Computed Tomography Enterography: Better Luminal Distension with a Shorter Ingestion Time Protocol in an Indian Population

Ambika R. 1  Vidhya Rani Reddy 1

1Department of Radiodiagnosis, Columbia Asia Referral Hospital, Yeshwanthpur, Bengaluru, Karnataka, India

Address for correspondence Ambika R., MBBS, DMRD, DNB, Department of Radiology, KIMS, No. 16, Santrupthi, Sampige Nagar Main, Rajeev Nagar Last Bus Stop, Vidya Nagar, Hubli 580031, Karnataka, India (e-mail: ambika13raja@gmail.com).

Abstract

Aim This article prospectively evaluates the adequacy of bowel distension in computed tomography enterography (CTE) with a 45-minute contrast ingestion time and compares it with the most widely used protocol in the literature of 1 hour 20 minutes.

Materials and Methods The CTE was performed in 42 consecutive patients divided into two groups—A and B. Group A patients were instructed to drink 2 L of polyethylene glycol electrolyte solution over 1 hour 20 minutes. Group B patients were instructed to do the same over 45 minutes. At the end of contrast ingestion, plain and contrast CT abdomen was performed and CTE images were reviewed. Manual quantitative analysis of degree of small bowel distension was performed in the following manner: on coronal images, the abdominal cavity was divided into four quadrants: right upper, left upper, right lower, and left lower quadrants. The maximum small bowel lumen diameter (inner-to-inner wall) was measured in five different loops within each of the four quadrants. If four or more measurements in a quadrant ≥ 1.8 cm (considered “adequate luminal distension”), a score of 1 was assigned to that quadrant. If less than 4 measurements in the quadrant > 1.8 cm, a score of 0 was assigned to that quadrant. The ensuing sum of scores from all four quadrants resulted in the distension grade for that CTE study (Grades 1–4).

Results There was a statistically significant difference in the degree of small bowel distension between the two groups with better distension seen in group B (p < 0.001).

Conclusion Indians have a rapid gut transit time compared with Western populations. Hence, CTE contrast ingestion time protocols optimized in Western populations may not be suitable in Indians. The shorter 45-minute ingestion protocol provided consistently better luminal distension in our population than the longer 1 hour 20-minute protocol described in the literature. To the best of our knowledge, there are no other studies comparing CTE ingestion time protocols in a given population.

Introduction

Despite advances in technology, the mesenteric small bowel continues to elude the reach of the endoscope. The barium meal follow through (BMFT) and the small bowel enteroclysis were the most commonly performed radiological examinations in suspected small bowel pathology. 1, 2 Recently, computed tomography (CT) and magnetic resonance imaging (MRI) of the abdomen after distension of the small bowel with neutral oral contrast, termed CT enterography (CTE) and MR enterography, have been increasingly advocated as an alternative to barium studies in view of the cross-sectional display of extraluminal structures, greater patient tolerance, and reduced procedural risks. 3, 4 The CTE with large volume oral contrast...
agent administered over a specified period of time provides adequate luminal distension and separation of small bowel loops, enabling high diagnostic accuracy for small bowel pathology. In CTE, detailed evaluation of the entire length of the small bowel is possible because of the uniform distension achieved by the ingestion of large volumes of contrast in a relatively short period of time. Thus, CTE allows simultaneous assessment of the lumen, wall thickness, and pattern of wall enhancement. CTE also eliminates the pitfalls associated with small bowel superimposition, allowing excellent depiction of mural and extraintestinal abnormalities. Multiple oral contrast agents including positive, negative, and neutral contrast agents have been tried to achieve small bowel distension on CT and it has been concluded that neutral oral agents are the most suitable for evaluation of small bowel pathology. In our study, we used polyethylene glycol (PEG) electrolyte solution to distend small bowel. Currently, the most commonly used CTE protocol is high volume (2 L) oral neutral contrast such as mannitol or PEG ingested over 1 hour 20 minutes. Gut transit time can, however, vary with different populations. Indians have a shorter gut transit time as compared with Western population. Several factors such as age, gender, dietary habits, lifestyle, and biological differences may contribute for shorter gut transit time among Indians with mean stool frequency being higher in several Asian populations. For example, a stool frequency of thrice a week (range: 3–21 per week) is considered normal in a Western population, while Indians have a stool frequency of at least one stool per day. Two Indians have a stool frequency of at least one stool per day. Two

