Low-Fiber Diet in Limited Bowel Preparation for CT Colonography: Influence on Image Quality and Patient Acceptance

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OBJECTIVE. The purpose of this study was to determine whether a low-fiber diet is necessary for optimal tagging-only bowel preparation for CT colonography.

SUBJECTS AND METHODS. Fifty consecutively enrolled patients received an iodine bowel preparation: 25 patients used a low-fiber diet and 25 used no special diet. One observer determined the tagging quality per segment on a 5-point scale (1, inhomogeneous tagging; 5, excellent preparation) and the largest size of untagged feces. Semiautomatic measurements of density and homogeneity of residual feces were performed. Patient acceptance was assessed with questionnaires. Per polyp sensitivity for polyps 6 mm in diameter and larger was calculated for two experienced observers.

RESULTS. Tagging quality was scored less than grade 5 in 15 segments (10%) in the low-fiber diet group and in 25 segments (17%) in the unrestricted diet group (p = 0.098). One piece of untagged feces 10 mm in diameter or larger was found in the low-fiber diet group, and 12 were found in the unrestricted diet group (p < 0.001). Automatic measurement of attenuation resulted in a mean value of 594 HU in the low-fiber diet group and 630 HU in the unrestricted diet group (p = 0.297). In the low-fiber diet group, 22% of patients indicated that the bowel preparation was extremely or severely burdensome; 8% of patients in the unrestricted diet group had this response (p = 0.19). Thirty-two polyps 6 mm in diameter or larger were found in the low-fiber diet group and 30 in the unrestricted diet group. Observer 1 had 84% and 77% sensitivity (C = 0.297). In the low-fiber diet group, 22% of patients indicated that the bowel preparation was extremely or severely burdensome; 8% of patients in the unrestricted diet group had this response (p = 0.19).

CONCLUSION. Use of a low-fiber diet in bowel preparation for CT colonography results in significantly less untagged feces and shows a trend toward better residue homogeneity.

CT colonography is an alternative to colonoscopy in the detection of polyps and carcinoma of the colon and rectum. High sensitivity and specificity have been reported for polyp detection [1–4]. Even though CT colonography is generally less burdensome to patients [5, 6], most patients still find the bowel preparation the most troublesome part of the examination, and therefore it is important to minimize this burden [6]. A cathartic preparation with polyethylene glycol or sodium phosphate causes diarrhea and considerable patient burden. Limited bowel preparation with an oral tagging agent alone and no laxatives decreases the patient burden of CT colonography while image quality is maintained [7–11].

In most studies performed with a tagging-only bowel preparation for CT colonography, a low-fiber or clear liquid diet is prescribed [12–14]. Dietary fiber is excreted almost intact from the colon because it is resistant to hydrolysis by the endogenous enzymes of the human gastrointestinal tract and to bacterial breakdown [15–18]. The assumption is that a low-fiber diet reduces residual bowel content and causes the tagged feces to be closer to homogeneous. In addition, the seeds and grains from a high-fiber diet can mimic polyps.

In a few previous studies [8, 9, 11], good image quality at CT colonography was obtained with a bowel preparation that did not require a special diet. The issue of bowel preparation has been addressed in studies of the use of a low-fiber and low-residue diets for barium enema [19–23]. Some of these studies showed no benefit from the use of a prescribed diet with respect to amount of fecal residue or diagnostic quality [19–21]. Other studies [22, 23], however, showed that the amount of fecal residue diminishes and image quality improves with the use of a...
low-residue diet. To our knowledge, no study has been performed to evaluate the influence of a low-fiber diet on a fecal tagging limited bowel preparation for CT colonography with respect to sensitivity and specificity and the quality of tagging of residual feces. The aim of this study was to compare limited bowel preparations with and without a low-fiber diet to determine whether a low-fiber diet is necessary for good image quality, high patient acceptance, and accuracy in polyp detection at CT colonography.

