



Comparison of two small bowel distending agents for enterography in pediatric small bowel imaging

Amy B. Kolbe¹ · Leonard A. Haas² · David J. Bartlett³ · Veena R. Iyer¹ · Kristen B. Thomas¹ · Jeanne Tung⁴ · Jeff L. Fidler¹ · Joel G. Fletcher¹

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Abstract

Objective To evaluate the ability of pediatric patients with known or suspected inflammatory bowel disease to ingest a new oral distending agent at CT or MR enterography (CTE/MRE), and to determine the impact on small bowel (SB) distension and diagnostic confidence.

Materials and methods The study design is that of retrospective review of pediatric patients who underwent CTE or MRE from January 2014 to June 2016. Patients ingested low-concentration barium suspension or flavored beverage containing sorbitol and mannitol. The need for nasogastric tube (NGT) administration, amount ingested, emesis, distal extent of contrast, SB distension, terminal ileum (TI) transverse dimension, and diagnostic confidence in TI disease were assessed. Three radiologists each blindly reviewed a subset of the studies.

Results Of the total 591 scans in 504 patients, 316 scans used low-concentration barium suspension and 275 scans flavored beverage. Nearly all consumed the entire amount (97% vs. 96%). Low-concentration barium suspension exams required NGT more often (7% [23/316] vs. 1% [3/275]; $p < 0.0003$), and tended to have more emesis (3% [9/316] vs. 1% [3/275]; $p = 0.13$). Diagnostic confidence score was nearly identical ($p = 0.94$). Qualitative and quantitative analyses showed no difference in SB distension, except for distension of mid-ileum (flavored beverage $>$ low-concentration barium suspension; $p = 0.02$). Flavored beverage exams demonstrated a slight increase in distal extent of luminal distension ($p = 0.02$).

Conclusions A new flavored beverage distends small bowel as well as low-concentration barium suspension, with decreased requirement for NGT insertion and improved distal extent of luminal distension, and without any decrease in diagnostic confidence in the presence or the absence of TI disease.

Keywords Enterography · Pediatric · Crohn's disease · Oral contrast · Enteric contrast

Introduction

CT and MR enterography (CTE/MRE) are useful noninvasive radiologic tests used to evaluate the gastrointestinal tract and extra enteric structures in patients with Crohn's disease, malignancy, inflammatory conditions, and gastrointestinal bleeding [1–4]. These tests should be performed in patients with suspected Crohn's disease at diagnosis, and considered for disease monitoring in patients with small bowel Crohn's disease, as 50% of pediatric Crohn's patients with a negative ileoscopy may have small bowel inflammation at CTE/MRE [5, 6]. Enterography exams require that patients ingest a large volume of enteric contrast in a short time period to act as a distending agent for improved visualization of the intestinal lumen and to provide high contrast between the lumen and the bowel wall. Ideally, enteric distending agents should have

✉ Amy B. Kolbe
Kolbe.Amy@mayo.edu

¹ Department of Radiology, Mayo Clinic, 200 1st St SW, Rochester, MN 55905, USA

² Department of Pediatrics, Weill Cornell Medical College-New York Presbyterian Hospital, 525 East 68th Street, Box 139, New York, NY, USA

³ Mayo Clinic School of Medicine, 200 1st St SW, Rochester, MN 55905, USA

⁴ Division of Pediatric Gastroenterology, Oklahoma University Children's Physicians, 1200 Children's Ave, Oklahoma, OK 73104, USA

minimal adverse side effects. To maximize the visualization of the bowel wall, enteric contrast agents should be isodense to water on CT and biphasic on MR, i.e., low signal intensity on T1-weighted images and high signal intensity on T2-weighted images [7–10].

There are many oral agents available for use in enterography, each with varying degrees of tolerability, luminal distension produced, and adverse side effect profile [11–20]. Water and milk have been associated with the least severe side effects; however, numerous studies have demonstrated significantly inferior effectiveness as a distending agent due to reabsorption within the SB [18–21]. Adding an osmotic agent, such as mannitol, reduces the reabsorption of fluid from the bowel lumen, but causes side effects such as diarrhea and cramping in some patients [12, 13, 18]. Thickening agents, such as locust bean gum and bulk fiber laxative, have been shown to increase luminal distension by increasing the viscosity of the contrast. This is, however, accompanied by reduced acceptability secondary to changes in the texture [22].