Materials and Methods

Patients and Control Subjects

Our study is a prospective observational study with study population of 42 patients in the age group of 18 to 75 years referred to radiology for contrast-enhanced CT of the abdomen and pelvis to evaluate suspected small bowel pathology. All patients with a clinical suspicion of high grade, acute intestinal obstruction were excluded from the study. Other exclusion criteria included pregnancy, history of allergy to iodinated contrast, history of severe drug allergy, renal insufficiency with serum creatinine > 1.5 mg/dL, and inability to ingest > 1 L of contrast. The patients were instructed to remain nil orally for solids for at least 4 hours prior to the start of CTE.

The CTE was performed in 42 consecutive patients divided into two equal groups—A and B. Group A patients were instructed to drink 2 L of neutral oral contrast (PEG electrolyte solution) over 1 hour 20 minutes. Group B patients were instructed to do the same over 45 minutes. At the end of contrast ingestion, routine CT abdomen was performed and the patient observed for 1 hour before leaving the hospital with an instruction to return to the hospital in case of serious side effects. Written informed consent was obtained from all patients. The study was conducted after Institutional Review Board and Ethics committee approval of the study protocol.

Image Acquisition

All scans were performed on a 64-slice CT scanner (Toshiba Aquilion). Using a pressure injector, 150 mL of intravenous (IV) Omnipaque (300 mg/mL) was injected 4 to 4.5 mL/second. Administration of contrast was followed by a flush of 40 mL normal saline at the same injection rate. A dual-phase CT scan was performed after an unenhanced CT scan. Bolus tracking method was used for acquisition of arterial and enteric phases; the trigger was placed on the descending thoracic aorta, arterial phase acquired after a delay of 15 to 20 seconds, and enteric phase after a delay of 45 seconds postthreshold achievement in the lower thoracic aorta.

Postprocessing

Images were acquired in the axial plane in a cephalocaudal direction, from the hepatic dome to the symphysis pubis, during one breath hold. Raw data were generated in axial planes with 3-mm thickness, later reconstructed in coronal and sagittal planes with a section thickness of 3 mm and reconstruction interval of 1 to 1.5 mm. Images were transferred to picture archiving and communication system for review. In addition, the 0.625-mm raw data were transferred to the workstation for three-dimensional volume rendering and maximum-intensity-projection displays.

Image Analysis

Manual quantitative analysis of the degree of small bowel distension was performed in the following manner: on coronal images, the abdominal cavity was divided into four quadrants: right upper, left upper, right lower, and left lower quadrants. The maximum small bowel lumen diameter (inner-to-inner wall) was measured in five different loops within each of the four quadrants. If 4 or more measurements in a quadrant ≥ 1.8 cm (considered “adequate luminal distension”), a score of 1 was assigned to that quadrant. If less than 4 measurements in the quadrant > 1.8 cm, a score of 0 was assigned to that quadrant. The ensuing sum of scores from all four quadrants resulted in the distension grade for that CTE study (Grades 1–4).

If each of the four quadrants scored 1, then distension grade for that CTE study is Grade 4. Similarly, if sum of all the four quadrants is 3, then the distension grade for that CTE study would be Grade 3, if sum of all four quadrants is 2, then the distension grade would be Grade 2, and if sum of all four quadrants is 1, then the distension grade would be Grade 1.

<table>
<thead>
<tr>
<th>Sum of all 4 quadrants</th>
<th>Distension grade for the CTE study</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/4</td>
<td>Grade 4</td>
</tr>
<tr>
<td>3/4</td>
<td>Grade 3</td>
</tr>
<tr>
<td>2/4</td>
<td>Grade 2</td>
</tr>
<tr>
<td>1/4</td>
<td>Grade 1</td>
</tr>
</tbody>
</table>
Grades 4 and 3 were considered to have optimal bowel distension (►Figs. 1–4), while Grades 2 and 1 (►Figs. 5–9) were considered to have poor bowel distension. None of our patients had Grade 1 distension.

