | Every: 1 year – 3 years – 5 years – 10 years – never |
| If <b>no preparation</b> was required, how often would you be willing to have the CTC done as a screening for colon polyps or cancer?   | Every: 1 year – 3 years – 5 years – 10 years – never |
| <b>Colonoscopy / Double Contrast Barium Enema</b>   |  |
| Please rate the level of discomfort you <b>expected</b> to experience during exam   | Extreme – Severe – Moderate – Mild – None            |
| Please rate the level of physical discomfort you <b>actually experienced</b> during the exam  | Extreme – Severe – Moderate – Mild – None            |
| How often would you be willing <b>to do the preparation and have the colonoscopy / double contrast barium enema exam</b> done as a screening for colon polyps or cancer?          | Every: 1 year – 3 years – 5 years – 10 years – never |
| If <b>no preparation</b> was required, how often would you be willing to have the colonoscopy / double contrast barium enema exam done as a screening for colon polyps or cancer? | Every: 1 year – 3 years – 5 years – 10 years – never |
| Since you had both CT Colonography and colonoscopy / DCBE: which exam did you prefer?   | CT Colonography – No preference – Colonoscopy / DCBE |

Figure 1. Abbreviated version of the questionnaire given to patients.

sitioning of the patient, acquisition of scout views, and supine and prone data acquisition.

After CT, patients were asked to evacuate as much CO<sub>2</sub> as possible. A delay of at least 1 hour before the subsequent DCBE or conventional colonoscopy was required to allow for additional expulsion and absorption of CO<sub>2</sub>.

### Colonoscopy

Experienced gastroenterologists performed all colonoscopy examinations on the routine clinical schedule. Most patients received intravenous sedation through a combination of midazolam hydrochloride (Versed; Abbott Laboratories, Abbott Park, Ill) and meperidine hydrochloride (Demerol; Abbott Laborato-

ries); the dose was determined by the colonoscopist. Average total colonoscopy time was 22 minutes during this study period, which included both diagnostic and therapeutic procedures. As per practice guidelines, each patient was observed in a monitored bed for at least 1 hour following colonoscopy.

### DCBE

All DCBE studies were performed in accordance with American College of Radiology standards, and results were interpreted by staff gastrointestinal radiologists (21). Sedation was not used on a routine basis, but glucagon was administered at the discretion of the staff radiologist for cramping or pain. The majority of patients did not receive

glucagon. Examinations were performed at fluoroscopy by a staff radiologist. The progression of the barium column and the adequacy of colon distention and barium coating was monitored at fluoroscopy. In all patients, CO<sub>2</sub> was used to cause distention. Spot radiographs were taken of the rectum, the sigmoid (right posterior oblique and left posterior oblique), splenic and hepatic flexures, and the cecum. The following overhead radiographs were obtained: posteroanterior and anteroposterior views of the abdomen, tilt (30°) craniocaudal view of the sigmoid colon, and a lateral view of the rectum. In addition, images of both lateral decubitus views of the colon were obtained with use of a horizontal beam.

## Patient Survey

The survey and instructions for its completion were given to the patients at the time informed consent was obtained. This usually occurred the day prior to the examinations. All patients were asked to complete a questionnaire (Fig 1) after the second examination (either colonoscopy or DCBE). To avoid the effects of sedation, group 1 patients were asked to complete the questionnaire not sooner than 12 hours after colonoscopy. Questionnaires were returned by mail. Specific questions were designed to assess the degree of inconvenience patients experienced with each screening intervention and the level of discomfort they associated with both the preparation and the actual examination. To assess the patients' potential future compliance with screening guidelines, questions were asked about their willingness to undergo a repeat examination with or without a bowel preparation. Last, patients were asked to give their overall preferences between CT colonography, colonoscopy, and DCBE.

