CT colonography in faecal occult blood test positives
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Low-fibre diet in CT colonography limited bowel preparation: influence on image quality and patient acceptance

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ABSTRACT

Purpose: To determine if a low-fibre diet is necessary for an optimal tagging-only bowel preparation for CT colonography.

Methods: 50 consecutive patients received an iodine bowel preparation; 25 patients had a low-fibre diet (group 1) and 25 had no special diet (group 2). 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 faeces. Semi-automatic measurements of density and homogeneity of residual faeces were performed. Patient acceptance was assessed with questionnaires. Per polyp sensitivity for polyps ≥6mm was calculated for two experienced observers.

Results: Tagging quality was scored less than grade 5 in 15 segments (10%) in group 1 and in 25 segments (17%) in group 2 (p=0.098). In total one piece of untagged faeces ≥10mm was found in group 1 compared to twelve in group 2 (p<0.0001). Automatic measurement of density resulted in a mean of 594 HU in group 1 and 630 HU in group 2 (p=0.297). 22% of patients in group 1 indicated that the bowel preparation was extremely or severely burdensome compared to 8% of patients in group 2 (p=0.19). 32 polyps ≥6mm were found in group 1 and 30 in group 2. Sensitivities for polyps ≥6mm for observer 1 were respectively 84% and 77% (p=0.443) and 97% and 83% for observer 2 (p=0.099).

Conclusion: Use of a low-fibre diet in bowel preparation for CT colonography results in significantly less untagged faeces and shows a trend towards a better residue homogeneity.
INTRODUCTION

Computed tomography colonography (CT colonography) is an alternative method for colonoscopy to detect polyps and carcinomas in the colon and rectum. In recent studies high outcomes on sensitivity and specificity are reported for polyp detection. The advantage of CT colonography is that patients generally experience less burden from CT colonography than from colonoscopy. Most patients find the bowel preparation the most burdensome part of the examination and therefore it is important to minimize this aspect. A cathartic preparation with polyethylene glycol or sodium phosphate results in diarrhoea and a considerable patient burden, but a limited bowel preparation with an oral tagging agent only and no laxatives has proven to lead to a decreased patient burden of CT colonography with still sufficient image quality.

In most studies with a tagging-only bowel preparation for CT colonography, a low-fibre diet or a clear liquid diet is prescribed. Dietary fibres are excreted almost intact from the colon because they are resistant to hydrolysis by endogenous enzymes of the human gastrointestinal tract and to bacterial breakdown. The assumption is that a low-fibre diet reduces residual bowel contents and that it results in a better homogeneity of the tagged faeces. Furthermore, left seeds and grains in a diet containing fibres may mimic polyps.

In a few previous studies however, good image quality was obtained by using CT colonography bowel preparation without any diet. The issue of bowel preparation has been addressed in studies that evaluated the use of a low-fibre or low-residue diet for barium enema. Some of these studies found no benefit from the use of a diet with respect to amount of faecal residue or diagnostic quality, but others did find that the amount of faecal residue diminishes and image quality improves after using a low-residue diet. To our knowledge, no study has been performed that evaluated the influence of a low-fibre diet on a CT colonography faecal tagging limited bowel preparation, with respect to sensitivity and specificity and tagging quality of the residual faeces.

This study aims to compare a limited bowel preparation with and without a low-fibre diet in order to determine if a low-fibre diet is necessary for a good image quality, high patient acceptance and accuracy for polyp detection in CT colonography.

MATERIALS AND METHODS

In total 50 consecutive patients who were Faecal Occult Blood Test (FOBT) positive in the frame work of the first or second round of a pilot study of FOBT-screening for bowel cancer were included. All were willing to undergo colonoscopy. Exclusion criteria were: patients who were unable to give informed consent, patients with terminal illness, severe psychiatric symptoms, colonoscopy or an FOBT in the previous two 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 group of 25 consecutive patients received a bowel preparation of 4*50 ml meglumine-ioxithalamate (Telebrix Gastro 300 mg I/ml; Guerbet, Cedex, France). The day before examination 50 ml Telebrix was taken during each meal and a final 50 ml was taken 1.5h before CTC (total amount 200 ml of Telebrix). All patients had to use a low-fiber diet (see Table 1). At the day of the CT colonography examination, patients were only allowed to take a liquid food diet before the examination. This consisted of only clear and opaque liquid foods with a smooth consistency. Patients were allowed to take drinks or, when preferred, also liquid foods such as milkshakes, custard and yoghurt. The 25 patients of this first group participated in a previously published study,26,27 and the CT colonographies examined as part of this study were acquired as part of that previous study. The research presented herein (stool tagging measurements, subjective stool scores, patient acceptance and polyp detection) are wholly unique to this study. The second group of 25 patients were new inclusions and not part of the previous mentioned study. They also received 4*50 ml of meglumine-ioxithalamate like the first group, but did not need to follow a special diet on the day before CT colonography. On the day of the CT colonography examination these patients were only allowed to take a liquid food diet before examination just like the low-fiber diet group. Furthermore, all patients in this group were asked to describe precisely their food intake during their days of preparation.