Data were tabulated and analyzed using statistical methods.

Statistical Analysis
Descriptive and inferential statistical analyses were done on the data collected and tabulated. Results on continuous measurements are presented as mean ± standard deviation (min–max) and results on categorical measurements presented in number (%). Chi-square/Fisher’s exact test was used to find the significance of study parameters on categorical scale between two or more groups.

Statistical software: The Statistical software, namely SAS 9.2, SPSS 15.0, Stata 10.1, MedCalc 9.0.1, Systat 12.0, and R environment ver.2.11.1 were used for the analysis of the data and Microsoft Word and Excel were used to generate graphs, tables, etc.

Results
Both the protocols were well tolerated by the patients, without any discomfort; none of the 42 patients who ingested 2 L PEG solution reported any major side effects. Forty-two patients ingested 2 L of oral contrast in the stipulated time without significant nausea or abdominal discomfort. There was a statistically significant difference in the degree of small bowel distension between the two groups with better distension seen in group B with shorter contrast ingestion time protocol ($p < 0.001$). Grade 4 distension was achieved in only 9.5% of group A subjects with the longer 1 hour 20-minute protocol. Grade 3 distension was achieved only in 33.3% of group A subjects as against 42.9% of group B. Overall, adequate and more uniform distension of small bowel was achieved with the group B 45-minute ingestion protocol compared with the group A 1 hour 20-minute protocol (►Table 1, ►Fig. 10).

Incidence of small bowel pathology was analyzed in two groups separately. 47.6% patients of group A had small bowel pathology while 23.8% of patients in group B had small bowel pathology. Thus, the bias associated with small bowel pathology induced shorter transit times was eliminated (►Tables 1 and 2, ►Figs. 1–11).

Discussion
Computed Tomography Enterography
Despite advances in technology, the mesenteric small bowel continues to elude the reach of the endoscope and provides the biggest challenge in bowel imaging. This is mainly due to the length, redundancy, overlap, and small caliber of the
Computed Tomography Enterography

Ambika R., Reddy

Journal of Gastrointestinal and Abdominal Radiology ISGAR
Vol. 1 No. 1/2018

small bowel. Because of the overlapping nature of bowel loops in the pelvis, inadequate and nonuniform distension of loops, lengthy procedure time, barium-related complications, and operator dependence associated with barium studies, cross-sectional imaging studies are becoming more popular for evaluation of small bowel pathology. Cross-sectional imaging of small bowel includes CT and MRI with oral and IV contrast agents. These studies not only prevent obscuration of small bowel loops by superimposition, but also depict mural and extraintestinal complications of the disease. They provide better depiction of small sinus tracts, abscesses, fistulas, and ulcerations especially when combined with oral contrast agents either via enterography or enteroclysis.1,2

The CT abdomen after distension of the small bowel with neutral oral contrast, termed CTE, has been increasingly advocated as an alternative to barium studies. CTE is a simple, noninvasive radiological investigation for evaluating small bowel and can be used as the primary investigation in suspected small bowel pathology. Irrespective of the CT technique used, adequate bowel distension is mandatory since mural thickening is the hallmark of small bowel disease. Complete evaluation of the small bowel is achieved with the addition of IV contrast and a large volume of neutral contrast to distend the intestinal lumen, allowing assessment of the lumen, thickness, and pattern of enhancement of the

Fig. 3 A 73-year-old female patient, proven case of Crohn’s disease with Grade 3 distension score computed tomography (CT) enterography study. Axial (A) and coronal reformation (B) through abdomen in enteric phase demonstrating both poorly distended (short arrows) loops and well distended (long arrows) small bowel loops. The image also demonstrates engorged vasa recta (positive comb’s sign) (white circle).

