Technical Innovation

Laxative-Free CT Colonography

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The current technique of performing CT colonography requires the colon to be as clean and dry as possible. As with other total colonic examinations, this cleansing and drying can only be achieved by means of an intensive cathartic preparation [1]. These laxative-based preparations are a major burden for the patient, interrupting normal daily activities because of possible fulminant diarrhea and side effects such as abdominal discomfort, nausea, and vomiting. Moreover, these side effects usually result in poor patient compliance in an asymptomatic screening population. Efforts have been undertaken to improve patient compliance by reducing the cathartic part of the preparation. Because this reduction results in a soiled colon, different methods of fecal tagging have been developed to label fecal residue in the colon with contrast material ingested orally during preparation for the examination. Fecal tagging has been used successfully in combination with full [2] and reduced [3] cathartic cleansing. Besides an improved differentiation between stool and polyphs, the method permits more residue to be left in the colon and hence a reduction of the cathartic part of the preparation.

The purpose of our study was to develop an efficient method of performing CT colonography using fecal tagging instead of cathartic colon cleansing using a dedicated low-residue diet developed and made commercially available by EZ-EM. The day before the patient underwent CT colonography, a hydration control component was added to this preparation protocol to obtain a dry colon and to increase the homogeneity of the tagged residue. At the same time, the influence of different barium concentrations administered over the course of 1 or 2 days was evaluated.

Subjects and Methods

The study population consisted of 15 patients, four men and 11 women whose ages ranged from 23 to 73 years (mean age, 58 years). Seven patients were enrolled for conventional colonoscopy as part of their colorectal cancer screening program. They agreed to undergo CT colonography in addition to conventional colonoscopy. Eight other patients who were referred for evaluation of vague abdominal pain and were scheduled for a conventional abdominal CT examination also agreed to undergo CT colonography. In cases of suspicious findings, additional conventional colonoscopy was performed. None of the patients complained of constipation or irritable bowel syndrome. The study was approved by the institutional review board.

On the morning of the day before undergoing CT colonography, the patients prepared for the examination by adhering to a dedicated low-residue diet that was presented in a single kit (Nutra Prep, EZ-EM), practicing hydration control (they were permitted to drink a maximum of 2 L of fluids), and ingesting barium as a fecal-tagging agent. No cathartic cleansing agent was used. This diet was designed to control fat intake and to decrease fecal output and contained meals and drinks: a vanilla drink, fruit juice, soup, apple sauce, potato chips, and chocolate-flavored nutrition bars. At breakfast, the patients drank the vanilla drink (= 250 mL). They could choose to drink an additional 250 mL in the morning (fruit juice, vanilla drink, soup, or water). At lunch, they ingested another 250 mL of fluid, choosing either the vanilla drink, soup, or fruit juice. In addition, they could eat applesauce and potato chips and were also allowed to have a supplementary drink (= 250 mL) in the afternoon. Between meals, the patients were allowed to eat the nutrition bars. At dinner, they had another 250-mL drink (vanilla drink or soup). After this time, the patients were not allowed any more drinks. This protocol resulted in a maximum fluid intake of 1.250 mL. The patients were not obliged to eat or drink all the contents of the preparation kit.

Fecal tagging was performed with barium. The aim was to obtain efficient tagging of all fecal residue in a dense and homogeneous way. To obtain an appreciation of the most suitable barium regimens to use, we evaluated different barium concentrations or different time tables. Fecal tagging was performed using barium suspensions with concentrations of 2.1%, 4%, and 40% weight/volume (w/v). The various concentrations allowed us to test different volumes of barium and to eventually reduce the volume of barium that patients needed to drink. Besides different barium concentrations and volumes, the efficacy of tagging was also tested by administering barium over the course of 1 or 2 days.

As a consequence, in this preliminary study of only 15 patients, five different regimens of barium intake were investigated to determine the best regi-
Vlemmen for eventual further clinical studies. To do so, we divided the patients into five groups of three each. The different barium sulfate regimens are listed in Table 1. Group 1 ingested a total of 750 mL of a 2.1% w/v barium sulfate suspension (Tagitol, EZ-EM) the day before CT colonography. The patients drank 250 mL of barium with each of their meals at breakfast, lunch, and dinner, resulting in a total intake of 15.75 g of barium. Group 2 also ingested a total volume of 750 mL of barium the day before CT colonography. However, they started with 250 mL of 4% w/v barium suspension at breakfast followed by 250 mL of the 2.1% w/v barium suspension at lunch and again at dinner, corresponding to a total barium load of 20.5 g. Group 3 ingested barium over 2 days. Two days before CT colonography, these patients ingested 50 mL of the 4% w/v barium suspension with each of their regular meals (breakfast, lunch, and dinner). The next day, they followed the same regimen as group 1, resulting in a total barium intake of 21.75 g. Group 4 was prepared with a 40% w/v barium suspension (Tagitol V, E-Z-EM) the day before undergoing CT colonography. They ingested 25 mL at breakfast and 12.5 mL each at lunch and dinner, corresponding to a total of 20 g of barium. Group 5 ingested barium over 2 days. Two days before the examination, they ingested 12.5 mL each of the 40% w/v barium suspension with their regular meals at breakfast, lunch, and dinner. On the day before the examination, this group followed the same diet scheme as group 4, receiving a total barium load of 35 g. This combination of fluid and barium intake resulted in a maximum fluid intake of 2 L, the day before CT colonography for groups 1, 2, and 3 and maximum fluid intake of 1.3 L for groups 4 and 5. Patients of groups 4 and 5 were allowed to have additional fluid (0.7–1.2 L) the day before CT colonography.

