Symbiosis

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www.symbiosisonlinepublishing.com
ISSN Online: 2374-815X

Research article | Journal of Gastroenterology, Pancreatology & Liver Disorders | Open Access

Adequacy of Bowel Wall Distension in Patients Undergoing CT Enterography: A Radiologist's Perspective

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Received: July 25, 2018; Accepted: August 18, 2018; Published: August 21, 2018

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Abstract

Objectives: To compare small bowel distension and bowel wall visualization among three different patients' positions (supine, sitting and right decubitus) during administration of oral contrast media in preparation for CT enterography (CTE).

Methods: A total of 150 consecutive patients (104 males and 46 females; mean age 34.6 years, range 15–78 years) who were scheduled to undergo CTE were recruited. Patients were randomly allocated into the three position groups during oral contrast media administration, and there were 50 patients in each group. Two blinded radiologists independently scored the luminal distension and visualization of the bowel wall using a continuous 5-point scale (1: worst and 5: best) at the jejunum and ileum. The Mann–Whitney U test was used to evaluate differences between any two groups among the three positions for bowel distension and wall visualization.

Results: For ileal distension, the supine and sitting positions performed better than the right decubitus position [for reader 1, mean: 3.4/3.2/2.9 (hereafter, supine/sitting/ right decubitus in order), $p = 0.002/0.033$; for reader 2, 3.3/3.0/2.6, $p < 0.001/0.027$]. However, there was no significant difference among the three groups for jejunal distension (for reader 1, 2.4/2.3/2.2; for reader 2, 2.4/2.4/2.2, $p > 0.05$, respectively). For bowel wall visualization, the supine and sitting positions were superior to the right decubitus position for the ileum when scored by one reader (4.0/3.8/3.4, $p = 0.001/0.015$).

Conclusion: Supine and sitting positions during the administration of oral contrast media provided better ileal distension than the right decubitus position in obtaining CTE.

Key Words: Bowel; Imaging; Distension; Enterography

Introduction

The evaluation of patients with suspected small bowel disease, particularly in inflammatory bowel disease (IBD), has always been challenging because of the small bowel length and location. Capsule endoscopy has the advantage of direct visualization of the bowel lumen, but it is relatively contraindicated in the presence of strictures and has limited ability to assess extraluminal abnormality [1]. CT enteroclysis, another modality of small bowel imaging, requires fluoroscopic placement of a naso-jejunal tube to infuse contrast material; therefore, it has the disadvantages of poor patient tolerance associated with naso-jejunal tube insertion and additional radiation exposure during the examination [2, 3].

In contrast, CT enterography (CTE) and MR enterography, which use the oral administration of neutral contrast agent, are more convenient, non-invasive imaging modalities. Enterography gives excellent contrast resolution, does not require radiation exposure and has equivalent accuracy with CT, but it is expensive and time-consuming [4]. Therefore, CTE has been commonly used to evaluate the small bowel pathology [5–8].

The quality of CTE examination largely depends on adequate luminal distension and fold visualization. This requires an oral contrast agent, which should cause uniform intraluminal attenuation, high contrast between the luminal content and bowel wall, minimal mucosal absorption with maximum distension and the absence of artefact formation, as well as have no significant adverse effects [9]. Therefore, multiple studies have compared the performance of different oral contrast agents at CTE. Neutral oral contrast agents that have near water density, such as mannitol, lactulose, and barium solution with sorbitol, have been shown to be useful [10–16].

Most of these studies that evaluate luminal distension have added comments about several other factors associated with luminal distension, including the oral contrast volume, continuous ingestion and time for ingestion and CT scanning [10–16].

Recently, a technical article with consensus statements on the technical performance of cross-sectional small bowel imaging was published [17]. It gives a detailed explanation of the patient's preparation and basic CTE technique. The consensus statements also include recommended oral contrast agents, optimal oral contrast volume and the ingestion time of oral contrast media [17].

However, no study has evaluated the effect of the patient's position during administration of oral contrast agents on small bowel distension and wall visualization. Therefore, the present study aimed to compare the small bowel distension and bowel wall visualization among three different patients' positions (supine, sitting and right lateral decubitus) during the administration of oral contrast agents in preparing the patient for CTE.