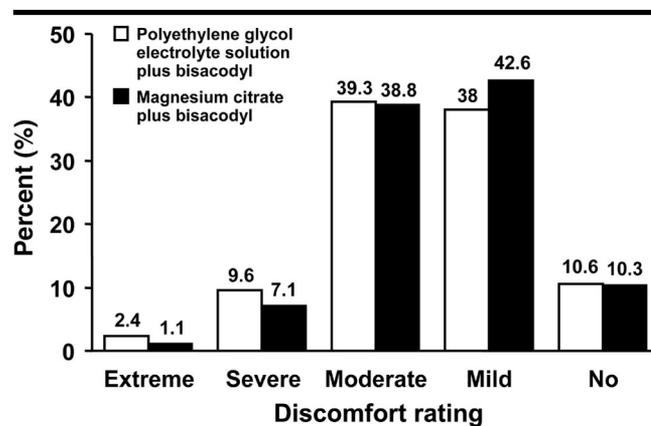
## Statistical Considerations

Survey outcomes within groups 1 and 2 were compared by using the Wilcoxon rank sum test or  $\chi^2$  test. Distributions of sex, age, and neoplasm prevalence were compared between participants and those patients declining participation in order to assess potential sampling bias. *P* values less than .05 are considered to denote statistical significance.

## RESULTS

### Characteristics of Patients

Among the patients who underwent CT colonography and colonoscopy (group 1), 437 of the 696 (63%) were men, and median age was 64.7 years (range, 41.2–84.2 years). A total of 515 patients (74%) returned the questionnaire. There was no significant difference between participants and nonparticipants in group 1 with respect to sex or prevalence of neoplasms found. A slight difference in age distributions was observed; the median age was 64.7 years (range, 41.2–84.2 years) for respondents and 63.1 years (range, 49.2–77.7 years) for nonrespondents ( $P < .02$ ). Among the patients who underwent CT colonography and DCBE (group 2), 303 of the 617 (49%) were men, and median age was 63.6 years (range, 49.5–81.7 years). A total of 538 patients (87%) responded to



**Figure 2.** Bar graph shows level of bowel preparation discomfort experienced by patients. Most patients considered the preparation to be mildly or moderately uncomfortable. There was no significant difference between the preparations for colonoscopy (polyethylene glycol electrolyte solution and bisacodyl) and DCBE (magnesium citrate and bisacodyl) (Wilcoxon rank sum test,  $P = .13$ ).

the questionnaire. No significant differences in either age or sex distributions or in the prevalence of polyps found with use of DCBE were noted between respondents and nonrespondents in group 2.

### Perceptions of Cathartic Bowel Preparations

The majority of patients in each group experienced discomfort associated with the bowel preparation (Fig 2). Among the 515 patients who received oral lavage preparation with polyethylene glycol electrolyte solution and bisacodyl (group 1), 61 (12%) patients reported extreme or severe discomfort, 395 (77%) reported mild or moderate discomfort, and 55 (11%) reported no discomfort. There were four nonrespondents. Among the 538 patients who underwent the barium enema preparation (magnesium citrate and bisacodyl) and tap water enema examinations (group 2), 44 (8%) reported extreme or severe discomfort, 434 (81%) reported moderate or mild discomfort, and 56 (10%) reported no discomfort. There were four nonrespondents. There was no significant difference in the reported discomfort between the two types of preparation ( $P = .14$ ). Most patients indicated that the preparations were inconvenient. In both groups 1 and 2, approximately 20% of patients considered the preparation to be very disruptive to daily life, and approximately 60% of patients considered it to be somewhat or not disruptive. Perceived inconvenience did not differ significantly between the types of preparation ( $P = .57$ ) (Fig 2).

### Perceptions of Discomfort at Screening Examinations

While most patients in group 1 reported that discomfort was mild or absent at both CT colonography and colonoscopy (Fig 3a), level of discomfort between the two was not statistically significant ( $P = .63$ ). There were marked differences in the amount of discomfort experienced between the two examinations in group 2. Among the 534 respondents, discomfort was rated as moderate or worse in 450 (84%) DCBEs but in only 64 (12%) CT colonography examinations ( $P < .001$ ) (Fig 3b). At both CT colonography and colonoscopy, patients experienced significantly less discomfort than expected ( $P < .001$ ). No differences were noted between expected and experienced discomfort at DCBE ( $P = .49$ ). Data are not shown.

