

Comparison of pineapple juice and mannitol as oral contrast agents for magnetic resonance enterography

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ABSTRACT

Introduction: We aimed to compare the degree of bowel distension and image quality between pineapple juice and different mannitol concentrations, as well as patients' acceptance and side effects of these different magnetic resonant enterography (MRE) oral contrast agents.

Materials and Methods: Seventy-five participants underwent MRE as an initial investigation or follow-up for inflammatory bowel disease. A systematic sampling method was used to divide the participants into three different groups: group 1 received 6.7% mannitol concentration, group 2 received 3.3% mannitol concentration and group 3 received pineapple juice as an oral contrast agent during their MRE examination. The degree of bowel distension on MRE images was assessed by a radiologist by measuring the bowel diameter from inner wall to inner wall at specified levels, while qualitative analysis was evaluated based on the presence of artefacts. All patients were asked to score their acceptance of the oral contrast and were asked about side effects such as diarrhoea, abdominal discomfort and vomiting.

Results: All patients were able to completely ingest 1.5L of oral contrast. The mean diameter of bowel distension was 2.1cm in patients who received 6.7% mannitol concentration, 2.0cm in patients who received 3.3% mannitol concentration and 1.6 cm in patients who received pineapple juice. Two-thirds of patients who received 6.7% mannitol and 3.3% mannitol solutions had good-quality MRE images, but 68% of patients who received pineapple juice had poor-quality MRE images. Twenty-four patients (96%) who received pineapple juice rated it as slightly acceptable and acceptable but only 12 patients (48%) who received 6.7% mannitol solution rated it as slightly acceptable and acceptable. Eighty-eight percent of patients who received 6.7% mannitol solution experienced at least one form of side effect as compared to 44% of patients who received 3.3% mannitol solution and 18% of patients who received pineapple juice.

Conclusion: Optimum small bowel distension and good image quality can be achieved using 3.3% mannitol concentration as an oral contrast agent. Increase in mannitol concentration does not result in significant improvement of small bowel distension or image quality but is instead related to poorer patient acceptance and increased side effects. Pineapple juice is more palatable

than mannitol and produces satisfactory small bowel distension. However, the small bowel distension is less uniform when using pineapple juice with a considerable presence of artefacts. Mannitol, 3.3% concentration, is therefore recommended as an endoluminal contrast agent for bowel in MRE.

KEYWORDS:

Oral contrast, magnetic resonance enterography, mannitol, pineapple juice

INTRODUCTION

The small bowel represents the largest section of the human digestive tract. Due to its length, small diameter and the variety of pathologic changes, this region often presents a diagnostic challenge. The most frequently encountered disorders include acute and chronic inflammatory processes along with their complications. Some diseases, such as Crohn's disease can cause mucosal changes like wall thickening, ulcerations, wall nodularity or areas of stricture. Others, such as lymphoma, may cause abnormal dilatation. Tumours of the small bowel are usually single but may be multiple, particularly in certain syndromes such as familial polyposis. Most small bowel diseases have similar signs and symptoms which are non-specific, for example, abdominal pain, diarrhoea, anorexia, and loss of weight, which make it difficult to diagnose by clinical examination alone.

A large variety of invasive and non-invasive diagnostic methods are available to assess the small bowel. However, despite the development of modern endoscopic techniques¹, radiological imaging remains central for diagnosis and therapeutic monitoring. Magnetic resonance enterography (MRE) is a specialised magnetic resonance imaging (MRI) technique which uses a biphasic oral non-absorbable contrast agent to assess the small bowel. MRE has been proven to be equivalent to computed tomography enterography (CTE) in evaluating the small bowel but has the added advantage of being non-ionising.²

An adequate degree of bowel distension is important for optimal imaging of the small bowel. Collapsed bowel segments may result in false negative or false positive results where small areas of abnormalities may be missed. Volumen® (E-Z-EM Canada), a mannitol-based solution, is currently the most frequently used oral contrast agent for

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MRE, but there has been a shortage of supply in our local setting due to logistic factors. Therefore, there has been a demand for an alternative oral contrast agent.

Several studies have described experiences using various types of oral contrast agents for MRE, from mannitol-based solution, barium-based solution to a natural solution such as pineapple juice.³⁻¹⁰ There are only a few studies comparing the different filling methods, and to the best of our knowledge, there is no study which draws a comparison between different mannitol concentrations and pineapple juice. The main objective of this study was to compare the effectiveness and patient acceptability of pineapple juice, a proven natural oral contrast agent for MRE,⁵ with different mannitol solution concentrations, that are both easily available in our setting, in patients undergoing MRE. Specifically, the study aimed to compare the degree of bowel distension and image quality between pineapple juice and different mannitol concentrations, as well as patients' acceptance and side effects of these different oral contrast agents.