Subjects and Methods
Fifty consecutively enrolled patients who had positive results of a fecal occult blood test in the framework of the first or second round of a pilot study [24, 25] of fecal occult blood test screening for bowel cancer were included in this study. The first 25 consecutively enrolled patients in this study participated in a previously published study of the accuracy of CT colonography in the detection of colorectal neoplasia [26], and the CT colonographic images examined as part of this study were acquired as part of that study. The findings presented herein are unique to the current study. All patients were willing to undergo colonoscopy. Exclusion criteria were inability to give informed consent, terminal illness, severe psychiatric symptoms, colonoscopy or a fecal occult blood test in the previous 2 years, examinations with radiation exposure in the last 12 months, iodine contrast allergy, hyperthyroidism, and pregnancy. The study was approved by the local medical ethics committee. All patients gave written informed consent.

Bowel Preparation
The first 25 consecutively enrolled patients used a bowel preparation of 4 × 50 mL meglumine ioxithalamate (Telebrix Gastro 300 mg I/mL, Guerbet). The day before the examination, the patients ingested 50 mL meglumine ioxithalamate with each meal. The patients consumed a final 50 mL 1.5 hours before CT colonography (total amount, 200 mL of meglumine ioxithalamate). All patients consumed a low-fiber diet (Table 1). On the day of CT colonography, these patients were allowed only a liquid diet before the examination. This diet consisted of only clear and opaque liquid foods with a smooth consistency. Patients were allowed to take drinks and, when preferred, liquid foods such as milkshakes, custard, and yogurt.

The second group of 25 patients also received 4 × 50 mL of meglumine ioxithalamate but did not need to follow a special diet the day before CT colonography. On the day of CT colonography, these patients were allowed the same liquid diet as the low-fiber diet group. All patients in this group were asked to carefully document their food intake during their days of preparation.

CT Colonography
CT was performed with a 64-MDCT scanner (Brilliance, Philips Healthcare). A low-dose protocol with a reference tube current–time product of 40 mAs was used with z-axis tube modulation and automatic current selection. Slice collimation was 64 × 0.625 mm; pitch, 1:2; slice thickness, 0.9 mm; rotation time, 0.4 second; and tube voltage, 120 kV. Patients were first in the supine and then the prone position for image acquisition. A muscle relaxant, 20 mg of butylscopolamine bromide (Buscopan, Boehringer Ingelheim), was injected before insufflation of the colon. When butylscopolamine bromide was contraindicated, 1 mg of glucagon hydrochloride (Glucagen, Novo Nordisk) was injected instead. Patients with contraindications to both agents were given no muscle relaxant. A rectal balloon catheter (20 French) was inserted for insufflation of approximately 3 L of CO2 gas into the colon. An automated insufflator (ProtoCO2,1, Bracco) with a manometer to measure the CO2 pressure and an automatic flow stop at 25 mm Hg was used.

CT Colonography Image Analysis
A primary 2D axial evaluation (window width, 1,500 HU; level, –250 HU) was performed with a 3D problem-solving application (View Forum, Philips Healthcare) for the detection of polyps. Two experienced observers (radiology research fellows with experience performing 450 and 750 CT colonographic examinations) reviewed all CT colonographic images and identified lesions. Lesions were measured on multiplanar reformatted images showing the maximal diameter of the lesion. The shape (sessile, flat, pedunculated) and size of each lesion in a segment location were noted. The segmental locations were the six colonic segments (cecum, ascending colon, transverse colon, descending colon, sigmoid, and rectum) defined by Dachman et al. [27]. The reading time per position also was recorded for each observer.

Colonoscopy
All patients underwent colonoscopy approximately 2 weeks after CT colonography. Bowel preparation for colonoscopy consisted of 4 L of polyethylene glycol electrolyte solution (Klean-Prep, Helsinn Birex Pharmaceuticals) or 2 L of another polyethylene glycol electrolyte solution (Moviprep, Norgine) and a clear liquid diet starting on the evening before colonoscopy. Experienced gastroenterologists and gastroenterology residents or nurse endoscopists with supervision performed optical colonoscopy with a standard colonoscope (Olympus). Sedation (midazolam, Dormicum, Roche), analgesics (fentanyl, Fentanyl, Janssen), and a muscle relaxant (butylscopolamine bromide, Buscopan) were used in the standard manner. According to the technique of segmental unblinding, the findings at CT colonography were revealed to the colonoscopist after completion of the examination of one segment. Polyp size was estimated by comparison with an opened biopsy forceps. The colonoscopic examination was video recorded starting from the cecum. The histologic findings on the lesions were classified according to the Vienna classification [28].