Materials & Methods

This prospective study was approved by the institutional review board, and informed consent was received from all patients.

Study Population

From July 2016 to June 2018, among the outpatients who were scheduled to undergo CTE, those who consented to the study were initially eligible. The inclusion criteria were as follows:

Patients clinically suspected of having IBD, irritable bowel syndrome and recurrent abdominal pain. The exclusion criteria were critical medical condition such as shock, apparent gastrointestinal bleeding and high-grade bowel obstruction. Finally, 150 patients were enrolled in the study. The patients were randomly allocated into three groups (50 patients per group) based on the position, i.e. the sitting, supine and the right decubitus positions, during oral contrast agent administration. Random allocation was done by using the envelope method. 150 sealed envelopes (50 for each position) indicating each allocated position were shuffled and chosen by each patient prior to examination.

Oral Contrast Agent Administration

All patients were fasted for at least 4 h prior to the CT examination. A total of 1300 ml of low density (0.1% w/v) barium sulfate suspension (Microbar, Eskay fine chemicals Co.Ltd., Mumbai, India) was steadily administered (130 ml at every 5 min) for 50 min prior to the examination. Each group-maintained position during the administration of oral contrast agent. To avoid aspiration of oral contrast media, the patients of supine and right decubitus position groups were only allowed to sit up momently to ingest the contrast media in our CT preparation room which was equipped with beds. After administration was complete, patients were asked to maintain their position and wait for an additional 10 min before CT scanning.

CT Technique

All scans were performed using a 64-multidetector CT scanner (Seimens; Healthcare, Milwaukee, WI). All patients were placed in a supine position and were scanned from the top of the diaphragm to the symphysis pubis. CT images were obtained in the enteric phase. Scanning was initiated using a fixed time delayed method, 45 s after intravenous administration of the contrast agent at 1.5 ml iohexol (CT VISION 350®; GKG HEALTH CARE Co. Ltd., Zorapur, INDIA) per kg of body weight, which was injected at a rate of 3 ml s^{-1} via the antecubital vein. No intravenous glucagon or metoclopramide hydrochloride was administered.

Reconstructions were performed using conventional filtered back projection with a reference noise index of 16, and coronal reformatted images were generated with a 3 mm section thickness. The scan parameters were as follows: a fixed tube potential of 120 kV, variable mA (90–210 mA) with an activated automatic exposure control, gantry rotation time, 0.5 s, pitch of 0.984 and helical acquisition mode.

CT Interpretation

Image analysis was independently performed by two radiologists (SJH, BJY) who were blinded to the patient data with 23 and 3 years of experience in reading CT. Each radiologist performed the image analysis twice with a 6-week interval to evaluate intraobserver agreements. Coronal images were used to assess the small bowel because it is easier to globally evaluate the anatomical location on coronal images than on axial images [12]. The bowel segments were divided into the jejunum and ileum. The jejunum was grossly defined as the proximal 2/5 of small bowel, and ileum as the distal 3/5 of the small bowel. The jejunum is characterized by more prominent and thicker plicae circulares and the ileum is characterized by less prominent and thinner plicae circulares as well as additional information from the size of the valvulae conniventes. It is known that, on average, the jejunum has four to seven folds every 2.5 cm, and the ileum has three to five folds in the same length [18].

Qualitative Image Analysis

Qualitative analysis was performed for luminal distension and visualization of the bowel wall using a continuous 5-point scale at each bowel segment. A score of 1 indicated that all bowel loops within the segment were collapsed without any luminal separation, the walls could not be seen and a fold pattern could not be recognized. On the other hand, a score of 5 indicated that all bowel loops within the segment were adequately distended, the contrast between the lumen and bowel wall was optimal and a fold pattern could be easily recognized. The scores of 2, 3 and 4 corresponded to the portion of the segment with adequate bowel distension and good wall visualization of less than 50%, 50 to 80% and more than 80% of the segment, respectively. Adequate bowel distension was defined as a bowel diameter more than 1.5 cm. To evaluate the composition of optimal/poor distension in each position group, the scores 3 or more were predefined as optimal distension whereas the scores 2 or less as poor distension. Visualization of the bowel wall and mucosal folds was defined as the reader's ability to delineate the bowel wall and mucosal folds from the bowel lumen as well as to measure their thickness [12]. Additional image analysis was performed by another two radiologists in consensus to reveal the global distribution of oral contrast media. Predominant distribution of oral contrast media was determined by comparing relatively larger distension among stomach, small bowel and colon.