CT colonography was performed after smooth-muscle relaxation with hyoscine-N-butyl bromide (Buscopan, Boehringer Ingelheim) [4] and inflation of the colon with room air. CT was performed on a single-detector helical CT scanner (Tomoscan AV/EUI, Philips Medical Systems) with a 5-mm slice collimation, a 7-mm table feed (pitch = 1.4), and a 3-mm reconstruction interval. Scans were obtained at 100 mAs and 120 kV.

The scans were sent to a workstation (Innerview GI, EZ-EM). The colon in each patient was reviewed to assess the amount of residue and the efficacy of tagging. The colon was divided in 6 segments: cecum, ascending colon, transverse colon, descending colon, sigmoid colon, and rectum.

In accordance with the protocol described by Callstrom et al. [5], all residue (i.e., residual stool and fluid) with a density exceeding 150 H was electronically labeled (green) on the axial scans to assess the efficacy of tagging. The residue was not deleted by digital stool subtraction. The efficacy of tagging was evaluated on each axial scan using a subjective visual labeling score. A score of 0%, 25%, 50%, 75%, and 100% was used, with 0% indicating a scan with only untagged residue; 25% indicating a scan with 25% of the residue tagged; 50% indicating a scan with 50% of the residue tagged; 75% indicating a scan with 75% of the residue tagged; and 100% indicating a scan with completely tagged residue. All the scores obtained for axial scans were added for each segment, and average percentage scores per segment and per group of patients were calculated.

The amount of fluid was assessed according to its proportion (0%, < 25%, 25–50%, and > 50% of the lumen) relative to the maximum anteroposterior diameter in the segment of the colon in which it was detected [6].

### Results

The electronic labeling was efficient (Fig. 1). The results of the subjective visual labeling scores are shown in Figure 2. For all groups, the labeling scores varied between 90–100% for all segments, except for the descending colon in group 2, in which a score of only 71% was obtained. In this group, one patient presented with stool less than 5-mm in diameter in the descending colon. In this patient, the score for the descending colon was only 20%. However, this segment was almost empty and did not hamper visualization of the colonic wall (Fig. 3). No difference in labeling was seen between patients who ingested barium over the course of 1 versus 2 days and between patients who received the 750-mL barium dose and those receiving the 50-mL barium dose the day before CT colonography (Fig. 4). In all patients of all groups, a 100% labeling score was obtained in the cecum.

Untagged residue greater than 1 cm in diameter was seen in the rectum of two patients. This untagged stool was easily recognizable because it contained air and was completely surrounded by barium (Fig. 5). Six small fluid levels (< 25%) were found in five patients. These fluid levels were located in the cecum [5] and the ascending colon [1]. One major fluid level (> 50%) was found in the rectum. All the fluid was labeled at 100%. One 8-mm polyp was detected and confirmed on conventional colonoscopy.

### Discussion

It is generally accepted that CT colonography yields the best results for lesion detection after a cathartic cleansing that produces a fully cleansed and dry colon. However, this preparation is both intensive and inconvenient for the patient and results in poor patient compliance. The ability to perform CT colonography without cathartic preparation of the colon could dramatically improve patient compliance [1]. In this preliminary study, we investigated a method of perform-

![Table 1](image-url)