Until recently, the only commercially available agent in the United States was a low-concentration barium suspension (0.1%) with sugar alcohols sorbitol and mannitol and thickening agent xanthan gum (VoLumen, Bracco Diagnostics). Enterography protocols generally require ingestion of large amounts of enteric contrast over 1 h [23, 24]. The volumes used in pediatric protocols are often weight-based with the decreasing total contrast amounts used for decreasing patient weight. Known side effects include undesirable taste and texture, nausea, cramping, and diarrhea [11, 17, 18, 25]. Consuming the required volume, even by NGT administration, can be problematic for all ages of patients, but perhaps even more so for pediatric patients who often have not developed the maturity to push themselves to do unpleasant tasks for their own health.

A commercially available flavoring agent containing sorbitol and mannitol for oral iodinated CT contrast (Breeza for oral iodinated contrast material, Beekley Medical) has been modified to be used in enterography by adding a thickening agent to increase viscosity (Breeza for neutral abdominal/pelvic imaging, Beekley Medical) and will be referred to as flavored beverage [17]. The objective of this study is to evaluate the ability of pediatric patients with known or suspected inflammatory bowel disease to ingest this new oral distending agent at CTE/MRE and to determine the impact on SB distension and diagnostic confidence.

Materials and methods

Study design and population

This retrospective study was approved by our Institutional Review Board. The Radiology Information Management

System database of clinical radiologic reports was searched for all pediatric patients with known or suspected IBD who underwent clinically indicated CTE or MRE between January 2014 and June 2016, and who ingested either low-concentration barium suspension or flavored beverage as the enteric distending agent. The study time period was selected to include all studies performed after our protocol change to flavored beverage in April 2015, and an equal number of months prior to that date. Through the medical record, all cases prior to that date were confirmed to be performed with low-concentration barium sulfate and all studies after with flavored beverage. Pediatric patients were defined as less than 18 years of age at the time of the enterography. Patients were excluded if they did not consume low-concentration barium suspension or flavored beverage or if the type of enteric agent was not documented. Patients who used non-oral routes of contrast administration other than NGT, such as a percutaneous gastrostomy or jejunostomy tube, were excluded. Patient records were reviewed for demographic information, type of scan (CTE or MRE), type of oral agent, amount of the drinking protocol completed, use of NGT for enteric agent administration, occurrence of emesis, and completion of the scan.

Enteric contrast protocol

At our institution, low-concentration barium suspension has historically been used for enterography. In 2015, based on results of Kolbe et al. [17] and with the consensus of our pediatric and adult gastroenterologists in the Inflammatory Bowel Disease clinic, the enterography protocols were modified for both adults and children, such that the first line enteric contrast offered is flavored beverage. The drinking protocol for pediatric patients at our institution is slightly different by contrast type as a bottle of flavored beverage has slightly more volume than a bottle of low-concentration barium suspension.

For both types of enteric contrast agents, the amount of contrast to be ingested varies by patient weight. For studies using flavored beverage, patients weighing greater than 45 kg consume a total of 1500 mL (3 bottles \times 500 mL) of flavored beverage and 500 mL of water evenly spaced out over an hour. Patients weighing 22.5 to 45 kg consume a total of 750 mL (3 \times 250 mL) of flavored beverage and 250 mL of water over an hour. Patients weighing 4.5 to 22.4 kg consume a total of 330 mL (3 \times 110 mL) of flavored beverage and 110 mL of water over an hour. For studies using low-concentration barium suspension, patients weighing greater than 45 kg consume a total of 1350 mL (3 bottles \times 450 mL) of low-concentration barium suspension and 500 mL of water over an hour. Patients weighing 22.5 to 45 kg consume a total of 675 mL (3 \times 225 mL) of low-concentration barium suspension and 225 mL of water

over an hour. Patients weighing 4.5 to 22.4 kg consume a total of 300 mL (3×100 mL) of low-concentration barium suspension and 100 mL of water over an hour. Patients and families who express concerns about being able to consume the entire amount of enteric contrast are offered placement of a small caliber NGT for contrast administration.

CTE and MRE were performed on a variety of clinical CT and MR scanners in our Radiology Department and in accordance with Society of Abdominal Radiology guidelines and joint society practice parameters [23, 24, 26, 27].

Image analysis

Images were read on a PACS workstation (Centricity, GE Healthcare). Three fellowship trained radiologists with 2, 5, and 21 years of experience, each reviewed an equal number of randomly assigned studies, comprising a subset of the studies with no cross-over between radiologists. Radiologists were blinded to demographic information and type of oral agent. Prior to reviewing the cases, the reviewers had a group training session to calibrate their definition and application of the qualitative scales to the studies. This consisted of all of the reviewers simultaneously looking at the same four example studies showing examples of each score of luminal distension. These cases were not included in the data set.