Statistical Analysis

The Mann–Whitney U test was used to evaluate any statistically significant difference between any two groups among the three positions (supine vs. sitting, sitting vs. right decubitus and right decubitus vs. supine) for bowel distension and wall visualization. To compare the distribution of oral contrast media between any two groups among the three positions, the X2 test was used. For interobserver and intraobserver agreement, the quadratic weighted κ value was calculated for bowel distension and wall visualization. The κ value was interpreted as follows: poor (< 0.20), fair (0.21–0.40), moderate (0.41–0.60), good (0.61–0.80) and very good (> 0.80). All statistical analyses were performed with software (MedCalc version 16.8.4, Mariakierke, Belgium). A p value of less than 0.05 was considered indicative of a statistically significant difference.

Results

Demographics of the study population a total of 150 patients (104 males and 46 females, mean age 34.6 years, range 15–78 years and body mass index 21.3 ± 3.3 kg m−2) were included in the study.

Qualitative image analysis

Luminal distension

As for the ileal distension, both the supine and sitting positions performed superior to the right decubitus position for both readers [for reader 1, mean: 3.4/3.2/2.9 (hereafter, supine/sitting/right decubitus in order), p = 0.002/0.033 (supine/sitting vs right decubitus) and for reader 2, mean: 3.3/3.0/2.6, p < 0.001/0.027] (Figure 1). There was no significant difference between the supine and sitting positions for both readers (for reader 1, p = 0.239; for reader 2, p = 0.120). Meanwhile, in terms of jejunal distension, no significant differences were found among the three position groups for both readers (for reader 1, mean: 2.4/2.3/2.2, p > 0.05 and for reader 2, mean: 2.4/2.4/2.2, p > 0.05) (Figure 2). The mean scores of each position for bowel distension are summarized in Table 2.

Figure 1: Coronal reformatted CTE images of 21/25/28-year-old males who maintained the supine/sitting/right decubitus position during oral contrast administration for (a), (b) and (c), respectively. For ileal distension (arrows), both readers scored Grade 4 for (a) and (b), while they scored Grade 3 for (c). Grade 4 corresponds to at least 80% and less than 100% of bowel was adequately distended. Grade 3 corresponds to 50–80% adequate bowel distension. Adequate bowel distension was defined as a bowel diameter more than 1.5 cm. CTE, CT enterography

Table 1: Demographics of the study population

		All participants	Supine	Sitting	Right decubitus
Mean age (years)		34.6	35.6	33.2	34.9
Sex (male/female)		104/46	31/19	37/13	36/14
Diagnosis[a]	Crohn's disease	104 (69%)	35 (70%)	34 (68%)	35 (70%)
	Tb enterocolitis	7 (5%)	2 (4%)	3 (6%)	2 (4%)
	Ulcerative colitis	3 (2%)	0	1 (2%)	2 (4%)
	Behcets disease	2 (1%)	1 (2%)	1 (2%)	0
	Non-specific enteritis	34 (23%)	12 (24%)	11 (22%)	11 (22%)
Low grade[a,b] obstruction		11 (7%)	1 (2%)	4 (8%)	6 (12%)
History of small bowel surgery[a]		17 (11%)	6 (12%)	5 (10%)	6 (12%)