Image Quality of CT Colonography
Fecal residue—For evaluation of the quality of the bowel preparation, one experienced CT colonography reader, who was blinded to the type of preparation, scored each segment (cecum, ascending, transverse, descending, sigmoid colon, and rectum). Segments were classified according to the segment description of Dachman et al. [27]. Scores were given on the supine scans only, as follows: The relative amount of fecal residue per segment compared with the luminal diameter

<table>
<thead>
<tr>
<th>Category</th>
<th>Allowed</th>
<th>Not Allowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>Fresh peeled and pitted fruits such as apples, pears, and bananas</td>
<td>Oranges, pineapple, mango, kiwi, dates, prunes, raisins, coconut</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Potatoes, cooked vegetables such as carrots, spinach, and cauliflower</td>
<td>Green peas, tomatoes, onion, corn, green beans, mushrooms, asparagus</td>
</tr>
<tr>
<td>Grains</td>
<td>White bread and toast, white rice and pasta, pancakes</td>
<td>Whole-grain bread, muesli, brown rice, whole-grain pasta</td>
</tr>
<tr>
<td>Sandwich fillings</td>
<td>Cheese, meat, fish, eggs, sugar, sweet sandwich spreads</td>
<td>Jam with fruit pieces</td>
</tr>
<tr>
<td>Drinks</td>
<td>Lemonade, soda, coffee, tea, water, milk, alcohol</td>
<td>Nuts, peanuts, popcorn, spices, herbs</td>
</tr>
<tr>
<td>Other</td>
<td>Candy, ice cream, cake, chocolate, salt, pepper</td>
<td></td>
</tr>
</tbody>
</table>
Low-Fiber Preparation for CT Colonography

Fig. 1—62-year-old man who used no special diet. CT colonographic image shows region of interest drawn in fecal residue that could not be measured automatically owing to low density.

was scored on a scale of 0–100%. The consistency of fecal residue was rated on a three point scale: 1, liquid; 2, partly solid and partly liquid; 3, solid. The presence of adherent feces was scored yes or no. In which segments untagged solid feces was present was recorded, and the size of the largest piece of untagged solid feces was documented as ≤ 5 mm, 6–9 mm, and > 10 mm). The quality of tagging on the supine scans was scored on a five point scale [11]: 1, uninterpretable images, untagged feces; 2, poor interpretation, large amount of unopacified feces; 3, moderate preparation, moderate amounts of unopacified feces; 4, good preparation, small amounts of unopacified feces; 5, excellent preparation, no unopacified feces.

The density (mean attenuation) and homogeneity (SD of attenuation) of the fecal residue were measured on the supine scans by automatic extraction of the residual feces from the colon. Voxels containing residual fecal residues were identified in cross sections at regular intervals of 10 mm perpendicular to the path by application of a threshold of 200 HU. Mean values of density and homogeneity were calculated per segment. A radiology research fellow defined the segments in one representative CT colonography data set with good distention. The distance of each segment border from the anus was compared with the total length of the colon and set as a reference distance ratio for definition of segments in all CT colonographic examinations. The radiology research fellow also verified all automatically measured fecal residues. For segments that contained fecal residues < 200 HU (which caused failure of automatic measurement), a research fellow made three manual region of interest measurements in this residual material by (Fig. 1). The slice numbers within a segment in which the measurements were to be obtained were randomly generated with a spreadsheet application (Excel 2003 for Windows, Microsoft). The mean attenuation of tagging can vary considerably among patients, and the consistency of residual feces, the quality of tagging, and colonic distention were compared by use of ordinal regression analysis; the low-fiber-diet patient group was considered the reference group.

The presence of adherent feces was compared by use of the chi-square test. The density (mean attenuation), homogeneity (SD of attenuation), and relative SD (SD attenuation divided by mean attenuation) of the residual feces were compared by use of Student’s t test, in which normal distribution of the data is assumed).

Patient acceptance—The characteristics of the participants, including age, sex, and socioeconomic status were compared by means of statistics based on the type of data (e.g., Student’s t test, chi-square test). The amount and burden of diarrhea, experience of burden of the preparation, and the preference of preparation in both groups were compared by performance of ordinal regression analysis.