MATERIALS AND METHODS

The local Institutional Research and Ethics Committee approved this case-control study which was carried out for a 1-year duration at a tertiary teaching hospital. Informed consent was obtained from the patients who agreed to participate in this study. A total of 75 participants were enrolled (38 women and 37 men; age range 14-71 years). All participants underwent MRE as an initial investigation or follow-up for inflammatory bowel disease (IBD).

a) Sampling

The systematic sampling method was then used to divide the participants into three different groups (groups 1, 2 and 3), which would determine the type of oral contrast agent that they would receive during their MRE examination. Each patient consumed only one type of oral contrast. The oral contrast agents that were given were as follows:

- (1) 6.7% mannitol concentration was given to patients in group 1 (500ml 20% W/V mannitol mixed with 1000ml of water),
- (2) 3.3% mannitol concentration was given to patients in group 2 (250ml 20% W/V mannitol mixed with 1250ml of water), and
- (3) pineapple juice was given to patients in group 3 (500ml of pure ready-made pineapple juice mixed with 1000ml of water).

Patient Preparation

All MREs were performed on a 3T Verio and a 1.5T Verio MRI scanner (Siemens). Patients fasted for at least 6 hours before the procedure and were required to ingest a total of 1.5 litres of oral contrast in 1 hour, taken in three separate doses. The first 600 ml was taken 1 hour before the scan, the second 600 ml was taken 30 minutes before the scan and the final 300ml was taken just prior to scan.

Procedure

Three sets of scans were performed, and IV hyoscine 10mg or IV glucagon 0.25mg was given in between the sets to reduce bowel movement. IV gadolinium was given after the second

set of the scan. Images were acquired in the axial and coronal planes. Multiple MRI sequences were used, namely T2 steady-state coherent, T1 spoiled 3D GRE variant and T2 echo-planar fast spin echo sequences. The summary of the scanning protocol is shown in Figure 1.

At the end of the procedure, patients were asked to score their acceptance of the oral contrast ranging from 1 (unacceptable) to 5 (acceptable). Within a week, the patients were contacted by phone and were asked about any side effects of the oral contrast given. Three main symptoms were asked: diarrhoea, abdominal discomfort and vomiting after they received the oral contrast agent.

Image Analysis

The degree of bowel distension on the MRE images was assessed by a senior radiologist, who was blinded to the type of oral contrast agents, by using T2 steady-state coherent coronal images. Quantitative analysis of small bowel distension was performed by measuring the bowel diameter from inner wall to inner wall at the following specified levels: (1) at the second part of duodenum (D2) for assessment of duodenum, (2) at the level of superior mesenteric artery for assessment of jejunum, (3) at the level of S1 vertebra for assessment of ileum, and (4) at the right iliac fossa for assessment of terminal ileum.

The bowel loops with the largest diameter were selected for measurement at each level, with a total of four measurements for each patient.

Meanwhile, qualitative analysis of bowel distension was carried out by the same radiologist based on the presence of artefacts, particularly chemical shift artefacts, or the amount of bowel collapse. Scored of a three-point scoring system were given as follows: 1=Poor (presence of artefacts/collapsed bowel in >70% of the small bowel); 2=Fair (presence of artefacts/collapsed bowel in 30-70% of the small bowel); and 3=Good (presence of artefacts/collapsed bowel in <30% of the small bowel). Examples of images with their respective scores are shown in Figure 2.

Statistical analysis was performed using SPSS version 26.0. A comparison between all three solutions in terms of bowel dilatation, image quality, patient acceptance and side effects were made using two-way ANOVA, and a comparison between two solutions was made using t-test. P value of <0.05 was considered to be significant.

RESULTS

Bowel Distension

All patients were able to completely ingest 1.5 L of oral contrast before the scan. Quantitative analysis of the bowel distension showed the highest and most uniform bowel distension in patients who received 6.7% mannitol concentration (mean diameter of 2.1cm), followed by patients who received 3.3% mannitol concentration (mean diameter of 2.0cm). Patients who received pineapple juice as oral contrast showed the poorest degree of bowel distension, most noticeably involving the distal small bowel (mean

Table I: Mean diameter of different segments of the small bowel.