Table 1 Low-fiber diet prescription for patients of preparation group 1

<table>
<thead>
<tr>
<th>Not allowed</th>
<th>Fruits</th>
<th>e.g. oranges, pineapple, mango, kiwi, dates, prunes, raisins, coconut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetables</td>
<td>e.g. green peas, tomatoes, onion, corn, French beans, mushrooms, asparagus</td>
<td></td>
</tr>
<tr>
<td>Grains</td>
<td>e.g. wholemeal bread, muesli, unpolished rice, wholemeal pasta</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Nuts, peanuts, popcorn, spiced herbs</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Allowed</th>
<th>Grains</th>
<th>e.g. white bread or toast, white rice or pasta, pancakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits/vegetables</td>
<td>e.g. potatoes, cooked vegetables such as carrots, spinach and cauliflower, fresh fruits such as apple, pear or banana after removal of skin and pits</td>
<td></td>
</tr>
<tr>
<td>Sandwich fillings</td>
<td>e.g. cheese, meat, fish, eggs, sugar, all sweet sandwich spreads (no jam with fruit pieces)</td>
<td></td>
</tr>
<tr>
<td>Drinks</td>
<td>e.g. lemonades, soda’s, coffee/tea, water, milk, alcohol</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>e.g. candy’s, ice-cream, cake, chocolate, salt, pepper</td>
<td></td>
</tr>
</tbody>
</table>

**CT colonography**

CT scanning was performed on a 64 slice CT scanner (Brilliance, Philips Medical Systems, Best, the Netherlands). A low dose protocol with 40 ref mAs was used with z-axis tube modulation and automatic current selection. Slice collimation was 64 x 0.625 mm, pitch 1.2, slice thickness 0.9 mm, rotation time 0.4s and tube voltage 120 kV. Patients were scanned in first supine and then prone position. A muscle relaxant, 20 mg of
butylscopalamine bromide (Buscopan; Boehringer-Ingelheim, Ingelheim, Germany) was injected before starting the insufflation of the colon. When contraindicated, 1 mg of glucagon hydrochloride (Glucagen; Novo-Nordisk, Bagsvaerd, Denmark), was injected instead. In patients with contraindications for both medicines, no muscle relaxant was administrated. A rectal balloon catheter (20 French Gauge) was inserted to insufflate approximately 3 liters of CO2 gas into the colon, using an automated insufflator with a manometer to measure the CO2 pressure and an automatic flow stop at 25 mmHg (Bracco, PROTOCO2L insufflator, New York, USA).

**CT colonography image analysis**

A primary 2D axial evaluation (window setting 1500, -250 HU) was done with 3D problem solving for the detection of polyps (View Forum, Philips Medical Systems, Best, the Netherlands). Two experienced observers (radiology research fellows; experience of 450 and 750 CT colonography examinations) reviewed all CT colonographies and identified lesions. Lesions were measured in multiplanar reformatted (MPR) images showing the maximal diameter of the lesion. Of each lesion the segment location, morphology (sessile, flat or pedunculated) and size were noted. The segmental location was recorded according the six colonic segments (coecum, ascending colon, transverse colon, descending colon, sigmoid and rectum) as defined in the article on CT colonography research reporting by Dachman et al.\(^2\) Additionally, the reading time per position was recorded for each observer.