Polyp Detection

Sensitivity and specificity were assessed as measures of the accuracy of polyp detection in both groups. Matching of polyps and tumors found at CT colonography was done by a research fellow, who reviewed the video recordings and reports of the colonoscopic examination. A polyp considered a true-positive finding at CT colonography measured within 50% of the corresponding polyp found at colonoscopy, was in the same or adjacent segment as the polyp found at colonoscopy, and had morphologic features resembling those of the lesion seen on the colonoscopic video recording. The number of technical false-negative findings, polyps retrospectively not visible at CT colonography, and number of false-positive findings were counted per group.

Statistical Analysis

Fecal tagging—Outcome with respect to quality of fecal tagging was analyzed in different ways. The relative amount of residual feces (percentage documented by reviewer) was calculated with Student’s t test. The consistency of residual feces, the quality of tagging, and colonic distention were compared by use of ordinal regression analysis; the low-fiber-diet patient group was considered the reference group.

Results

The group who prepared with the low-fiber diet consisted of 14 men and 11 women, and the group who prepared without a prescribed diet consisted of 15 men and 10 women (p = 0.77). The mean age was 60.4 ± 5.4 years in the low-fiber diet group and 61.1 ± 7.2 years

Patient Acceptance

Standardized questionnaires used in previous studies [6, 13] were given to all patients to fill in at home before both examinations and to fill out before CT colonography. A third questionnaire was sent 5 weeks after colonoscopy. In the first questionnaire patients were asked about their normal defection pattern and their educational background. In the second questionnaire, the patients were asked about the amount of and burden from diarrhea before CT colonography. The answers had a 5-point scale (1, no discomfort; 2, mild; 3, moderate; 4, severe; 5, extremely burdensome). In the third questionnaire patients were asked which examination, including the bowel preparation, they found more burdensome; how burdensome they found the CT colonography examination (on the previously mentioned 5-point scale); and on a 7-point scale which examination they would prefer in the future (1, definitely CT colonography; 7, definitely colonoscopy).

Colonic distention—The radiology research fellow scored colonic distension per segment with the patient in the prone and supine positions. The following 4-point scale was used to score degree of distention: 1, bad distention, 0–25% of estimated maximal diameter; 2, poor distention, 25–50% of maximal diameter; 3, sufficient distention, 50–75% of estimated maximal diameter and no collapsed lumen at any point; 4, good distention, 75–100% of estimated maximal distention and no collapsed lumen at any point.

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Patient acceptance—The characteristics of the participants, including age, sex, and socioeconomic status were compared by means of statistics based on the type of data (e.g., Student’s t test, chi-square test). The amount and burden of diarrhea, experience of burden of the preparation, and the preference of preparation in both groups were compared by performance of ordinal regression analysis.

Polyp Detection—The sensitivity and specificity of CT colonography for lesions 10 mm or larger in diameter (including colorectal cancers, adenomas, and hyperplastic polyps) and lesions 6 mm in diameter or larger detected at colonoscopy were determined. Comparison between outcomes of the two patient groups was performed with the chi-square test. Reading times were compared by use of Student’s t test. Software (SPSS version 15.0.1 for Windows, SPSS) was used for statistical analyses, and for all analysis, p < 0.05 indicated a significant difference between the two preparation groups.

Results

The group who prepared with the low-fiber diet consisted of 14 men and 11 women, and the group who prepared without a prescribed diet consisted of 15 men and 10 women (p = 0.77). The mean age was 60.4 ± 5.4 years in the low-fiber diet group and 61.1 ± 7.2 years

Figure 1—62-year-old man who used no special diet. CT colonographic image shows region of interest drawn in fecal residue that could not be measured automatically owing to low density.
TABLE 2: Amount and Consistency of Residual Feces