Oral contrast agent	Mean diameter of small bowel (cm)				
	Duodenum	Jejunum	Ileum	Terminal ileum	Overall
6.7% mannitol concentration	2.1	2.1	2.1	2.1	2.1
3.3% mannitol concentration	2.0	2.0	2.1	1.9	2.0
Pineapple juice	1.7	1.8	1.5	1.5	1.6

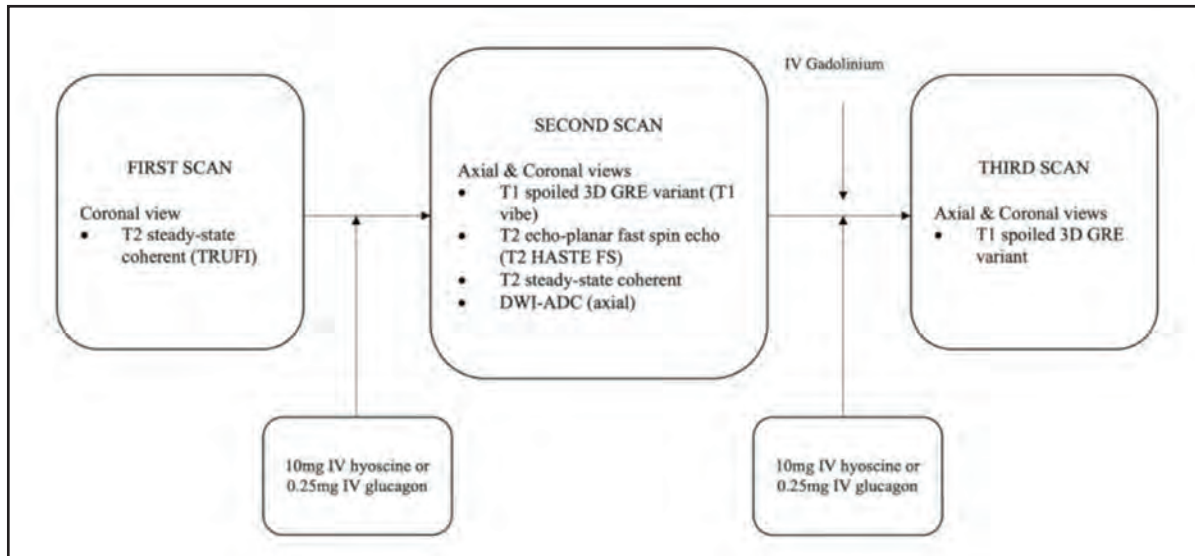


Fig. 1: Summary of the MRE scanning protocol.

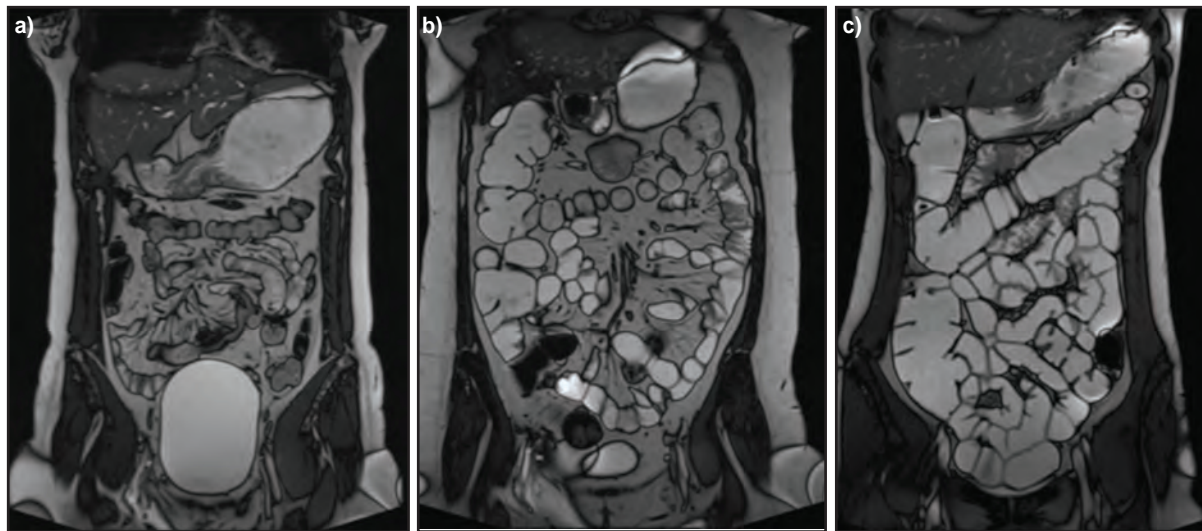


Fig. 2: (a-c) Example of images on coronal T2 steady-state coherent with (a) score 1, (b) score 2 and (c) score 3.

diameter of 1.6cm). The mean diameter of the different segments of the small bowel is shown in Table I.