**Colonoscopy**

In all patients the colonoscopy was performed within approximately 2 weeks after CT colonography. Bowel preparation for colonoscopy consisted of 4 liters polyethylene glycol electrolyte solution (KleanPrep; Helsinn Birex Pharmaceuticals, Dublin, Ireland) or 2 liters of another polyethylene glycol electrolyte solution (Moviprep; Norgine Limited, Mid Glamorgan, United Kingdom) 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, Tokyo, Japan). Sedation (midazolam, Dormicur; Roche, Basel, Switzerland), analgetics (fentanyl, Fentanyl-Janssen; Janssen Pharmaceuticals, Beerse, Belgium) and a muscle-relaxant (butyl scopolamide bromide, Buscopan; Boehringer-Ingelheim, Ingelheim, Germany) were standardly used. According to the technique of segmental unblinding, the findings of the CT colonography were revealed to the colonoscopist after completing the examination of one segment. Polyp size was estimated by comparison to an opened biopsy forceps. The colonoscopy was videotaped starting from the coecum. Lesion histology was classified according to the Vienna classification.\(^2\)

**Image quality of CT colonography**

1. **Faecal residue**

   For evaluation of the quality of the bowel preparations one experienced CT colonography reader (M.L.), who was blinded for the type of preparation, gave a score per segment (coecum, ascending, transverse, descending, sigmoid colon and rectum). Segments were
classified according to the segment description in Dachman et al.\textsuperscript{28} Scores were given on the supine scans only:

- The relative amount of faecal residue per segment compared to the luminal diameter was scored on a scale between 0 and 100%.
- The consistency of the faecal residues rated on a three point scale: 1. liquid, 2. partly solid/ partly liquid or 3. solid.
- The presence of adherent faeces was scored (yes/no).
- It was noted in which segments untagged solid faeces was present and per segment the size of the largest piece of untagged solid faeces was recorded (≤5mm, 6-10mm, and ≥10mm).
- The quality of tagging in the supine scans on a five point scale\textsuperscript{11}: 1= uninterpretable images, untagged faeces, 2= poor interpretation, large amount of unopacified faeces, 3= moderate preparation, moderate amounts of unopacified faeces, 4= good preparation, small amounts of unopacified faeces, 5= excellent preparation no unopacified faeces.

At last the density (mean HU) and homogeneity (HU SD) of the faecal residue were measured on the supine scans by automatically extracting the residual faeces from the colon. Voxels containing residual faeces were identified in cross-sections at regular intervals of 10 mm perpendicular to the path by applying a threshold of 200 HU. Mean values of density and homogeneity were calculated per segment. Segments were defined by a radiology research fellow in one representative CT colonography dataset with a good distension. The distance of each segment border from the anus was compared to the total length of the colon and set as a reference distance-ratio for definition of segments in all CT colonographies. The radiology research fellow also verified all automatically measured faecal residues. For segments that contained faecal residues <200 HU (due to which automatic measurement failed), three manual ROI measurements were performed in this residual material by a research fellow (M.L.) (see fig. 1).

**Fig. 1** Example of a drawn region of interest (ROI) in fecal residue that could not be measured automatically due to a low density.
The slice numbers within a segment in which to perform these measurements were randomly generated (Excel for Windows, 2003). The mean attenuation of tagging can vary considerably between patients, and therefore we also calculated the relative standard deviation (SD / mean HU).

2. Colonic distension
The radiology research fellow (M.L.) gave a score for colonic distension per segment in the prone and supine position. A four point scale was used to score degree of distension: 1= bad distension (0-25% of estimated maximal diameter), 2= poorly distended (25-50% of maximal diameter), 3= sufficient distension (50-75% of estimated maximal diameter and no collapsed lumen at any point), 4= well distended (75%-100% of estimated maximal distension and no collapsed lumen at any point).

Patient acceptance
Six standardized questionnaires (used in previous studies)\(^6\)\(^,\)\(^13\) were given to all patients: questionnaire (Q) 1 to fill in at home before both examinations, Q2 before the CT colonography and Q3 was sent five weeks after colonoscopy. In Q1 patients were asked about their normal defecation pattern and their education background. In Q2 questions about the amount and burden from diarrhoea were asked before CT colonography. Answers were filled in on a 5 point scale (1=no discomfort, 2=mild, 3=moderate, 4=severe or 5=extreme burdensome). In Q3 patients were asked which examination (including the bowel preparation) they found most burdensome, how burdensome they found the CT colonography examination (on the previously mentioned 5 point scale) and what examination they would prefer in the future (answered on a 7 point scale: 1=definitely CT colonography~ 7=definitely colonoscopy).