<table>
<thead>
<tr>
<th>Segment</th>
<th>Amount of Fecal Residue (% of Lumen Filled)</th>
<th>Consistency of Feces (fluid/partly fluid and partly solid/solid)</th>
<th>No. of Segments Containing Adherent Feces</th>
<th>Untagged Feces (none/&lt;6 mm/6–9 mm/&gt;10 mm)</th>
<th>Quality of Fecal Tagging (grades 1/2/3/4/5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Fiber</td>
<td>Unrestricted</td>
<td>Low Fiber</td>
<td>Unrestricted</td>
<td>Low Fiber</td>
</tr>
<tr>
<td>Cecum</td>
<td>25 ± 23</td>
<td>24 ± 18</td>
<td>21/2/0a</td>
<td>23/1/1</td>
<td>0</td>
</tr>
<tr>
<td>Ascending colon</td>
<td>33 ± 19</td>
<td>32 ± 20</td>
<td>25/0/0</td>
<td>24/0/1</td>
<td>2</td>
</tr>
<tr>
<td>Transverse colon</td>
<td>6 ± 7</td>
<td>9 ± 10</td>
<td>23/1/0a</td>
<td>19/5/1</td>
<td>7</td>
</tr>
<tr>
<td>Descending colon</td>
<td>29 ± 24</td>
<td>25 ± 19</td>
<td>25/0/0</td>
<td>18/5/2</td>
<td>4</td>
</tr>
<tr>
<td>Sigmoid colon</td>
<td>10 ± 10</td>
<td>11 ± 9</td>
<td>23/1/0a</td>
<td>10/14/1b</td>
<td>9</td>
</tr>
<tr>
<td>Rectum</td>
<td>20 ± 17</td>
<td>15 ± 18</td>
<td>23/0/1b</td>
<td>15/6/2b</td>
<td>1</td>
</tr>
<tr>
<td>All colonic seg.</td>
<td>20 ± 8</td>
<td>19 ± 9</td>
<td>140/4/1a</td>
<td>109/31/9b</td>
<td>23</td>
</tr>
</tbody>
</table>

*Note—Except for percentage of lumen filled by fecal residue, values are number of segments.

**a**No feces was present in some segments.

**b**p ≤ 0.05 compared with low-fiber diet group.

Image Quality

Fecal residue—The amount of fecal residue detected per segment is presented in Table 2. The largest amounts of feces were present in the ascending and descending colon. Neither the per-segment nor the total amounts were significantly different between groups. Compared with that in the low-fiber diet group, the consistency of residual feces in the unrestricted diet group was more often solid in the descending colon (p = 0.034), sigmoid (p = 0.001), and rectum (p = 0.020) (Table 2). Adherent feces was present in nearly all segments, but in the unrestricted diet group, 10 patients had adherent feces in the rectum compared with one patient in the low-fiber diet group (p = 0.005). With respect to the largest piece of untagged solid feces in each segment, there were significantly more untagged fecal pieces in the unrestricted diet group (p ≤ 0.001). A total of 12 pieces of untagged feces 10 mm in diameter or larger were found in the unrestricted diet group; only one was found in the low-fiber diet group (p < 0.001).

Tagging quality was scored less than grade 5 in 15 segments (10%) in the low-fiber diet group and in 25 segments (17%) in the unrestricted diet group (p = 0.098) (Table 2). When the fiber intake of patients in the unrestricted diet group was analyzed, however, we found that 10 patients in that group had not eaten any fiber the day before CT colonography (according to the list of fiber-rich foods in Table 1). When groups were divided into patients who had eaten fiber (15 patients) and patients who had not eaten fiber (35 patients) regardless of the original group assignment, the ratios were 0.14 for the fiber group and 0.15 for the nonfiber group (p = 0.868), and only in the rectum was a significant difference found in homogeneity.

Colonic distention—In total, two segments in the low-fiber diet group were graded as insufficiently or badly distended compared with six segments in the unrestricted diet group (p = 0.23).

TABLE 3: Tagging Density and Homogeneity Measurements

<table>
<thead>
<tr>
<th>Segment</th>
<th>Density (HU)</th>
<th>Homogeneity (SD)</th>
<th>Homogeneity/Density Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Fiber</td>
<td>Unrestricted</td>
<td>Low Fiber</td>
</tr>
<tr>
<td>Cecom</td>
<td>584</td>
<td>608</td>
<td>0.516</td>
</tr>
<tr>
<td>Ascending</td>
<td>585</td>
<td>616</td>
<td>0.409</td>
</tr>
<tr>
<td>Transverse</td>
<td>616</td>
<td>653</td>
<td>0.340</td>
</tr>
<tr>
<td>Descending</td>
<td>651</td>
<td>665</td>
<td>0.712</td>
</tr>
<tr>
<td>Sigmoid</td>
<td>587</td>
<td>626</td>
<td>0.298</td>
</tr>
<tr>
<td>Rectum</td>
<td>534</td>
<td>619</td>
<td>0.063</td>
</tr>
<tr>
<td>Averagea</td>
<td>594</td>
<td>630</td>
<td>0.297</td>
</tr>
</tbody>
</table>