Distal extent of the oral contrast was defined as the most distal intestinal segment in which the lumen contained oral agent; jejunum, ileum, TI (last 10 cm of ileum before the cecum), and colon. Luminal distension for the jejunum, ileum, and TI was assessed on a four point scale; 0 = collapsed, 1 = suboptimal (majority of segment is not fluid filled), 2 = acceptable (majority of segment contains fluid and lumen is visible but not maximally distended), and 3 = optimal (majority of segment contains fluid and is well distended). Two separate measurements approximately 3 cm apart were taken to assess distension of the TI. If a stricture was present, defined as a segment of unequivocal narrowing with unequivocal upstream dilatation, this was not measured. Finally, for each case, the readers assessed their diagnostic confidence in the presence or the absence of active inflammatory Crohn's disease in the TI using a four point scale; 0 = no confidence, 1 = slight confidence, 2 = moderate confidence, and 3 = high confidence.

Statistical analysis

Univariate analyses were performed using Chi square or Fisher's exact test for categorical variables as appropriate. Continuous variables were compared using the Student's *t* test for normally distributed and the nonparametric Wilcoxon rank-sum test for nonnormally distributed continuous variables as appropriate. Ordered categorical variables were

compared using the Wilcoxon rank-sum test. Variables with a $p < 0.05$ were considered statistically significant. All statistical analysis was performed on JMP®, Version 12 (SAS Institute Inc., Cary, NC, 1989–2007).

Results

Demographics

During the catchment period, 652 CTEs and MREs were performed on pediatric patients at our institution (198 CTE and 454 MRE). Of these, 61 scans were excluded due to incomplete data regarding enteric contrast protocol or use of alternative means of contrast administration besides NGT (e.g., gastrostomy tube). Of the remaining 591 CTE and MRE performed in 504 patients (314 females, 190 males), flavored beverage was used in 275 (46.5%) and low-concentration barium suspension was used in 316 (53.5%). The demographic data for the patients is shown in Table 1. The two types of enteric agents were fairly evenly distributed across patient demographics including age, gender, weight, and prior diagnosis of inflammatory bowel disease. There was also no significant difference between the two enteric contrast groups in percentage of scans with active inflammation, presence of stricture, or presence of bowel dilatation.

Tolerability

Ninety-seven percent and 96% of pediatric patients consumed the entire amount of enteric contrast with flavored beverage and low-concentration barium suspension, respectively (Table 2 and Fig. 1). Slightly more patients had emesis with low-concentration barium suspension (3%, 9/316) than flavored beverage (1%, 3/275); however, this was not statistically significant ($p = 0.13$). Flavored beverage was associated with a significantly decreased need for NGT placement, with 7% of scans using low-concentration barium suspension (23/316) requiring the use of an NGT, compared to 1% of scans using flavored beverage (3/275; $p < 0.0003$). In a subset analysis by age, 40 enterography exams were done in children 8 years old and younger, 22 using flavored beverage and 18 using low-concentration barium suspension. In this age group, one child needed NGT for flavored beverage administration, and all children completed the drinking protocol, compared to no children needing NGT for low-concentration barium suspension, but two children were unable to complete the drinking protocol.

Distal extent

There was a statistically significant difference in the distal extent of luminal distension by flavored beverage compared

Table 1 Demographics of pediatric patients undergoing CTE/MRE

	Flavored beverage (<i>n</i> = 275)	Low-concentration barium suspension (<i>n</i> = 316)	<i>p</i> -value
Age (years)			
Mean (SD)	13.6 (3.1)	13.9 (2.9)	0.21 [‡]
Median	14	15	
Range	3–17	3–17	
Age groups (<i>n</i>)			
≤ 8 years old	22 (8%)	18 (6%)	0.27 ^Ω
≥ 8 years old	253 (92%)	298 (94%)	
Gender (<i>n</i>)			
Male	137 (49.8%)	140 (40%)	0.18 ^Ω
Female	138 (50.2%)	176 (60%)	
Weight (kg)			
Mean	52.2	52–7	0.77 ^μ
Range	14.5–133.4	12.6–135.3	
Weight groups (<i>n</i>)			
4.5–22.4 kg	13 (5%)	14 (4.5%)	0.86 ^Ω
22.5–45 kg	69 (25%)	89 (28%)	0.40 ^Ω
> 45 kg	193 (80%)	213 (67.5%)	0.47 ^Ω
Scans in patients with known IBD at time of scan (<i>n</i> = 257)	124 (45%)	133 (42%)	0.46 ^Ω
Active inflammation (<i>n</i>)	114 (41%)	126 (40%)	0.70 ^Ω
Stricture present (<i>n</i>)	14 (5%)	19 (6%)	0.63 ^Ω
Proximal bowel dilation (<i>n</i>)	10 (4%)	12 (4%)	0.92 ^Ω

^ΩChi squared[‡]Wilcoxon rank-sum^μStudent's *t*-test

to low-concentration barium suspension ($p < 0.02$) (Table 2 and Fig. 2). For low-concentration barium suspension, the distal extent of contrast reached the jejunum in 0.3% of scans, the ileum in 12%, the TI in 6%, the ileocecal valve in 7%, and the cecum in 74%. For flavored beverage, the distal extent of contrast reached the ileum in 9%, the TI in 5%, the ileocecal valve in 3%, and the cecum in 84%.