Fig. 4 Computed tomography (CT) enterography study (with Grade 4 distension score) of a 36-year-old male patient, known case of Crohn’s disease presented with recurrent pain abdomen 1 year post-resection. Coronal reformation in enteric phase shows short segment stricture with wall thickening and marked enhancement suggesting recurrence at the anastomotic site (long arrow). The short arrow points to another similar segment (just inferior) with wall thickening, enhancement, and pseudosacculations (short arrow).

Fig. 5 A 26-year-old female patient, proven case of abdominal tuberculosis. Axial computed tomography (CT) enterography image in enteric phase demonstrating Grade 2 distension score with collapsed small bowel loops. The image shows asymmetrical wall thickening involving ileocecal junction (arrow) with multiple necrotic mesenteric lymph nodes in right lower quadrant.
Computed Tomography Enterography

Ambika R., Reddy

Journal of Gastrointestinal and Abdominal Radiology ISGAR Vol. 1 No. 1/2018

small intestinal wall. The CTE with large volume of neutral oral contrast agent provides adequate luminal distension and separation of small bowel loops, thus accounting for a high diagnostic accuracy for small bowel pathology. Currently, CTE is commonly performed using high-volume (2 L) oral neutral contrast agents such as mannitol or PEG ingested over 60 to 90 minutes followed by an IV contrast. Many authors have reported CTE to be highly sensitive and specific in the diagnosis and characterization of various small bowel pathologies. Solem et al performed a comparison study between CTE, ileocolonoscopy, capsule endoscopy, and BMFT on 41 patients with Crohn's disease and concluded that the sensitivity of CTE was equal to that of capsule endoscopy (83%) and more than that of ileocolonoscopy (74%) and BMFT (65%). In this study, specificity of CTE (82%) was found to be less than that of ileocolonoscopy (100%) but more than that of capsule endoscopy (53%) and BMFT (94%). In 2011, Minordi et al compared CTE and CT enteroclysis in 145 patients. Seventy patients underwent CT enteroclysis after jejunal intubation and infusion of methylcellulose, and 75 patients underwent CTE after orally ingesting 2 L of PEG solution over 45 minutes. CTE showed findings of Crohn's disease as well as CT enteroclysis, although CT enteroclysis gave better bowel distension, especially in the jejunum, and had a higher specificity than CTE.

A study performed in 2011 by Huprich et al on 22 patients demonstrated that multiphasic CTE was more than twice as sensitive as capsule endoscopy for finding the source of obscure gastrointestinal (GI) bleeding (88 vs. 38%). In India, Sodhi et al in 2012 performed CTE on 35 patients with occult GI bleed—15 had positive findings that were confirmed on

**Fig. 6** A 30-year-old female patient, biopsy-proven case of Crohn's disease demonstrating Grade 2 distension score computed tomography (CT) enterography study. Coronal reformation through the abdomen in the enteric phase shows skip lesions in the ileal loops located in the right lower quadrant (arrows).

**Fig. 7** Computed tomography (CT) enterography study with Grade 2 distension score in a 35-year-old male patient, known case of Crohn's disease presented with recurrent pain abdomen. Axial CT enterography image in enteric phase demonstrating pseudosacculations along the antimesenteric border of sigmoid colon and shortening of the mesenteric border (arrow).

**Fig. 8** A 37-year-old male patient, biopsy-proven case of Crohn's disease. Axial (A) and sagittal (B) reformatted plain computed tomography (CT) enterography image with Grade 2 bowel distension. Stratified wall thickening (arrows) is seen in the affected distal ileal segment.
Computed Tomography Enterography

Ambika R., Reddy

Journal of Gastrointestinal and Abdominal Radiology ISGAR Vol. 1 No. 1/2018

Exploratory laparotomy. They concluded that CTE was a useful investigation tool in the evaluation of both occult and overt GI bleeding. 21

**Table 1** Comparison of small bowel diameter in two groups with different contrast ingestion times: Group A (1 hour 20 minutes) and group B (45 minutes)

<table>
<thead>
<tr>
<th>Group A</th>
<th>Group B</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right upper quadrant</td>
<td>1.92 ± 0.26</td>
<td>2.14 ± 0.28</td>
</tr>
<tr>
<td>Left upper quadrant</td>
<td>2.76 ±3.74</td>
<td>2.25 ±0.31</td>
</tr>
<tr>
<td>Right lower quadrant</td>
<td>2.04 ±0.33</td>
<td>2.20 ±0.34</td>
</tr>
<tr>
<td>Left lower quadrant</td>
<td>1.95 ±0.26</td>
<td>2.16 ±0.32</td>
</tr>
</tbody>
</table>

*Statistically significant (p < 0.05).