### Willingness to Repeat Screening Examination

Patients' degree of willingness to repeat a full structural colorectal examination with cathartic preparation is depicted in Figures 4 and 5. This was assessed by determining the frequency of re-examination that patients would accept for each examination. Patients were willing to repeat screening with colonic preparation at shorter intervals with CT colonography than with either colonoscopy (Fig 4a) or DCBE (Fig 5a) ( $P < .001$  with each comparison). All examinations were judged by patients to be more acceptable (ie, acceptable at shorter intervals) if the cathartic prep-

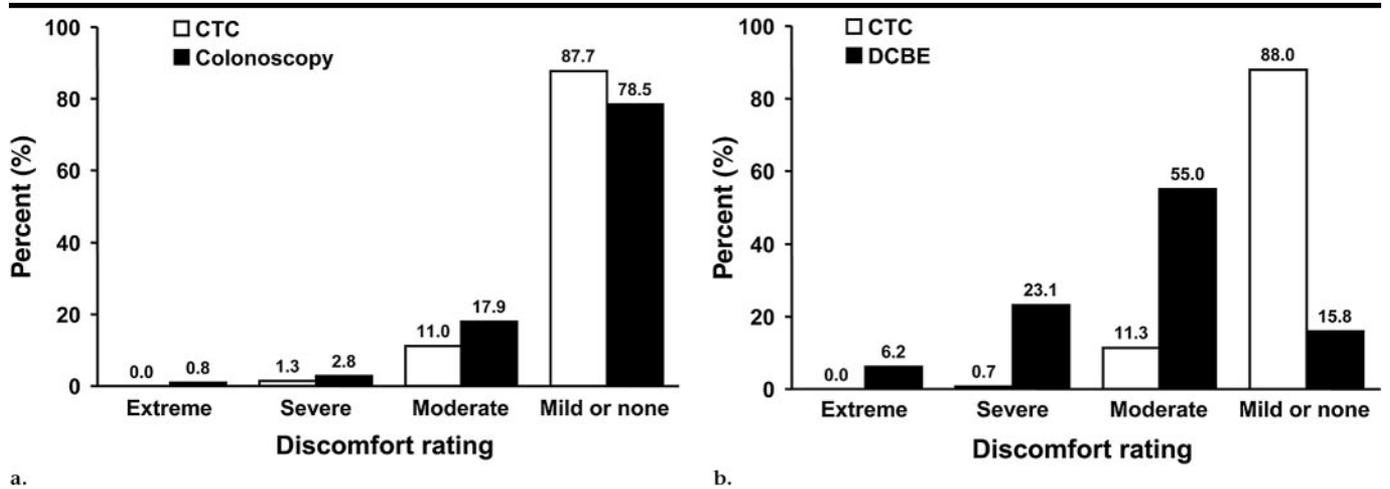


Figure 3. Bar graphs show level of examination discomfort experienced by patients. (a) CT colonography (CTC) versus colonoscopy. Discomfort experienced at CT colonography is slightly less than at colonoscopy; however, this difference is not statistically significant ( $P = .63$ ). (b) CT colonography (CTC) versus DCBE. Discomfort experienced at CT colonography is significantly less than at DCBE ( $P < .001$ ).