Luminal distension

Comparing luminal distension score, there was a slight increase in the distension of the mid-ileum with flavored beverage compared to low-concentration barium suspension ($p = 0.02$), and equivalent distension in the jejunum and TI. This is shown in Table 2 and Fig. 3. While the medians of the distension scores in the mid ileum were no different for the two enteric agents, there was a higher proportion of score 3 for flavored beverage (71%, 195/275) signifying optimal distension (majority of segment contains fluid and is well distended) compared to low-concentration barium suspension (63%, 198/316). There was also a lower proportion of score 1 for flavored beverage (1%, 4/275) signifying sub-optimal distension (majority of segment is not fluid filled)

compared to low-concentration barium suspension (4%, 14/316). These differences likely account for the statistical significance.

For specific measures of luminal diameter of the terminal ileum, no difference was observed in the overall cohort (Table 2 and Fig. 4). An example of excellent SB distension can be seen in Fig. 5, while an example of poor distension can be seen in Fig. 6.

Diagnostic confidence of terminal ileum inflammatory bowel disease

Using a four-point scale for diagnostic confidence in the presence or the absence of active inflammatory bowel disease (0 = no confidence to 3 = high confidence), there was no difference between the two enteric contrast agents ($p = 0.94$) (Table 2 and Fig. 6).

Sub-analysis with multiple scans removed

Several of the children had multiple scans throughout the study period, using either low-concentration barium suspension and/

Table 2 Comparison of drink tolerability, distal extent of distension, SB distension, and diagnostic confidence between oral distending agents; all scans for each patient

	Flavored beverage (n=275)	Low-concentration barium suspension (n=316)	p-value
Entire amount ingested (n)	266 (97%)	302 (96%)	0.47 ^Ω
Emesis (n)	3 (1%)	9 (3%)	0.13 ^Ω
Nasogastric tube used (n)	3 (1%)	23 (7%)	0.0003 ^{*Ω}
Distal extent (n)			
Jejunum	0 (0%)	1 (0.3%)	0.02 ^{*π}
Ileum	24 (9%)	39 (12%)	
Terminal ileum	13 (5%)	19 (6%)	
Ileocecal valve	7 (3%)	22 (7%)	
Cecum	231 (84%)	235 (74%)	
Distension score ^a , median (25–75% IQR)			
Jejunum	2 (1–2)	2 (1–2)	0.96 [£]
Ileum	3 (2–3)	3 (2–3)	0.02 ^{*£}
Terminal ileum	3 (2–3)	3 (2–3)	0.28 [£]
Terminal ileum measurements, mean cm (SD)			
Measurement 1	1.07 (0.5)	1.01 (0.6)	0.19 ^μ
Measurement 2	1.20 (0.6)	1.14 (0.5)	0.18 ^μ
Diagnostic confidence of TI disease ^b , median (25–75% IQR)	3 (2–3)	3 (2–3)	0.94 [£]

IQR interquartile range

*Indicates a statistically significant difference compared with the results of the other beverage

^ΩChi squared

^πFischer exact test

[£]Wilcoxon rank-sum

^μStudent's *t*-test

^aThe scores used to assess distension were as follows: 0=collapsed, 1=mildly distended, 2=moderately distended, and 3=excellent distension

^bThe scores used to assess the diagnostic confidence of presence of TI disease were as follows: 0=no confidence, 1=slight confidence, 2=moderate confidence, 3=high confidence