**Table 2** Grade/Distension scores

<table>
<thead>
<tr>
<th>Grade/distension score</th>
<th>Group A (number)</th>
<th>Group A Percentage (%)</th>
<th>Group B (number)</th>
<th>Group B Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 1</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Grade 2</td>
<td>12</td>
<td>57.1</td>
<td>3</td>
<td>14.3</td>
</tr>
<tr>
<td>Grade 3</td>
<td>7</td>
<td>33.3</td>
<td>9</td>
<td>42.9</td>
</tr>
<tr>
<td>Grade 4</td>
<td>2</td>
<td>9.5</td>
<td>9</td>
<td>42.9</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>100</td>
<td>21</td>
<td>100</td>
</tr>
</tbody>
</table>

**Fig. 9** Computed tomography (CT) enterography study of a 37-year-old male patient, suspected case of Crohn’s disease demonstrating poor/Grade 2 distension score. Axial (A) and reconstructed coronal (B) CT enterography image in the enteric phase shows thickening of the ileocecal junction, terminal ileal loop with engorged vasa recta/positive Comb’s sign (short arrows). The image also demonstrates enhancing appendix (long arrows). Histopathological examination (HPE) revealed Crohn’s disease.

**Fig. 10** Comparison of small bowel diameter in two groups.

**Fig. 11** Grade/distension score—comparison between two groups: Group I (A) and group II (B).

Exploratory laparotomy. They concluded that CTE was a useful investigation tool in the evaluation of both occult and overt GI bleeding. 21

**Polyethylene Glycol as Oral Neutral Contrast Agent**

Multiple oral contrast agents have tried to achieve small bowel distension on CT including positive, negative, and neutral contrast agents. Neutral oral agents have been found to be the most suitable for the evaluation of small bowel pathology. 5,6,7 PEG electrolyte solution has been shown to distend small bowel better than water or methyl cellulose solution as well as low-density barium. 8,9 The neutral oral
contrast agent in conjunction with IV contrast results in the
depiction of the lumen as well as the thickness and enhance-
ment pattern of the wall. PEG electrolyte solution is the best
known neutral contrast used widely as a colonoscopy pre-
paratory agent. It is easily available, less expensive, palat-
able, and has no known serious side effects.3–5 CTE with PEG
solution was performed by Minordi et al and found to be 93%
sensitive and 94% specific compared with CT enteroclysis
that had a sensitivity of 94% and specificity of 100%.6 In our
study, PEG electrolyte was well tolerated in concordance with
the studies conducted by Solem et al and Minordi et al.7,8