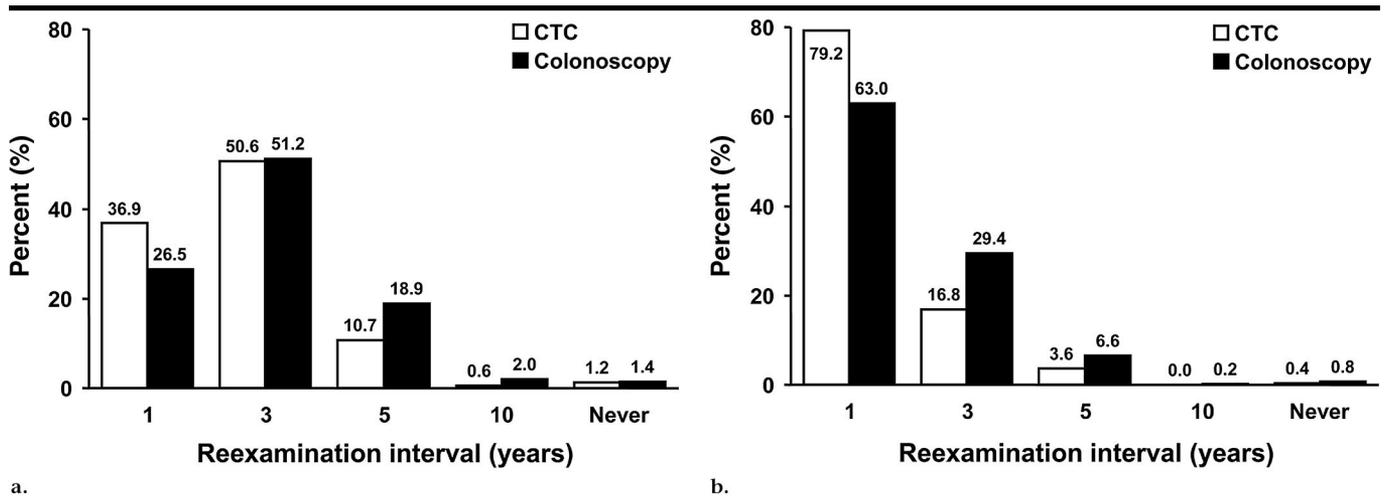


Figure 4. Bar graphs show patient willingness to be reexamined at various time intervals. (a) CT colonography (CTC) versus colonoscopy with bowel preparation. Patients were significantly more willing to undergo CT colonography at shorter intervals than colonoscopy with bowel preparation ( $P < .001$ ). This may indicate that patient compliance for colorectal screening would be improved if CT colonography was used. (b) CT colonography (CTC) versus colonoscopy without bowel preparation. Omitting bowel preparation significantly improves patients' willingness to undergo CT colonography or colonoscopy; however, patients are still more willing to undergo CT colonography at shorter intervals than colonoscopy ( $P < .001$ ).

aration could be avoided. However, patients were still more willing to repeat CT colonography at shorter intervals than either colonoscopy (Fig 4b) or DCBE (Fig 5b) ( $P < .001$  for each comparison).

### Preference for Screening Examinations

CT colonography was strongly preferred overall to both the other full structural examinations (Fig 6). In group 1, 357 (72.3%) of 494 patients preferred CT colonography while 25 (5.0%) preferred colonoscopy ( $P < .001$ ). In group 2, 518

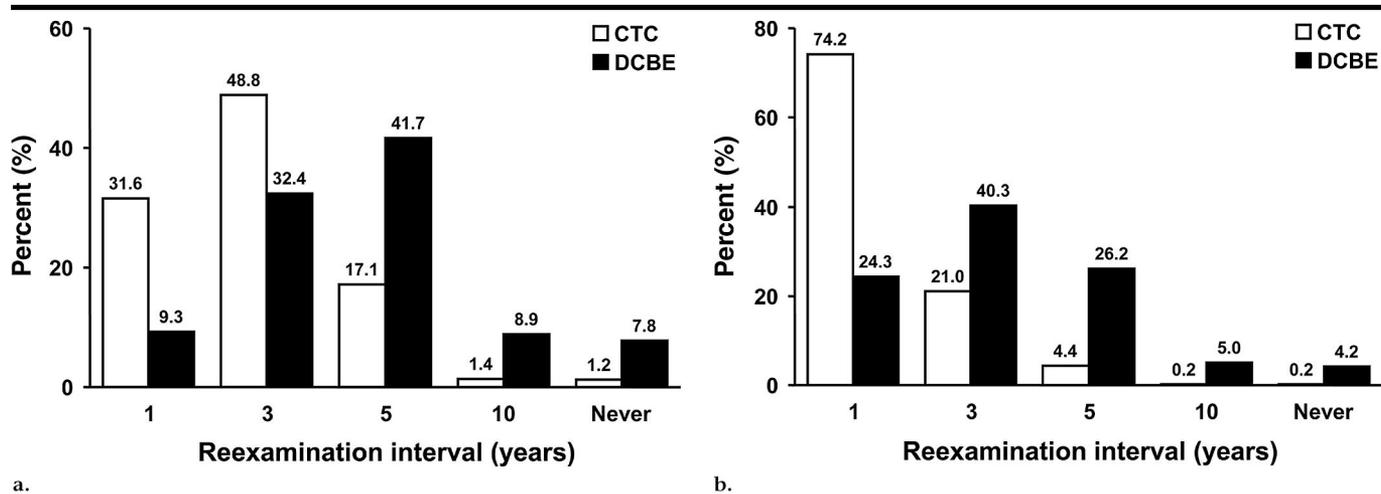
(97.0%) of 534 patients preferred CT colonography while two (0.4%) preferred DCBE ( $P < .001$ ).