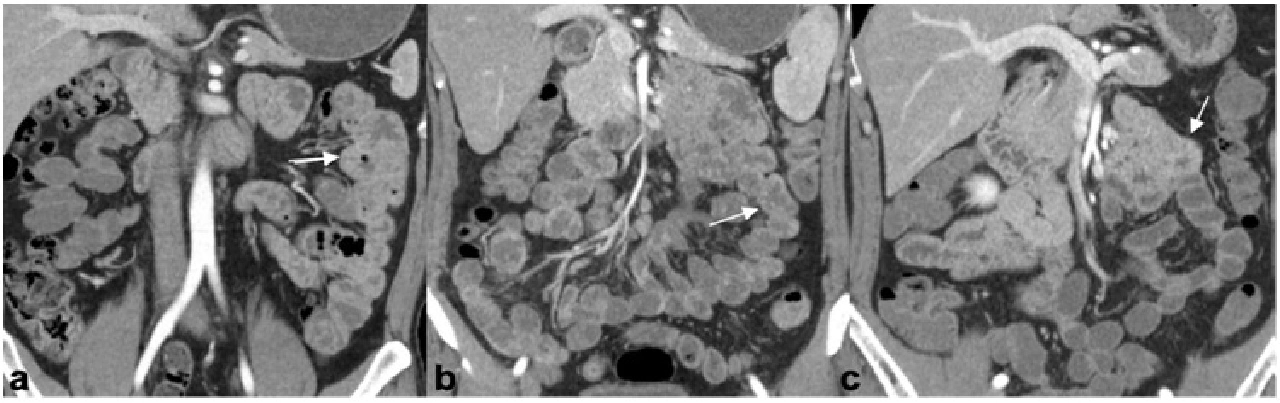

Figure 2: Coronal reformatted CTE images of 37/35/37-year-old males who maintained the supine/sitting/right decubitus position during oral contrast administration for (a), (b) and (c), respectively. For jejunal distension (arrows), both readers scored Grade 2 for (a), (b) and (c). Grade 2 indicates less than 50% segment of bowel was adequately distended. CTE, CT enterography

Table 2: Results of the qualitative analysis in luminal distension

		Supine	Sitting	Right decubitus	p-value[a]		
Reader 1	Jejunum	2.4 (33%)	2.3 (30%)	2.2 (26%)	0.763	0.102	0.121
	Ileum	3.4 (60%)	3.2 (56%)	2.9 (47%)	0.239	0.002	0.033
Reader 2	Jejunum	2.4 (36%)	2.4 (30%)	2.2 (27%)	0.843	0.114	0.068
	Ileum	3.3 (57%)	3.0 (49%)	2.6 (37%)	0.120	<0.001	0.027

The proportion of optimal distension was higher in supine (86%) and sitting (78%) positions than in the right decubitus position (62%) in the ileum. A similar trend was observed in the jejunum in the same order (40, 28 and 20%, respectively). Further observation revealed that the distribution of oral contrast media was different between any two groups among the three positions (p < 0.0001, respectively). The right decubitus position showed colonic predominance in 23 patients (46%), compared with the sitting position (8 patients, 16%) and supine position (11 patients, 22%) (p < 0.0001). The results of oral contrast media distribution for three position groups are summarized in Table 3.

Table 3: Results of the global distribution of oral contrast media

	Supine	Sitting	Right decubitus	*p*-value
Gastric predominance	20 (40%)	19 (38%)	12 (24%)	<0.0001[a]
Colonic predominance	11(22%)	8 (16%)	23 (46%)	<0.000l[b]
Even distribution	19 (38%)	23 (46%)	15 (30%)	<0.0001[c]

Wall visualization

With respect to jejunal wall visualization, the supine position was superior to the right decubitus position for both readers (for reader 1, mean: 2.5/2.3/2.2, p = 0.034 and for reader 2, mean: 2.9/2.7/2.5, p = 0.005) (Figure 3). However, there were no statistically significant differences between the supine and sitting positions (for reader 1, p = 0.362 and for reader 2, p = 0.170) and between the sitting and right decubitus positions (for reader 1, p = 0.192 and for reader 2, p = 0.164).