Oral Contrast Ingestion Time in Computed
Tomography Enterography

It is a well-known fact that gut transit time varies widely
with different populations, races, and ethnicity. Age, gender,
dietary habits, degree of physical activity, and biological fac-
tors are some factors influencing the gut transit time. Hence,
GI protocols used in one population may not be globally ap-
plied on all populations.9–12 There is paucity of literature on
normal range of gut transit time in healthy Indian subjects
and ideal or standard oral contrast ingestion time to be used
among Indian population. However, Indians are found to have
a rapid gut transit time compared with the Western popu-
lation. The stool frequency is considerably higher among the
Asian population. Mean stool frequency is higher in several
Asian populations. For example, a stool frequency of thrice a
week (range: 3–21 per week) is considered normal in a West-
ern population while Indians have a stool frequency of at least
one stool per day. Two stools per day is considered as normal
among Indians.12 The most commonly used CTE protocol in
the West is high-volume (2 L) oral neutral contrast agents such
as mannitol or PEG ingested over 1 hour 20 minutes. In view
of faster gut transit time, we postulated that Indian popula-
tions may need a shorter contrast ingestion time. In our study,
we decreased the oral contrast ingestion time to 45 minutes
and compared this with the standard protocol of 1 hour 20
minutes described in the literature. We found that ingestion
of oral contrast over a period of 1 hour 20 minutes provid-
ed suboptimal distension of the small bowel, particularly the
jejunum with more uniform distension of the colon. This is
likely due to rapid gut transit time among Indians. Adminis-
tration of the oral contrast agent over a period of 45 minutes
resulted in improved distension of the jejunum and a more
uniform distension of the small bowel. A similar protocol of a
45-minute oral contrast ingestion time was recommended for
optimal bowel distension by Ilangovan et al9, where patients
were instructed to drink 2 L of 2.5% mannitol solution over
45 minutes. Minordi et al in 2011 also used a similar proto-
col with 2 L of PEG solution administered over 45 minutes
and achieved optimal bowel distension. Their study conclu-
ded that results obtained with PEG CTE using the 45-minute
oral contrast ingestion protocol for demonstrating findings
of Crohn’s disease was comparable with that of CT enteroclysis.10

Limitations: We addressed bias due to shortening of
gut transit because of small bowel disease, by comparing
the occurrence of small bowel pathology between the two
groups. We found that the shorter ingestion protocol group
had fewer patients with small bowel pathology (24 vs. 48%),
thus eliminating this potential bias. However, our study had
other limitations: our sample size of 42 was relatively small
and we did not match our patients for age, gender, or diet in
the two groups; intrinsic differences in gut transit time be-
tween the two groups were therefore not corrected.

Conclusion

Gut transit time can vary amongst different ethnicities. CTE
contrast ingestion protocols need to be optimized for specif-
ic populations. Populations with faster gut transit time need
shorter oral contrast ingestion time. CTE contrast ingestion
protocols optimized in one population may not be suitable in
another population. We found statistically significant improve-
ment in small bowel distension with the shorter 45-minute
ingestion CTE protocol compared with the 1 hour 20-minute
protocol recommended by many authors. Ours is the first study
to compare two contrast ingestion time protocols in an Indian
population. To the best of our knowledge, there are no other
studies comparing CTE oral contrast ingestion time protocols
in a given population. Further studies with a larger sample size
are recommended to investigate optimum oral contrast ingestion
protocols for CTE among different populations.

Funding

None.

Conflict of Interest

None.

References

1 Gore R, Levine M. Barium examinations of small intestine.
Textbook of Gastrointestinal Radiology. 3rd ed. Philadelphia,
PA: Saunders; 2007:735–897
2 Wold PB, Fletcher JG, Johnson CD, Sandborn WJ. Assessment
of small bowel Crohn disease: noninvasive peroral CT
enterography compared with other imaging methods and
3 Paulsen SR, Huprich JE, Fletcher JG, et al. CT enterography as
a diagnostic tool in evaluating small bowel disorders: review
of clinical experience with over 700 cases. Radiographics
SA. CT enterography: review of technique and practical tips.
Br J Radiol 2012;85(1015):876–886
5 Macari M, Balthazar EJ. CT of bowel wall thickening:
significance and pitfalls of interpretation. Am J Roentgenol
2001;176(5):1105–1116
6 Upegu J, Daniel, Mendoza B Oscar D, Segura C Wilber O, He-
redia S Fabian M, Galvis R German, Fuentes Jorge E. Use of
CT enterography for small bowel pathology: experience and
findings in 90 patients. Revista Colombiana de Radiologia
2010;21(1):2818–2825
distention and bowel wall appearance by using neutral
oral contrast agent for multi-detector row CT. Radiology
2006;238(1):87–95
8 Prakashini K, Kakkar C, Sambhaji C, Shetty CM, Rao VR. Quan-
titative and qualitative bowel analysis using mannitol, water
and iodine-based endoluminal contrast agent on 64-row
detector CT. Indian J Radiol Imaging 2013;23(4):373–378