Polyp detection
The sensitivity and specificity were assessed as measures of the accuracy of polyp detection in both groups. Matching of polyps and tumours found on CT colonography was done by a research fellow (M.L.) by reviewing the colonoscopy video’s and reports. A true positive CT colonography polyp had a size within 50% margin of the corresponding colonoscopy polyp, was in the same or adjacent segment as at colonoscopy and resembled in morphology compared to the lesion seen on the videotaped colonoscopy. Furthermore the number of technical false negatives, polyps that were retrospectively not visible at CT colonography, and the number of false positives were counted per group.

Statistical analysis
Faecal tagging: Outcomes on faecal tagging quality were analyzed in different ways. The outcomes on the relative amount of residual faeces (percentage given by reviewer) were calculated using the Student-T-test. Consistency of residual faeces, the largest piece of untagged faeces, the quality of tagging and the colonic distension were compared performing an ordinal regression analysis; the first patient group (with low-fibre diet) was considered as the reference group. The presence of adherent faeces was compared with the Chi-square test. The density (mean HU), homogeneity (HU SD) and the relative
standard deviation (SD / mean HU) of the residual faeces were compared by using the Student-T-test (which assumes normally distributed data).

**Patient acceptance:** Characteristics of participants, including age, sex and socio-economical status were compared by means of proper statistics (e.g. Student-T-test, Chi-square test) depending on the type of data. The amount and burden of diarrhoea, the experience of burden of the preparation and the preference for preparations in both groups were compared by performing an ordinal regression analysis.

**Polyp detection:** The sensitivity and specificity of CT colonography for lesions larger or equal to 10 mm (including colorectal cancers, adenomas and hyperplastic polyps) and lesions larger or equal to 6 mm detected at colonoscopy were determined. Comparison between outcomes of the two patient groups was done with the Chi-square test. Reading times were compared by using the Student-T-test.

Statistical analyses were performed using SPSS version 15.0.1 for Windows (SPSS). For all analysis, a p-value of <0.05 indicated a significant difference between the two preparation groups.

**RESULTS**

The first group (group 1; preparation with low-fibre diet) consisted of 14 men and 11 women and the second group (group 2; preparation without diet) of 15 men and 10 women (p=0.77). The mean age was 60.4 years (SD 5.4) in group 1 and 61.1 (SD 7.2) in group 2 (p=0.71). Educational level was high (university or higher vocational education) in 9 patients in both groups and moderate to low (only primary school, high school, or lower vocational education) in 16 patients in both groups (p=1.0). Regular daily stool consistency was soft in 21 patients in group 1 and 17 patients in group 2 (p=0.10).

**Image quality**

1. **Faecal residue**

The amount of faecal residue detected per segment is presented in Table 2. The largest amounts of faeces were present in the ascending and descending colon. Neither the per-segment nor the total amounts were significantly different between both groups.

Consistency of the residual faeces was more often solid in patients of group 2 in the descending colon, sigmoid and rectum when compared to patients of group 1 (p=0.034; p=0.001 and p=0.020 respectively; see Table 2). Adherent faeces was present in nearly all segments, but in the rectum 10 patients of group 2 had adherent faeces versus one patient of group 1 (p=0.005). When considering the largest piece of untagged solid faeces in each segment, there were significantly more untagged faecal pieces in the segments in group 2 (p=<0.001). In group 2, in total twelve pieces of untagged faeces ≥10 mm were found compared to only one in group 1 (see Table 2 for overall results).

For the subjective scores of the quality of tagging no differences were found between the segments in both groups (p=0.098; see Table 2). But when the fibre-intake of patients in group 2 was analyzed we found that 10 patients from group 2 had not eaten
any fibres at the day before CT colonography (according to the list of fibre-rich food in Table 1). When groups were divided in patients that had eaten fibres (15 in total) and patients that had not eaten fibres (35), then a significantly lower taggig quality was found for the fibre-group (p=0.001). In figure 2, three examples are given of good and moderate bowel preparations.

The automated measurements resulted in a mean density of 594 HU for group 1 and 630 HU for group 2 (p=0.297 See Table 4). The measurements for the homogeneity resulted in a mean SD of 90 for group 1 and 77 for group 2 (p=0.005). The ratio’s (mean SD/ mean HU) were 0.16 in group 1 and 0.13 in group 2 (p=0.081). But when groups were divided in patients that had eaten fibres (15) and patients that had not eaten fibres (35), then the ratio’s were 0.14 for the fibre-group and 0.15 for the non-fibre group (p=0.868) and only for the rectum a significant difference was found for the homogeneity.