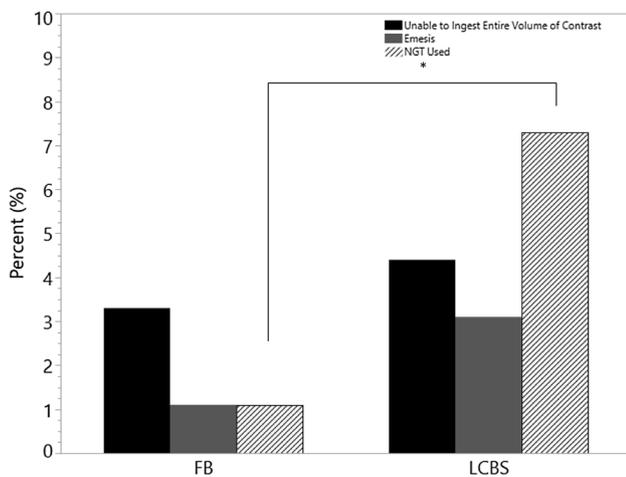
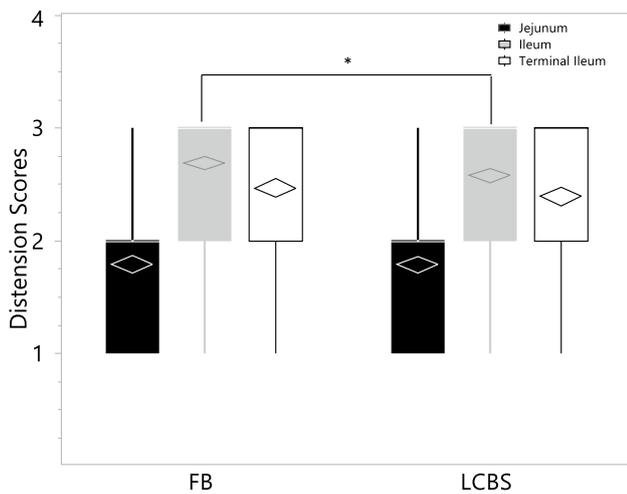
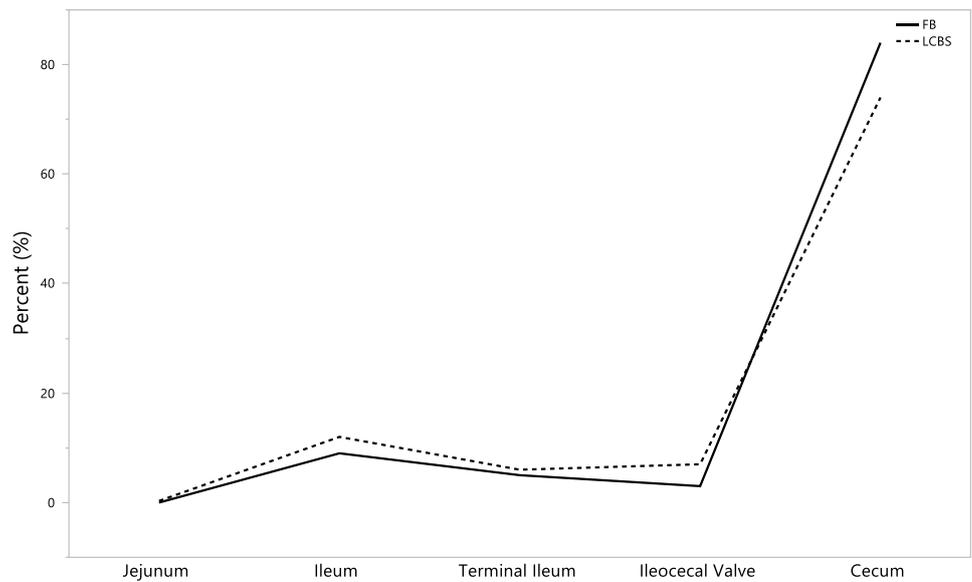


Fig. 1 Comparison of drink tolerability. FB flavored beverage, LCBS low-concentration barium suspension. *Indicates *p*-value of <0.05

or flavored beverage. A sub-analysis was performed removing all but the first scan with low-concentration barium suspension and the first scan using flavored beverage (Table 3). The results of removing these 59 studies mirror the results for the overall cohort. Flavored beverage was again associated with a significantly decreased need for NGT placement, with 0.4% (1/245) of scans using flavored beverage requiring the use of an NGT compared to 6% (18/287) of scans using low-concentration barium suspension ($p < 0.0001$). Slightly more patients experienced emesis with low-concentration barium suspension (3%, 8/287) compared to flavored beverage (1%, 2/245) ($p = 0.12$). Consumption of the entire amount was again neither statistically different, nor was distal extent of enteric contrast or diagnostic confidence in the presence or the absence of disease in the terminal ileum. Small but statistical differences were seen in distension of ileum.

Fig. 2 Distal extent of contrast luminal distension. Percentage of patients in which the enteric contrast reached a segment but not into the next segment. *FB* flavored beverage, *LCBS* low-concentration barium suspension

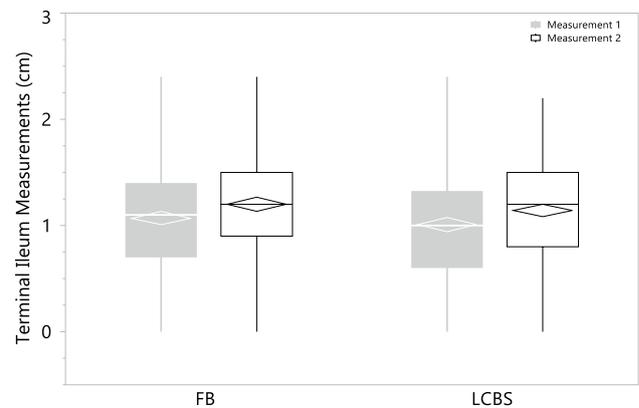


The boxes represent the 1st and 3rd quartile of distension scores for each variable. The confidence diamond represents the values between upper and lower 95% of the mean. The whisker represents the outermost data points collected.