**TABLE 1**

<table>
<thead>
<tr>
<th>Patient Group</th>
<th>2 Days Before Examination</th>
<th>1 Day Before Examination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Breakfast</td>
<td>Lunch</td>
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<td>1a Volume</td>
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<td>2.1%</td>
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<td>2a Volume</td>
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<tr>
<td>Concentration</td>
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<td>4%</td>
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<tr>
<td>3a Volume</td>
<td>250 mL</td>
<td>250 mL</td>
</tr>
<tr>
<td>Concentration</td>
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<td>2.1%</td>
</tr>
<tr>
<td>4b Volume</td>
<td>25 mL</td>
<td>12.5 mL</td>
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<td>Concentration</td>
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<td>40%</td>
</tr>
<tr>
<td>5b Volume</td>
<td>12.5 mL</td>
<td>12.5 mL</td>
</tr>
<tr>
<td>Concentration</td>
<td>40%</td>
<td>40%</td>
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Barium administered over the course of 1 day.
Barium administered over the course of 2 days.
Laxative-Free CT Colonography

ing laxative-free CT colonography. Our purpose was to obtain efficient tagging of fecal residue with a small amount of tagging agent. A commercially available dedicated low-residue diet was combined with the administration of barium as the sole fecal tagging agent. The dedicated low-residue diet was designed to reduce the fat contents of the stool. In addition to this diet, patients were asked to follow a hydration control protocol that allowed them to drink no more than 2 L of fluid the day before CT colonography. This hydration control was instituted to increase the efficacy and homogeneity of fecal tagging and to obtain a dry colon. Hydration control was expected to yield a balance between the amount of ingested fluid and the amount of fluid absorbed in the gastrointestinal tract.

It is a well-established fact that a sedentary person living in a temperate climate and eating a normal diet needs a daily fluid intake of approximately 1.7 L [7]. An obligatory amount of urine—from 480 to 1,200 mL/day—has to be excreted by the kidneys. Furthermore, an additional water loss of between 450 and 1,100 mL/day occurs through the skin, during respiration, and in the gastrointestinal tract [8]. Taking the dietary restrictions imposed by the dedicated low-residue diet with the lower protein load into account, we allowed a maximum fluid intake of 2 L the day before CT colonography. This hydration control was expected to result in a colon with a minimum of fluid. In fact, the colon in most patients was dry, with only one major fluid level in the rectum, and all the fluid was efficiently tagged. In this way, we avoided having to use an additional dose of iodinated contrast material to label the residual fluid in the colon. Iodine has been used to perform fluid tagging in some studies [2, 5]. However, in addition to being expensive, iodine can cause diarrhea and has an unpleasant taste. We expected to obtain efficient and homogeneous stool tagging with even a small amount of barium. Because stool is composed of a mixture of 75% water, 12% fiber, and 12% bacteria [9], we reduced the watery content of the stool by reducing the fluid intake to the minimum required for 1 day and eliminating the need for fluid tagging with iodine. The efficient and homogeneous tagging was confirmed by the results of the electronic labeling.

In all groups, we obtained good to excellent labeling. Only one patient in group 2 presented with a small amount of untagged stool in the descending colon, resulting in only 70% labeling for that group. No difference of efficacy in labeling the fecal residue was noted between the patients who ingested barium for 1 day and those who ingested barium over the course of 2 days. We also found it striking that there was no difference in tagging efficacy found among the different bar-
ium regimens. Efficient tagging was obtained with only 50 mL of a 40% w/v barium suspension administered the day before CT colonography. Because of the results of this preliminary study, we prefer to use this method because only a small volume of barium ingested for 1 day resulted in efficient tagging. However, the method could be less efficient in patients, especially older patients, who do not have a normal stool habit because of irritable bowel syndrome, constipation, or diverticulosis. Such patients might require more barium.

Our study has several other limitations, the most important being the small patient group that we studied. Our findings need to be confirmed in a large and polyp-rich patient group (including older patients or patients with constipation and irritable bowel syndrome) using conventional colonoscopy as the golden standard. Bowel cleansing with the use of a dedicated low-residue diet was still necessary with our method, and to achieve hydration control, patients were not allowed to drink more than 2 L of fluid the day before CT colonography. Reducing these restrictions could improve patient compliance. The hydration regimen was conceived for patients with a normal level of physical activity in a temperate climate. Obviously, adaptations will have to be made for patients living in a hot climate or engaging intense physical activity. Finally, our study was performed on a single-detector helical CT scanner. Although the type of scanner we used did not influence the efficacy of tagging, MDCT partial volume averaging was eliminated, resulting in better assessment of the residue (tagged or untagged) and eventually of the tumoral lesions.

We conclude that in our preliminary study, promising results were obtained in the achievement of a new colonic preparation for CT colonography. This preparation—consisting of the combination of a dedicated low-residue diet, hydration control, and barium as the sole tagging agent with no cathartic bowel cleansing—produced an almost completely dry bowel cleansing—produced an almost completely dry colon with efficient tagging of fecal residue.

**References**


**Fig. 4.**—Axial CT colonographic scan obtained in group 4 patient shows dense and homogeneous tagging of residual stool (arrows).

**Fig. 5.**—Axial CT colonographic scan obtained in group 1 patient shows untagged residual stool in rectum (arrow). Stool is easily recognizable because it is completely surrounded by barium. Some inhomogeneous tagging with air inclusions is seen in the other stool ball (arrowheads).