There was a significant difference in the degree of small bowel distension between the three oral contrast agents in all segments of the small bowel ($p \leq 0.01$) (Figure 3). Specifically, there was a significant difference between 6.7% mannitol and pineapple juice, and between 3.3% mannitol and pineapple juice in all small bowel segments ($p \leq 0.04$). However, there was no significant difference in the degree of

bowel distension in patients who received 6.7% mannitol and 3.3% mannitol for all segments of the small bowel ($p = 0.11-0.88$).

Image Quality

The quality of MRE images in patients who were given 6.7% mannitol and 3.3% mannitol solutions was superior to pineapple juice. The MRE images were scored as 3 (i.e. good) in 64% of patients who received 6.7% mannitol and 3.3% mannitol solutions, respectively. Only less than 10% of MRE

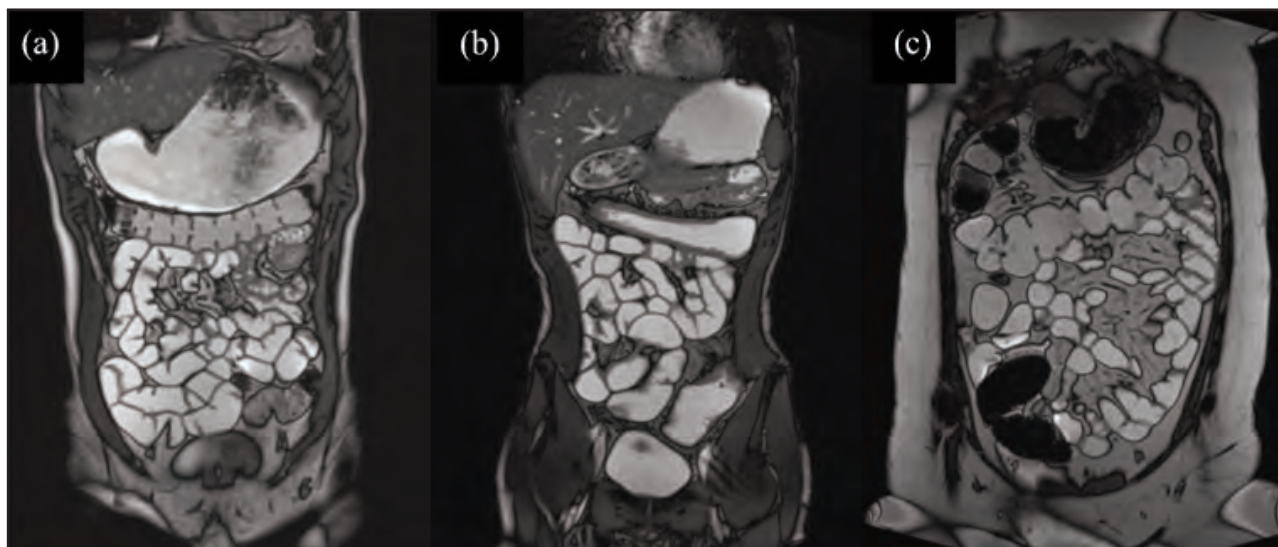


Fig. 3: (a-c) T2 steady-state coherent coronal images demonstrating different bowel distension between (a) 6.7% mannitol, (b) 3.3% mannitol, and (c) pineapple juice.