### DISCUSSION

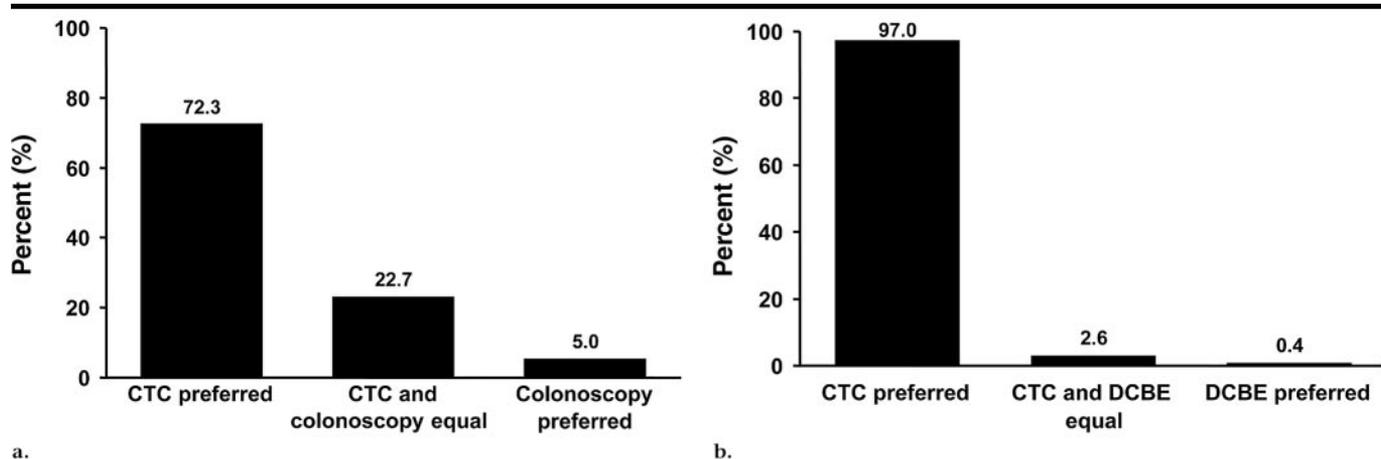
In this large prospective study, we addressed perceptions that influence patients' decisions to participate in colorectal screening by full structural examinations. All patients underwent either back-to-back CT colonography and colonoscopy or CT colonography and DCBE, and all screening examinations were performed by experienced practitioners. The survey question-

naires, which were completed by patients after screening examinations, measured perceptions regarding cathartic bowel preparation, examination discomfort, willingness to repeat examinations, and overall preference.

CT colonography was preferred by a wide margin over the other two types of colorectal examinations. The conclusion that there was a strong preference for CT colonography was based on responses to direct and indirect questions. The majority of patients directly expressed their overall preference for CT colonography (Fig 6), and most also indicated that they would be



**Figure 5.** Bar graphs show patient willingness to be reexamined at various time intervals. (a) CT colonography (CTC) versus DCBE with bowel preparation. Patients were significantly more willing to undergo CT colonography at shorter intervals than DCBE with bowel preparation ( $P < .001$ ). This may indicate that patient compliance for colorectal screening would be improved if CT colonography was used. (b) CT colonography (CTC) versus DCBE without bowel preparation. Patients are still significantly more willing to undergo CT colonography at shorter intervals than DCBE ( $P < .001$ ).



**Figure 6.** Bar graphs show patients' overall preferences for examination type. (a) CT colonography (CTC) versus colonoscopy. Significantly more patients preferred CT colonography to colonoscopy ( $P < .001$ ). (b) CT colonography (CTC) versus DCBE. Significantly more patients preferred CT colonography to DCBE ( $P < .001$ ).

more willing to return for repeat screenings with CT colonography and at shorter intervals than with either of the other types of examinations. Reasons for this preference were not specifically solicited. Patients reported significantly less discomfort from CT colonography than from DCBE, which may have contributed to this preference. Discomfort at CT colonography was less than at colonoscopy, but this difference was not statistically significant. The minimal discomfort experienced at CT colonography might be explained by the brief examination time, the care taken to avoid overdistention of the colon, and the use of glucagon. Glucagon was administered as needed during DCBE to relieve moderate or severe abdominal cramping or

pain. This policy is consistent with and reflects common practice.