Fig. 3 Comparison of luminal distension scores. The scores used to assess distention were as follows: 0=collapsed, 1=mildly distended, 2=moderately distended, and 3=excellent distension. *FB* flavored beverage, *LCBS* low-concentration barium suspension. *Indicates *p*-value of <0.05

Discussion

Proper ingestion of an oral distending agent prior to CTE and MRE is critical to adequately visualize the SB lumen and wall to assist in diagnosis of a myriad of diseases. Prior studies show that patients prefer the taste of enteral agents such as water and milk, find them easier to drink, and have less side effects compared to the low-concentration barium



The boxes represent the 1st and 3rd quartiles of distension scores for each variable. The confidence diamond represents the values between upper and lower 95% of the mean. The whisker represents the outermost data points collected.

Fig. 4 Comparison of separate terminal ileum measurements. *FB* flavored beverage, *LCBS* low-concentration barium suspension

suspension and other agents containing sugar alcohols [17, 18, 28]. These agents, however, fail to give adequate luminal distension and remain inferior to low-concentration barium suspension for this reason [18]. In this study, we retrospectively compared commercially available low-concentration barium suspension with a new commercially available flavored beverage containing sugar alcohol and a thickening agent in our pediatric patient population with known or suspected IBD. A previous prospective, blinded pilot study comparing these two enteric contrast agents in healthy adults demonstrated strong preference for flavored beverage and greater willingness of the subjects to repeat the drinking protocol with no significant differences in side effects [17]. A subsequent prospective, blinded study

Fig. 5 CT enterography with flavored beverage as the enteric distending agent in a 12-year-old male with ileocolonic Crohn's disease and history of TI resection shows enteric contrast extending throughout the bowel into the colon (a) and excellent distension of the ileum (b). There is mild mural hyperenhancement at the ileocolonic anastomosis (arrow)

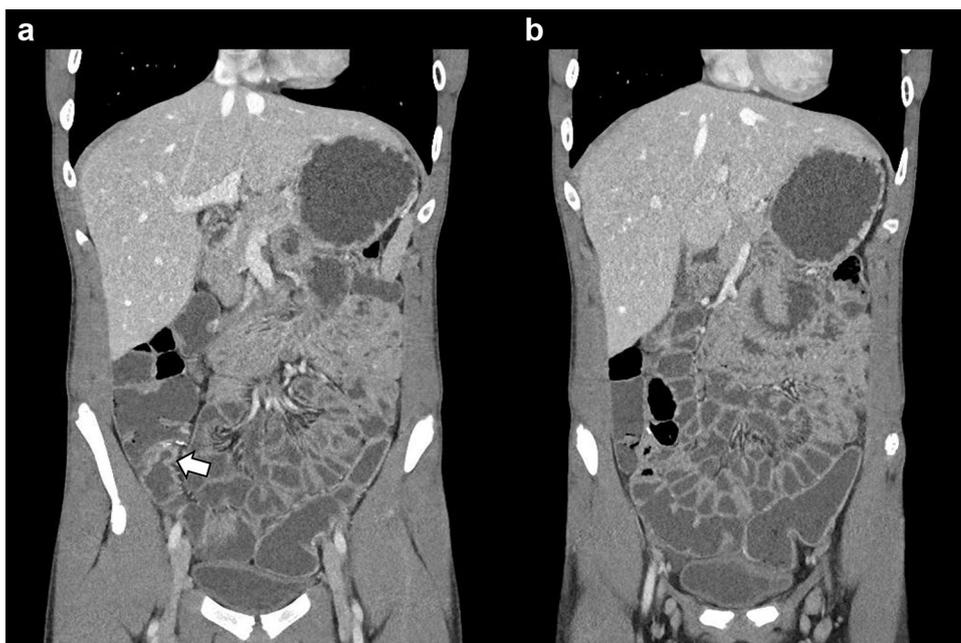


Fig. 6 CT enterography with flavored beverage as the enteric distending agent in a 10-year-old male with ileocolonic Crohn's disease shows suboptimal distension of the jejunum and most of the ileum (arrows)

in 33 pediatric patients receiving flavored beverage and 33 patients receiving barium suspension yielded similar results [29].