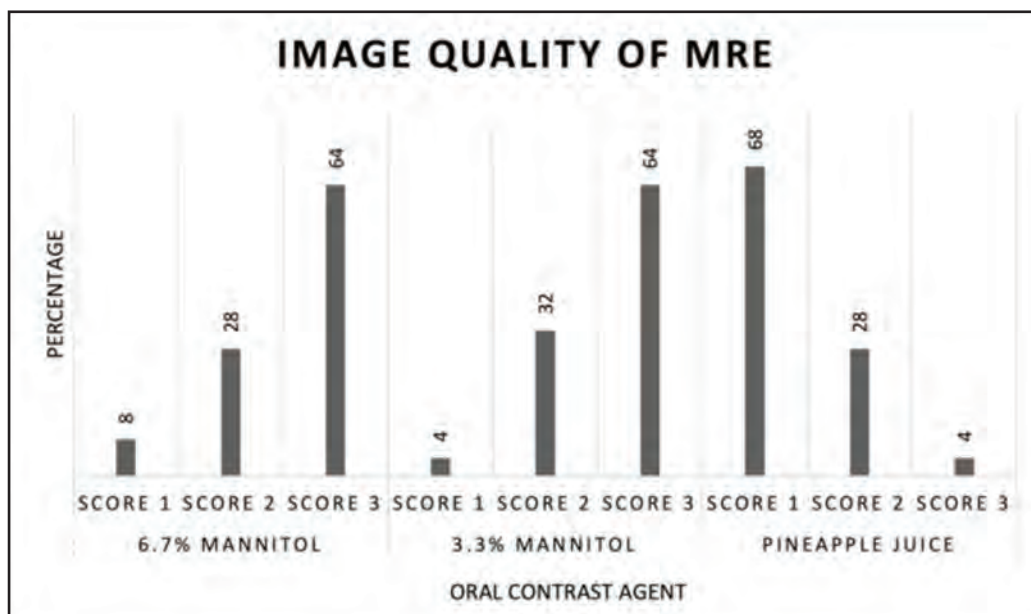


Fig. 4: Distribution of image quality scores of different oral contrast agents.

images in these two groups were scored as 1 (i.e., poor). On the contrary, 68% of patients who received pineapple juice had MRE images which were scored as 1 (i.e., poor) with only 4% had MRE images which were scored as 3 (i.e., good). The distribution of image quality scores of each oral contrast agent is shown in Figure 4.

All three solutions showed a significant difference in image quality ($p \leq 0.01$), where there is a significant difference in the image quality between the two mannitol solutions and pineapple juice ($p < 0.01$, respectively). However, no significant difference was found in the image quality between 6.7% mannitol and 3.3% mannitol ($p = 0.82$).

Patients' acceptance

Patients who received pineapple juice as oral contrast gave higher acceptance scores as compared to those who received mannitol. Twenty-four patients (96%) who received pineapple juice rated it as 4 (slightly acceptable) and 5 (acceptable). Among patients who received 6.7% mannitol solution, only 12 patients (48%) rated it as 4 (slightly acceptable) and 5 (acceptable). Three patients (12%) rated it as 2 (slightly unacceptable) and 1 (unacceptable) while 10 patients (40%) rated it as 3 (neutral). Most patients who received 3.3% mannitol found it to be slightly acceptable, with 20 patients (80%) rating it as 4, while five patients (20%) rated it as 3 (neutral) and 2 (slightly unacceptable).

Side Effects

Side effects such as vomiting, diarrhoea and abdominal discomfort were more common in patients who received 6.7% mannitol solution as oral contrast; 88% of them experienced at least one form of side effect as compared to 44% of patients who received 3.3% mannitol solution and 18% of patients who received pineapple juice. Diarrhoea was the commonest side effect among patients who received 6.7% mannitol solution (17 patients), while vomiting was the commonest side effect among patients who received 3.3% mannitol solution (5 patients). None of the patients who received pineapple juice experienced vomiting; the commonest side effect in this group was abdominal discomfort (3 patients).

DISCUSSION

MRE is one of the excellent methods to investigate small bowel pathology such as IBD, but it needs to be done using the correct type of oral contrast, suitable oral contrast volume, proper timing of oral contrast administration and correct image acquisition.¹¹ Advantages of MRE include superior soft tissue characteristics and nonionizing, which is very beneficial in young patients with Crohn's disease who will require multiple repeated examinations.³ Many oral contrast agents have been studied, including the different mannitol concentrations, milk, water and even pineapple juice.^{3,5} The ideal oral contrast for assessing endoluminal pathology must produce good bowel distension and image quality by demonstrating good contrast between bowel wall and bowel content.^{12,13}

Mannitol solution is generally accepted as an oral contrast agent for MRE due to its non-absorbable and non-metabolized properties.¹⁴ Small bowel distension was most optimal in our patients who received 6.7% and 3.3% mannitol concentrations as compared to those who received pineapple juice. The mean distension for both mannitol concentrations was 2.1cm and 2.0cm, respectively, which is comparable to published literature which used 3% mannitol concentration.¹⁴ There is no significant increase in the degree of bowel distension despite an increase in mannitol concentration. The small bowel distension achieved using mannitol in this study is superior to published literature, which used water, juice and milk as oral contrast agents.⁵