For many patients, cathartic bowel preparation represents a substantial disincentive to undergo colorectal cancer screening, and such preparations are currently required for all conventional types of structural examination. Most of our patients reported discomfort from bowel preparations. Discomfort was similar with oral lavage and laxative/enema-type preparations, and the degree of anticipated discomfort generally exceeded the degree of actual discomfort experienced with the screening examinations. Most patients also indicated that bowel preparations were inconvenient. Patients were more willing to undergo repeat screening examinations if

bowel preparations could be avoided. However, the potential for eliminating the need of cathartic bowel preparation exists only with CT colonography. In a preliminary report (22), our group has demonstrated the feasibility of polyp detection at CT colonography with "virtual preparation," whereby stool is removed from the image by computer using digital subtraction rather than by preprocedural bowel catharsis.

In addition to its accuracy, minimal invasiveness, and potential for avoiding cathartic preparation, CT colonography has several other features that should be considered, as they could further influence screening rates in the future. Sedation, with the attendant risks and post-

procedural restrictions, is not required. Finally, there may be distribution and access advantages with CT colonography, as the scanning could be performed at peripheral sites by technologists with CT colonography display and the interpretation could be done at central sites by experienced radiologists with electronically sent data.

There was a difference in the percentage of patients who responded by survey: 74% of the patients who underwent CT colonography and colonoscopy responded compared with 87% of the patients who underwent CT colonography and DCBE. Individuals who underwent CT colonography and colonoscopy with sedation were asked to wait at least 12 hours before completing and returning the questionnaire, but individuals who underwent CT colonography and DCBE were not. This time delay might have contributed to the difference in response rates. There was also a sex difference between the patient groups that underwent colonoscopy (63% men) and DCBE (49% men). The reasons for this difference remain unclear. Patient referral to either colonoscopy or DCBE was at the discretion of the referring physician.

Several potential limitations of our study merit consideration. First, responses by the study patients may not be representative of those from the general population. Our patients may represent a more highly motivated subset of the population, as they were at higher-than-average risk for colorectal cancer and were already scheduled for a screening examination. As such, their responses comparing the screening interventions may be of greater value than their absolute responses. Second, the study design mandated that CT colonography be performed prior to the other structural examinations, and this nonrandomized sequence may have introduced a technical or response bias favoring CT colonography in some way. Conceivably, residual gas from CT colonography could have contributed to technical difficulty or greater patient discomfort during subsequent procedures, but use of CO<sub>2</sub> for colon distention with CT colonography should have minimized this possibility. Also, patients may have recalled discomfort from the earlier CT colonography with less accuracy than from the subsequent procedures. The sedation required for patients undergoing colonoscopy may have obscured their recall of the discomfort level at CT colonography. However, patients were instructed to allow at least 12 hours to elapse following

colonoscopy before they completed the questionnaires, in order to minimize any effect from antegrade amnesia. Furthermore, responses regarding CT colonography from patients in group 1 (who underwent both CT colonography and colonoscopy) were nearly identical to those from patients in group 2 (who underwent CT colonography and DCBE with no sedation).

Two recent studies refer to patients' preferences between CT colonography and colonoscopy. One study by Akerkar et al (19) concerns the results of a survey of 295 patients who underwent both CT colonography and colonoscopy. In this study, the patients reported less discomfort and pain at colonoscopy than at CT colonography. However, the majority of patients were symptomatic men, and only 28% of the respondents returned the questionnaire, which raises the possibility of nonresponse bias. The second study, performed by Svensson et al (20), is based on a cohort of 111 symptomatic patients. In this group, significantly more patients favored CT colonography. Our study results, which were taken from a large asymptomatic population, show that patients strongly favor CT colonography over colonoscopy.

The present study highlights that discomfort and inconvenience are often experienced by patients undergoing cathartic bowel preparation, that a greater willingness for colorectal cancer screening is possible if bowel preparation can be avoided, that less discomfort is experienced with CT colonography than with either colonoscopy or DCBE, and that a strong preference exists for CT colonography over other full structural examinations of the colorectum. Our questionnaire responses show that patients consider CT colonography to be more comfortable than either colonoscopy or DCBE and suggest the possibility of a higher rate of patient compliance with CT colonography. These findings should be considered when modeling future colorectal cancer screening algorithms.

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