Regarding ileal wall visualization, both the supine and sitting positions were superior to the right decubitus position for one reader [mean, 4.0/3.8/3.4, p = 0.001/0.015 (supine/sitting vs right decubitus)], which was similar to the ileal distension. There was no significant difference between the supine and sitting positions (p = 0.255). Meanwhile, only the supine position was superior to the right decubitus position for another reader (mean; 3.4/3.3/3.1, p = 0.017). There were no significant differences between the supine and sitting positions (p = 0.440) or between the sitting and right decubitus positions (p = 0.093). The mean scores of each position for bowel wall visualization are summarized in Table 4.

Figure 3: Coronal reformatted CTE images of 37/29/39-year-old females who maintained the supine/sitting/right decubitus position during oral contrast administration for (a), (b) and (c) respectively. For jejunal wall visualization (arrows), both readers scored Grade 3 for (a), while they scored Grade 2 for (b) and (c). Grade 3 indicates a 50 to 80% segment of bowel wall was well visualized.
Grade 2 indicates less than a 50% segment of bowel shows good wall visualization. Visualization of bowel wall and mucosal folds was defined as the reader's ability to delineate the bowel wall and mucosal folds from the bowel lumen

Table 4: Results of qualitative analysis in wall visualization

		Supine	Sitting	Right decubitus	*p*-value[a]		
Reader 1	Jejunum	2.5	2.3	2.2	0.362	0.034	0.192
	Ileum	3.4	3.3	3.1	0.440	0.170	0.093
Reader 2	Jejunum	2.9	2.7	2.5	0.170	0.005	0.164
	Ileum	4.0	3.8	3.4	0.255	0.001	0.015

Interobserver agreement

The weighted kappa values for luminal distension and wall visualization are summarized in Table 5. Jejunal distension in the right decubitus position group showed very good agreement.

Jejunal wall visualization in the sitting position group and ileal wall visualization in all groups showed moderate agreement. Other results indicated good agreement.

Intraobserver agreement

The weighted κ values in each reader for luminal distension and wall visualization are summarized in Table 6. Luminal distension and wall visualization of all position groups showed very good intraobserver agreement for both readers except good agreement in jejuna wall visualization in the right decubitus position for one reader.

Table 5: Interobserver agreement in the luminal distension and wall visualization

		Supine	Sitting	Right decubitus
Luminal distension	Jejunum	0.695	0.782	0.847
	Ileum	0.735	0.658	0.652
Wall visualization	Jejunum	0.613	0.453	0.750
	Ileum	0.520	0.530	0.551

Table 6: Intraobserver agreement in the lumina! distension and wall visualization

		Supine	Sitting	Right decubitus
Luminal distension	Jejunum	0.847/0.823	0.852/0.896	0.826/0.874
	Ileum	0.926/0.956	0.946/0.942	0.820/0.901
Wall visualization	Jejunum	0.807/0.890	0.813/0.927	0.716/0.890
	Ileum	0.858/0.911	0.918/0.906	0.827/0.861

Discussion

Our results demonstrated that both the supine and sitting positions were superior to the right decubitus position for ileal distension; however, there were no significant differences between them for jejunal distension.

We expected that ileal distension would be better in the right decubitus position than in the sitting or supine position based on the previous results that gastric emptying was easily observed in the right decubitus position compared to in the supine or sitting position [19, 20]. Unexpectedly, our results were as mentioned above. Our further observation revealed that the distribution of oral contrast media showed colonic predominance in the right decubitus position compared with the supine or sitting positions. Therefore, our results could be explained by this further observation, which reflected that the shifting of the oral contrast media from small bowel to the colon might be more boosted by rapid gastric emptying in the right decubitus position than by the fluid shifting in the supine or sitting positions.

Another interesting finding in our study is that the ileum was more distended than the jejunum for all positions. This observation is in contrast to those of previous studies [16, 21].

Megibow et al16 and Oliva et al [21] demonstrated relatively better luminal distension and wall visualization in the stomach, which was followed by the small bowel, and each bowel segment

(Duodenum, jejunum and ileum) showed similar luminal distension and wall visualization. The discrepancy between those results and ours could be explained by the volume of oral contrast media ingested as well as the time between oral contrast ingestion and CT scanning. The time interval in Megibow's study was approximately 30 min; in addition, the amount of oral contrast media in Oliva's study was 900 ml. Therefore, in our study, the predominant luminal distension in the ileum may reflect that fluid shifting from jejunum to ileum could be achieved within the time interval of 60 min as well as with 1300 ml of oral contrast media.