These prior small prospective studies, performed in well controlled study environments with blinding, showed a clear preference for the flavored beverage as well as noninferiority to low-concentration barium suspension in luminal distension and other markers of imaging quality. These types of

differences, however, can be reduced or eliminated in actual clinical practice due to confounding variables and lack of monitoring of conditions and adherence to parameters carefully controlled in the test environment. This large retrospective evaluation of almost 600 studies in approximately 500 patients used NGT administration, emesis, and ability to complete the drinking as surrogates for preference, as they are factors that would be readily experienced in an actual radiology department, and flavored beverage showed significantly decreased need for NGT administration. The desire to use an NGT for administration is associated with oral tolerability, which varies between types of enteric agent. The choice to use NGT may also reflect the patients' beliefs as to whether they can consume the amount needed. If they believe they may have a hard time, they may desire the tube administration. However, NGTs are very onerous in the pediatric population and ultimately add cost to the examination. They require explanation and acceptance from both the child and the parents or caregivers. They require a skilled provider to place and, in our institution, confirmation of placement with radiograph prior to use. Administration through NGT requires high level supervision by a nurse to slowly push the contrast into the bowel over 1 h. The time to perform these tasks is not accounted for in the child's pre-scan workflow and usually delays the start of the exam causing disruption to the scanner schedule.

Emesis is also a surrogate for preference. While our nurses do not record the number or nature of patients' complaints about the flavor or texture of the enteric contrast, they do record whether or not the patient vomited. This may be due to unpleasant flavor, texture, or overfull feeling related to the texture and slow transit of the fluid. In the current

Table 3 Comparison of drink tolerability, distal extent of distension, SB distension, and diagnostic confidence between oral distending agents; each patient's initial scan with each agent, excluding subsequent scans

	Flavored beverage (n = 245)	Low-concentration barium suspension (n = 287)	p-value
Entire amount ingested (n)	238 (97%)	274 (95.5%)	0.31 ^Ω
Emesis (n)	2 (1%)	8 (3%)	0.12 ^π
Nasogastric tube used (n)	1 (0.4%)	18 (6%)	<0.0001 ^{*,Ω}
Distal extent (n)			
Jejunum	0 (0%)	1 (0.4%)	0.11 ^π
Ileum	22 (9%)	34 (12%)	
Terminal ileum	12 (5%)	17 (6%)	
Ileocecal valve	7 (3%)	19 (7%)	
Cecum	204 (83%)	216 (75%)	
Distension score ^a , median (25–75% IQR)			
Jejunum	2 (1–2)	2 (1–2)	0.97 [£]
Ileum	3 (2–3)	3 (2–3)	0.04 ^{£,*}
Terminal ileum	3 (2–3)	3 (2–3)	0.11 [£]
Terminal ileum measurements, mean cm (SD)			
Measurement 1	1.1 (0.50)	1.02 (0.54)	0.07 ^μ
Measurement 2	1.24 (0.54)	1.13 (0.53)	0.02 ^{μ,*}
Diagnostic confidence of TI disease ^b , median (25–75% IQR)	3 (2–3)	3 (2–3)	0.80 [£]

IQR interquartile range

*Indicates a statistically significant difference compared with the results of the other beverage

^ΩChi squared

^πFischer exact test

[£]Wilcoxon rank-sum

^μStudent's *t*-test

^aThe scores used to assess distension were as follows: 0 = collapsed, 1 = mildly distended, 2 = moderately distended, and 3 = excellent distension

^bThe scores used to assess the diagnostic confidence of presence of TI disease were as follows: 0 = no confidence, 1 = slight confidence, 2 = moderate confidence, 3 = high confidence

study, there was a trend toward increased emesis with the low-concentration barium suspension compared to flavored beverage. It is intuitively known that bowel strictures can predispose patients to nausea and emesis, and we individually reviewed the studies of all patients who experienced emesis. It was shown that only one of the three patients receiving flavored beverage, who had emesis had active disease with structuring. This patient also had bilateral tubo ovarian abscesses with fever and sepsis. Of the nine patients receiving low-concentration barium suspension who had emesis, three out of nine had active inflammation although none had strictures of the small bowel. Therefore, strictures were not directly influencing whether or not these children vomited.