*a*Of each column.
Patient Acceptance

Almost all patients (24 in the low-fiber diet group, 25 in the unrestricted diet group) experienced diarrhea during the bowel preparation. Ten patients (42%) in the low-fiber diet group considered the diarrhea extremely to severely burdensome compared with 13 patients (52%) in the unrestricted diet group ($p = 0.70$). In the questionnaire 6 weeks after colonoscopy, five patients (22%) in the low-fiber diet group indicated that the bowel preparation for CT colonography was extremely or severely burdensome compared with two patients (8%) in the unrestricted diet group ($p = 0.19$). When the respective preparations for CT colonography and colonoscopy were compared, 71% of patients in the low-fiber diet group found colonoscopy the more burdensome, compared with 92% in the unrestricted diet group ($p = 0.12$). In the low-fiber diet group, 65% of patients would definitely or probably choose CT colonography for a future examination, compared with 64% in the unrestricted diet group ($p = 0.75$).

Polyp Detection

In the low-fiber diet group, 14 polyps 10 mm in diameter or larger were found at colonoscopy in 13 patients, and 18 polyps measuring 6–9 mm were found in 12 patients. In the unrestricted diet group, 15 polyps 10 mm in diameter or larger were found in 10 patients, and 15 polyps measuring 6–9 mm were found in nine patients (Table 4). The sensitivities for the two observers were not significantly different in either preparation group. No technical false-negative findings of polyps 6 mm or larger were made in the low-fiber diet group, and three were made in the unrestricted diet group. Observer 1 made five false-positive findings in the low-fiber diet group and six in the unrestricted diet group. The respective numbers for observer 2 were three and six. Observer 1 had a mean reading time of 15 minutes 16 seconds ± 3 minutes 26 seconds for the low-fiber diet group and 16 minutes 41 seconds ± 5 minutes 21 seconds for the unrestricted diet group ($p = 0.27$). The reading times of observer 2 were 11 minutes 32 seconds ± 4 minutes 7 seconds) for the low-fiber diet group and 14 minutes 47 seconds ± 4 minutes for the unrestricted diet group ($p = 0.007$).

Discussion

Our study showed that for CT colonography a bowel preparation consisting of iodine tagging only with consumption of a low-fiber diet leaves fewer pieces of untagged feces and less solid feces in the colon than does...
TABLE 4: Per-Polyp Sensitivity

<table>
<thead>
<tr>
<th>Polyp Diameter</th>
<th>Low-Fiber Diet</th>
<th>Unrestricted Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (%)</td>
<td>95% CI</td>
</tr>
<tr>
<td>≥ 6 mm</td>
<td>Observer 1</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>Observer 2</td>
<td>97</td>
</tr>
<tr>
<td>≥ 10 mm</td>
<td>Observer 1</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Observer 2</td>
<td>100</td>
</tr>
</tbody>
</table>

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an iodine preparation without a specific diet prescription, but use of a prescribed diet had no statistically significant influence on measured tagging density. In analyzing food intake without respect to group assignment, however, we found that patients who had eaten a low-fiber diet (all patients in the low-fiber diet group, 10 patients in the unrestricted diet group) had significantly better subjective tagging quality than patients who had eaten a diet containing fiber. The two study groups did not differ significantly with respect to polyp detection and patient burden.

For readability of CT colonographic images, it is important that good homogeneity and high tagging density be obtained, certainly when a tagging-only preparation is used without laxatives to remove residual feces. When density decreases, the difficulty of polyp detection increases, more false-positive findings are made, and diagnostic accuracy can decrease [11]. In phantom studies [29, 30], the optimum tagging density was approximately 700 HU and greater. In the current study, we found tagging densities of approximately 600 HU in each group, which approaches the optimum tagging density. The homogeneity (SD of attenuation) was significantly better for the group without a diet prescription, but when the ratios of homogeneity to density were compared, a significant difference was not found. This finding indicates that the density was high enough to compensate for differences in homogeneity. For example, a measured homogeneity of 200 HU SD will have less influence in a preparation with a mean density of 700 HU than will a preparation with a mean density of 300 HU. Furthermore, the absolute differences in homogeneity were small (maximum difference, 27 HU in the rectum), and although significantly different, these relatively small differences probably do not greatly influence the CT colonographic reading. Evidence for this supposition is the subjective scores of tagging quality that were slightly more favorable for the low-fiber diet group. Zalis et al. [11] found that measured homogeneity did not reflect differences in qualitative assessment ratings by readers.