2. Colonic distension
In total two segments in group 1 were graded as insufficiently or badly distended compared to six segments in group 2 (p=0.23).

Table 2 Amount and consistency of residual feces

<table>
<thead>
<tr>
<th></th>
<th>Amount fecal residue (% of lumen filled)</th>
<th>Consistency feces (fluid/ partly fluid and solid/ solid)</th>
<th>No. of segments containing adherent feces</th>
<th>Size of untagged feces (no/&lt;6mm/ 6-9mm/&gt;10mm)</th>
<th>Quality of fecal tagging; grade 1 (bad) to grade 5 (excellent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1 (SD 23)</td>
<td>Group 2 (SD 18)</td>
<td></td>
<td>Group 1 Group 2</td>
<td>Group 1 Group 2</td>
</tr>
<tr>
<td>Coecum</td>
<td>25 (SD 19)</td>
<td>24 (SD 20)</td>
<td>21/2/0*</td>
<td>23/1/1</td>
<td>0 2</td>
</tr>
<tr>
<td></td>
<td>24/0/1/0/1</td>
<td>22/2/1/0</td>
<td>17/4/2/2†</td>
<td>0/0/1/20</td>
<td>0/0/1/4/20</td>
</tr>
<tr>
<td>Ascending colon</td>
<td>33 (SD 19)</td>
<td>32 (SD 20)</td>
<td>25/0/0</td>
<td>24/ 0/ 1</td>
<td>2 4</td>
</tr>
<tr>
<td></td>
<td>22/2/1/0</td>
<td>17/3/2/3</td>
<td></td>
<td>0/0/1/22</td>
<td>0/0/1/5/19</td>
</tr>
<tr>
<td>Transverse colon</td>
<td>6 (SD 7)</td>
<td>9 (SD 10)</td>
<td>23/1/0*</td>
<td>19/5/1</td>
<td>7 10</td>
</tr>
<tr>
<td></td>
<td>24/1/0/0</td>
<td>21/1/2/1</td>
<td></td>
<td>0/0/0/1/23†</td>
<td>0/0/1/3/21</td>
</tr>
<tr>
<td>Descending colon</td>
<td>29 (SD 24)</td>
<td>25 (SD 20)</td>
<td>25/0/0</td>
<td>18/5/2†</td>
<td>4 8</td>
</tr>
<tr>
<td></td>
<td>23/0/2/0</td>
<td>19/2/2/2</td>
<td></td>
<td>0/0/0/2/22†</td>
<td>0/1/0/2/22</td>
</tr>
<tr>
<td>Sigmoid colon</td>
<td>10 (SD 9)</td>
<td>11 (SD 10)</td>
<td>23/1/0*</td>
<td>10/14/1†</td>
<td>9 13</td>
</tr>
<tr>
<td></td>
<td>25/0/0/0</td>
<td>20/1/1/3†</td>
<td></td>
<td>0/0/0/1/23†</td>
<td>0/0/1/3/21</td>
</tr>
<tr>
<td>Rectum</td>
<td>20 (SD 17)</td>
<td>15 (SD 18)</td>
<td>23/0/1*</td>
<td>15/6/3†</td>
<td>1 10†</td>
</tr>
<tr>
<td></td>
<td>23/1/0/1</td>
<td>22/1/1/1</td>
<td></td>
<td>0/0/1/22†</td>
<td>0/0/1/3/22</td>
</tr>
<tr>
<td>All colonic segments</td>
<td>20 (SD 8)</td>
<td>19 (SD 9)</td>
<td>140/4/1</td>
<td>109/31/9†</td>
<td>23 47†</td>
</tr>
<tr>
<td></td>
<td>141/4/4</td>
<td>116/12/1</td>
<td></td>
<td>0/0/4/1</td>
<td>0/1/4/20</td>
</tr>
</tbody>
</table>

*in some segments no feces was present; †p<0.05 when compared to group 1
Table 3 Tagging density and homogeneity measurements