According to recent consensus statements, it is recommended that the optimal volume of oral contrast is 1000–1500 ml and the ingestion time of oral contrast should be 46–60 min in cases without previous major small bowel resection [17].

We believe that our observations may be used in individual patients on a customized basis. As the terminal ileum is the predominant site of small bowel pathology for IBD, [2–4, 18] the supine or sitting positions would be preferable for patients who are suspected of having small bowel pathology. For patients who are suspected of having combined colonic and small bowel pathology, the right decubitus position may be tried to evaluate both the colon and small bowel. Regarding wall visualization, our results exhibited that both the supine and sitting positions were superior to the right decubitus position for ileal wall visualization according to one reader. There was a similar trend for bowel distension. It can easily be understood that adequate bowel wall visualization can be guaranteed by optimal bowel distension with neutral oral contrast media.

In terms of interobserver and intraobserver agreement, intraobserver agreement was higher than interobserver agreement. We found that reader 2 graded the wall visualization higher than reader 1 did. We acknowledge that it might be due to systematic discrepancy, because the visual assessment of wall visualization could be subject to individual reader's variation. However, regarding the bowel distension, the scoring system can be assumed to be reproducible based on the good agreements.

There are several limitations to our study. First, the study population had various small bowel pathologies and a high prevalence of IBD. Our results may not be transferable to daily practice with a lower prevalence of IBD. As the single greatest determinant of luminal distension is the presence of stricturing disease (both inflammatory and fibrostenotic phenotypes), we caution drawing firm conclusion from our results. Although 12 patients (8%) had low grade obstruction, it might affect the passage of contrast media. However, there was no high-grade obstruction associated with terminal ileal stricture in this study. Second, only qualitative evaluations were performed in this study, which contrasts with previous studies in which quantitative measures were accompanied by qualitative assessments [14, 16]. However, our image analyses were conducted using a continuous 5-point scoring system on luminal distension and wall visualization. In addition, we tried to score the extent of the bowel segment by the percentage as well as luminal distension by the diameter. Therefore, our scoring method could be considered semi-quantitative. Furthermore, to the best of our knowledge, there is no readily available method that would allow for volumetric assessment of the gastrointestinal segment of interest [15]. Third, complete matching of the disease activity and bowel length could not be achieved due to random allocation. We conducted this study by using simple randomization, but not by stratified randomization. Fortunately, there was no significant difference among the three position groups when it comes to the composition of disease, the grade of obstruction and surgical resection of small bowel by chance. However, it was difficult to eliminate the effects of individual variability in disease activity. Fourth, only three different positions were evaluated. Other positions such as prone, standing and the left decubitus position [22, 23] could not be tested. However, we chose the three different positions evaluated in this study because they are clinically applicable, patient-friendly positions. In our study, the patient's tolerance of the procedure was good and there were no complaints from patients. Last, in terms of bowel segments which were analyzed, we divided them into jejunum and ileum and we didn't evaluate focusing on the terminal ileum, which is the predominant site of small bowel pathology for IBD. In other studies, more segments were used such as duodenum, jejunum, ileum and terminal ileum 12 or four quadrants [14]. Although more segments may have given more information, we believe that our classification is simple and convenient, thus easily incorporated into clinical practice. Although we didn't focus on the terminal ileum, however, we evaluated the entire ileum by our grading system in terms of proportion of the segmental length.

Therefore, we believe that the terminal ileum may be assumed to show a similar trend to the entire ileum.

Conclusion

In conclusion, maintaining a supine or sitting position during the administration of oral contrast media provided better ileal distension than maintaining the right decubitus position. The performance of CTE largely depends on adequate luminal distension and wall visualization. As the terminal ileum is the predominant site of small bowel pathology for inflammatory bowel disease, the supine or sitting position would be preferable for patients who are suspected of having small bowel pathology.

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