Additionally, being able to complete the drink protocol can also be considered a surrogate for acceptability. In the current study, the rate of completion was very high at 97% and 96%. NGT administration was not excluded in this study as this was an end point. However, not allowing NGT administration would have certainly decreased completion in the

low-concentration barium suspension group, for which 7% required NGT administration. Our results are in contrast to Dillman et al. [29] in which 85% completed flavored beverage and only 50% completed low-concentration barium suspension, and patients who required NGT administration were excluded. It is uncertain why the completion rate is so different between the two studies, although it may be related to differences in study design, as it is likely that in that prospective study, children were not given active encouragement to drink in an effort to eliminate bias or confounding factors. At our institution, dedicated pediatric nurses and child life specialists frequently monitor the drink process in order to maximize the exam preparation. Distraction techniques, such as sucking on hard candy to mask flavors, and reward systems are utilized. Finally, parents are encouraged to participate in the process. These practices have been in place since we began performing enterography in children and were used over the time period of this study. Regardless, because patients with Crohn's disease require surveillance with enterography to help guide medical and/or surgical

management, prior emesis may be important in determining willingness to repeat the tests.

Prior studies have shown that children may have upper SB involvement despite normal or nonspecific TI endoscopy [6, 30], and that the TI and colon are the most common locations for Crohn's disease [31, 32], highlighting the need for maximal distension throughout the bowel. Our study showed farther distal extent of oral contrast in the bowel with flavored beverage, as a higher percentage of studies had contrast fully through the ileocecal valve and into the cecum. As the TI is the most common location of disease in the small bowel in children, this is critical. The increased extent of luminal distension may be related to viscosity differences of the flavored beverage compared to low-concentration barium suspension [17].

As in the prior studies, similar distension between the two agents was seen in this study, both qualitatively and quantitatively. Our measurements in the terminal ileum are confounded by the fact that some patients had active disease. While we avoided measuring strictures and obvious areas of pre-stenotic dilatation, there were some patients with diffuse TI disease and luminal narrowing due to long segments of circumferential wall thickening which could not be avoided. Therefore, we believe the qualitative assessment of bowel distension by amount of contrast throughout the segment of bowel provides more information than a few focal measurements. For these reasons, we acknowledge our physical measurements in the TI may be flawed and place more value in our subjective assessment by segment, which were equivalent between the contrast agents.

Perhaps even more important than the direct measurement of luminal distension is the quality of the study in terms of allowing for a confident diagnosis to be made. Our study showed no significant difference in confidence in diagnosing the presence or the absence of disease in the TI. This has not previously been reported. When changes to a CTE or MRE protocol are made, it is paramount that diagnostic quality of the exam is maintained. This study shows that in clinical practice, replacing low-concentration barium suspension with the flavored beverage does not hinder the radiologist's confidence in identifying the presence or the absence of disease in the terminal ileum.

There are several limitations to our study, first and foremost of which is the retrospective nature. We were unable to directly assess patient preference and precisely control factors such as length of drinking time. We would argue, however, that given the ultimate objective of assessing the performance of the oral agent in a clinical setting, these limitations are necessary. As stated earlier, the volume of fluid in a bottle of flavored beverage is slightly more than that in low-concentration barium suspension due to differences in manufacturers. To maintain ease of drink instructions, the number of bottles given to a patient to drink was maintained

when our institution made the change from one agent to the other. Due to the retrospective nature of the study, this could not be controlled and does introduce a source of bias, particularly with respect to distal extent of contrast and luminal distension. Additionally, we do not track the actual length of the drink process and time to table and are therefore not able to analyze our data in this context. We do feel, however, that our data in over 500 patients represents actual practice in a busy radiology department and shows we have maintained acceptable exam quality despite these limitations. The inclusion of healthy children and children with IBD and other gastrointestinal pathologies confounds the results but does give a more realistic performance of the enteric contrast agent. Lastly, given the large number of cases that needed to be reviewed, we were unable to have all three readers review every study in order to determine interreader variability, and instead had each reader review a subset. Interreader variability has been shown, in general, to be very good for enterography [33], and we see no reason it should be different for our experienced readers, especially given the training they collectively did prior to reviewing the studies. Lastly, while all three radiologists reviewed the same number of cases, the number of flavored beverage versus low-concentration barium suspension cases was not made equal between the radiologists and this may have been a source of bias.

In summary, given the results of Kolbe et al. which showed a strong preference for taste of flavored beverage in healthy adults, the enteric contrast protocol at our institution was changed to use the flavored beverage as the first line enteric distending agent for CTE and MRE. This subsequent large retrospective evaluation of nearly 600 enterography exams in almost 500 pediatric patients showed decreased need for NGT administration, trend toward decreased emesis, mildly increased distal extent of enteric distending contrast, and equivalent distension with no decrease in diagnostic confidence in the presence or the absence of TI disease. Since we have integrated the flavored beverage into our practice, requests for NGT administration have been nearly eliminated in children, such that since the conclusion of this study we stopped offering it as a clinical service for enterography. This change has been very well received by patients and their families, clinicians, and radiologists and radiology department personnel, while maintaining high quality diagnostic enterography exams in children.

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Compliance with ethical standards

Conflicts of interest The authors have no conflicts of interest related to this work.

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