<table>
<thead>
<tr>
<th></th>
<th>Density (HU)</th>
<th>p-value</th>
<th>Homogeneity (SD)</th>
<th>p-value</th>
<th>Ratio (SD/HU)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
<td>Group 2</td>
<td>Group 1</td>
<td>Group 2</td>
<td>Group 1</td>
<td>Group 2</td>
</tr>
<tr>
<td>Coecum</td>
<td>584</td>
<td>608</td>
<td>0.516</td>
<td>85</td>
<td>81</td>
<td>0.535</td>
</tr>
<tr>
<td>Ascending</td>
<td>585</td>
<td>616</td>
<td>0.409</td>
<td>88</td>
<td>76</td>
<td>0.047</td>
</tr>
<tr>
<td>Transverse</td>
<td>616</td>
<td>653</td>
<td>0.340</td>
<td>80</td>
<td>74</td>
<td>0.394</td>
</tr>
<tr>
<td>Descending</td>
<td>651</td>
<td>665</td>
<td>0.712</td>
<td>89</td>
<td>77</td>
<td>0.020</td>
</tr>
<tr>
<td>Sigmoid</td>
<td>587</td>
<td>626</td>
<td>0.298</td>
<td>92</td>
<td>74</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Rectum</td>
<td>534</td>
<td>619</td>
<td>0.063</td>
<td>104</td>
<td>77</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Average*</td>
<td>594</td>
<td>630</td>
<td>0.297</td>
<td>90</td>
<td>77</td>
<td>0.005</td>
</tr>
</tbody>
</table>

*Average of each column

Patient acceptance
Almost all patients in both groups (24 in group 1 and 25 in group 2) experienced diarrhoea during the bowel preparation. Ten patients (42%) in group 1 experienced this as extremely to severely burdensome compared to 13 patients (52%) in group 2 (p=0.70). In the questionnaire six weeks after colonoscopy, five patients in group 1 (22%) indicated that the bowel preparation of CT colonography was extremely or severely burdensome compared to two patients (8%) in group 2 (p=0.19). When CT colonography and
Chapter 3 | Low-fibre diet in CT colonography bowel preparation

colonoscopy including their respective preparation were compared, 71% of patients in group 1 found the colonoscopy most burdensome compared to 92% in group 2 (p=0.12). 65% of patients in group 1 would definitely or probably choose CT colonography for a future examination versus 64% in group 2 (p=0.75).

**Polyp detection**
In group 1, 14 polyps ≥10 mm were found at colonoscopy in 13 patients and 18 polyps of 6-9 mm in 12 patients. In group 2, 15 polyps of ≥10 mm were found in 10 patients and 15 polyps 6-9 mm in 9 patients. In Table 3 the per polyp sensitivity is presented. Sensitivities for both observers were not significantly different in both groups. The number of technical false negatives ≥6 mm was zero in group 1 and three in group 2. The number of false positives for observer 1 was five in group 1 and six in group 2. For observer 2 this was three and six respectively.

Observer 1 had a mean reading time of 15 minutes 16 seconds (SD 3 minutes 26 seconds) in group 1 and 16 minutes 41 seconds (SD 5 minutes 21 seconds) in group 2 (p=0.27). Reading times of observer 2 were 11 minutes and 32 seconds (SD 4 minutes and 7 seconds) in group 1 and 14 minutes and 47 seconds (SD 4 minutes) in group 2 (p=0.007).

**Table 4** Per polyp sensitivity

<table>
<thead>
<tr>
<th>Polyps ≥6mm</th>
<th>Group 1</th>
<th>Group 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer 1</td>
<td>84% (72-97) (27/33)</td>
<td>77% (62-92) (23/30)</td>
<td>p=0.443</td>
</tr>
<tr>
<td>Observer 2</td>
<td>97% (91-100) (31/32)</td>
<td>83% (70-97) (25/30)</td>
<td>p=0.099</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Polyps ≥10mm</th>
<th>Group 1</th>
<th>Group 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer 1</td>
<td>100% (14/14)</td>
<td>80% (60-100) (12/15)</td>
<td>p=0.224</td>
</tr>
<tr>
<td>Observer 2</td>
<td>100% (14/14)</td>
<td>87% (69-100) (13/15)</td>
<td>p=0.483</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Our study found that an iodine tagging-only bowel preparation with a low-fibre diet for CT colonography results in less pieces of untagged faeces and less solid stool than an iodine preparation without specific diet prescription. A prescribed diet had no significant influence on the measured tagging density. When however the patients’ food intakes were analyzed we found that patients that had eaten a low-fibre diet (all patients from group 1 and 10 patients from group 2) were compared with patients that had eaten a diet containing fibres, we found a significantly better subjective tagging quality in patients that had eaten a low-fibre diet. There were no significant differences when comparing the polyp detection and the patient burden in both groups.