When the subjective reader scores were assessed, we found the group without a diet prescription had more pieces of untagged feces and more adherent and solid feces than did the low-fiber diet group. This inadequate preparation can result in deterioration in polyp detection. We found that the sensitivity for detection of polyps 6 mm in diameter or larger was lower for both observers in the unrestricted diet group but that the difference was not statistically significant, probably because the patient groups were too small for conclusions in this regard.

Several previous studies of CT colonography were conducted with limited, tagging-only bowel preparation with barium or iodine [8, 11, 12, 14, 31, 32]. In some studies [12, 14, 32] a low-fiber diet or a low-residue diet kit was prescribed for CT colonographic bowel preparation, whereas in others a specific diet prescription was not used [8, 11, 31]. In addition, a few studies [19, 21, 33] have been conducted with low-fiber or low-residue diets in bowel preparation for double contrast barium enema. One half of these studies showed no effect of ingestion of a specific diet on colon cleanliness. Lee and Ferrando [22], however, found a significant difference in the amount of retained fecal material. Vierik and Makela [23] found that a low-residue diet with hydration resulted in the presence of significantly less residual fecal material and significantly denser mucosal coating. In preparation for barium enema, the amount of residual fecal material is important because a clean colon is preferable. For CT colonography the amount may not influence image readability, but the density and the homogeneity of the residual feces are important. These variables were not assessed in the barium enema studies.

Regarding patient acceptance, with respect to degree of burden, we found no statistically significant difference between patients who followed the restricted diet and those who did not. Therefore, we believe the diet consumed has minimal influence on patient burden and therefore that a prescribed diet should be used to obtain good image quality.

Reading time may be an indicator of image quality. In this study the reading time of observer 2 increased significantly for the unrestricted diet group, and observer 1 had a trend toward an increase in reading time. This finding may indicate that the images of the unrestricted diet group were more difficult to interpret because of reduced quality of the images. The number of polyps 6 mm in diameter or larger in both groups was nearly equal, so this factor probably did not cause the difference in reading times.

There were a few potential limitations to this study. First and most important, the patient groups were relatively small; only 25 patients were included in each group. The sample size was calculated to be sufficiently large to meet the primary aim of evaluating homogeneity and amount of untagged feces, which were the main parameters of this study. Indeed, significant differences were found in these parameters. No differences were found in polyp detection rate, which might have been higher if larger patient groups had been compared. A second limitation was that patients were consecutively included, that is, without randomization. This method was chosen because the bowel preparation scheme was changed from a low-fiber diet to a preparation without diet prescription during the study period. Both groups, however, had similar numbers of men and women, and usual stool consistency did not differ between groups. Third, the measurements of density and homogeneity were not completely automated because they had to be manually adjusted for regions with a tagging density less than 200 HU. This method was chosen because
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at a density less than 200 HU normal tissues, such as muscle and kidney, are measured, resulting in incorrect measurements of the density and homogeneity of fecal material. Fourth, subjective scoring was performed by only one observer. Because the observer was blinded to the type of bowel preparation and the main aim was to compare the outcomes of the groups, we believe this limitation is not important. The last limitation was that we tested only whether diet influences an iodine tagging bowel preparation. A high-osmolar ion preparation often causes diarrhea, whereas a barium preparation does not and tags mainly solid feces [32]. From the results of this study, we cannot conclude whether a specific diet is necessary with a barium tagging bowel preparation.

We found in this study that use of a low-fiber diet in iodine tagging bowel preparation for CT colonography results in improved subjective tagging quality of residual feces while the measured tagging density remains the same. Adding a specific diet does not increase patient burden due to the prescribed bowel preparation. No significant effects on polyp detection were found.

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References

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