For the readability of CT colonography images it is important that a good homogeneity with a sufficiently high tagging density is obtained, certainly when a tagging
only preparation is used without laxatives that can remove residual faeces. When density decreases, detection of polyps becomes more difficult and more false positives are generated, thus as result the diagnostic accuracy can decrease. In phantom studies the optimum tagging density was probably around 700 HU or more. Currently we found tagging densities around 600 HU in each group which approaches this optimum tagging density. The homogeneity (mean SD) was significantly better for the group without diet, but when ratio’s (mean SD/ mean HU) were compared this did not result in a significant difference. This indicates that the density was high enough to compensate for differences in homogeneity (HU SD). For example, a measured homogeneity of 200 HU SD will have less influence in a preparation with a mean density of 700 HU compared to a preparation with a mean density of 300 HU. Furthermore the absolute differences in homogeneity were small (maximum difference was 27 HU in the rectum), and although significantly different, these relatively small differences probably do not greatly influence the CT colonography reading. This can be observed from the subjective scores of tagging quality that were even slightly more favourable for group 1 (with the low-fibre diet prescription). In a study of Zalis et al. it was also found that the measured homogeneity did not reflect the differences in qualitative assessment ratings of the readers.

When the subjective reader scores were assessed, we found that in group 2 (without diet prescription) more pieces of untagged faeces and more adherent and solid stool was found compared to group 1. This could also result in a deterioration of polyp detection. We found that the sensitivity for detection of polyps ≥6mm was lower for both observers in the group 2, albeit not significantly. This may be due to the fact that patient groups were too small to draw conclusions on this.

Several previous studies in CT colonography have used a limited, tagging-only bowel preparation with barium or iodine tagging. In some studies a low-fibre diet or a low-residue diet kit was prescribed for CT colonography bowel preparation, while others did not use a specific diet description. In addition, there are a few studies on low-fibre or low-residue diets in double contrast barium enema bowel preparation. In half of these studies there was no effect found from the ingestion of a specific diet on the colon cleanliness. However, in the study of Lee et al. there was a significant difference in the amount of retained faecal material and Virrki et al. found that a low residue diet with hydration resulted in significantly less residual faecal material and a significantly denser mucosal coating. For barium enema preparation the amount of residual faecal material is important because a clean colon is preferable. For CT colonography the amount may not influence the image readability. Instead the density and the homogeneity of the residual faeces are the most important aspects. This was not assessed in the barium enema studies.

Regarding the patient acceptance, we found no difference in degree of burden in patients that had to follow a restricted diet and in patients that did not. Therefore we think that a diet has a very minimal influence on patient burden and therefore it should be used to retain a good image quality.

Reading times might be an indicator for image quality. In this study the reading time of the second experienced observer increased significantly for group 2 and for observer 1 a trend towards an increase in reading time was seen. This could indicate that
the images of the second group were more difficult to interpret because of a reduced quality of the images. The number of polyps ≥6mm in both groups was nearly equal thus this probably did not cause a difference in reading times.

There are a few potential limitations of this study. First and most important is probably that 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 comparing in the homogeneity and amount of untagged faeces, which were the main parameters of this study. Indeed, significant differences were found in these parameters. No differences were found in polyp detection, which might have been found when larger patient groups would have been compared. A second limitation is that patients were consecutively included and no randomization had taken place. This was due to the fact that the bowel preparation scheme was changed from low-fibre diet to a preparation without diet prescription during the study period. Both groups, however, consisted of a similar number of males and females and also regular 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 beneath 200 HU. This is due to the fact that at a density beneath 200 HU also normal tissues, such as muscles and kidneys, are measured resulting in wrong outcomes for density and homogeneity of faecal material. Fourth, the subjective scores were performed by only one observer. Because the type of bowel preparation was blinded to the observer and the main aim was to compare outcomes between groups we think this is not a very important limitation. A last limitation is that we only tested if a diet influences an iodine tagging bowel preparation. A high-osmolar ionic preparation often results in diarrhoea while a barium preparation does not and tags mainly the solid faeces. From this study we cannot conclude if a specific diet is necessary with a barium tagging bowel preparation.

To conclude we have found in this study that a low-fibre diet used in a CT colonography iodine tagging bowel preparation results an improved subjective tagging quality of the residual faeces, while the measured tagging density remained equal. Adding a specific diet does not increase patient burden from the prescribed bowel preparation. No significant effects on polyp detection were found.

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References