Pineapple juice is a natural manganese-containing agent that has been shown to produce satisfactory results when used as an oral contrast agent in abdominal MRI.^{5,15,16} The mean small bowel dilatation in patients who received pineapple juice in our study was 1.6cm, similar to the published literature done by Elsayed NM et al., in 2015.⁵ Distension of ileum and terminal ileum was poorer in this group of patients, with significantly inferior image quality compared to those in the mannitol group, which was not observed in other studies.^{15,16} A possible explanation for this is that the manganese concentration of the pineapple juice that was given to our patients was not quantified, and this is one of the limitations of our study. Our study used commercially available pineapple juice which was diluted in 1000 ml water to make it more palatable, which could affect the manganese concentration. Reported manganese concentration levels of 2.76mg/dl and 12.7mg/dl have been shown to produce good image quality.^{15,16}

To our knowledge, there is no specific diameter to determine acceptable bowel distension. In order to get an adequate bowel distension for diagnosis, the absorption of water molecules needs to be delayed by adding some additives such as sorbitol or mannitol.³ However, this will lead to water retention in the bowel, thus causing adverse effects such as vomiting, diarrhoea and abdominal discomfort as observed in our subjects who received mannitol as the oral contrast agent.

In our study, the subjects involved were either suspected to have IBD or follow-up patients. Based on a systematic review by Dominik et al., the degree of bowel distension is depending on a few factors such as the presence of bowel wall thickening, fibrosis, and strictures as a result of chronic inflammation in IBD.¹⁷ Although these conditions may affect the result of our study, the measurement of bowel distension is made at the widest and non-affected bowel segment.

We noticed that poor image quality is mainly due to poor bowel distension and the presence of chemical shift artefact. Chemical shift artefacts occur due to spatial misregistration of fat and water molecule, which can frequently present in abdominal MRI, particularly involving the water in the bowel lumen and the surrounding mesenteric fat. Poor bowel distension causes clumping of the bowel, and with the presence of air within the collapsed bowel lumen, the diagnostic quality of the image will be degraded.

Overall, our patients rated pineapple juice as the most palatable oral contrast agent with the least side effects. Patients who received 6.7% mannitol experienced the most side effects, particularly diarrhoea which was experienced by 68% of them, followed by abdominal discomfort and vomiting which were experienced by 56% and 28% of patients, respectively. These adverse effects are significantly lesser ($p=0.02$) for the lower mannitol concentration (3.3%), which shows only 40% of the patients had mild symptoms of either vomiting, diarrhoea and abdominal discomfort. To reduce the possibility of overlapping symptoms from the underlying IBD, close monitoring within a 1-week duration is made, where we assume the symptoms within this period are likely attributed to the oral contrast given.

Based on our observation, most of the patients who received mannitol as oral contrast showed distended stomach which can lead to vomiting. Therefore, a proper measurement of bowel capacity should be considered to reduce vomiting as a side effect. Mannitol is a type of sugar alcohol used as a sweetener and medication,¹⁸ thus it produces a sweet taste and was well-tolerated by subjects. However, because of its high incidence of side effects, most of the subjects gave a lower score for acceptance, especially for 6.7% mannitol solution.

Another limitation of this study is that we only use one radiologist to evaluate our MRE images in a limited time as we have a limited experts on reading MRE images in our local setting.

CONCLUSION

Small bowel distension and image quality are better with mannitol than with pineapple juice. Optimum small bowel distension and good image quality can be achieved using 3.3% mannitol concentration as an oral contrast agent. Increase in mannitol concentration does not result in significant improvement of small bowel distension or image quality but is instead related to poorer patient acceptance and increased side effects. Pineapple juice is more palatable compared to mannitol and produces satisfactory small bowel distension. However, the small bowel distension is less uniform when using pineapple juice with a considerable presence of artefacts. Therefore, a 3.3% mannitol concentration, which is widely available, should be the preferred endoluminal contrast agent for MRE.

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FINANCIAL DISCLOSURE

This research has not received specific aid from agencies of the public sector, commercial sector or non-profit entities.

CONFLICT OF INTEREST DISCLOSURE

The authors declared no conflict of interest.

MAIN POINTS:

- MRE is a specialised MRI technique which uses a biphasic oral non-absorbable contrast agent to assess the small bowel and has been proven to be equivalent to CTE in evaluating the small bowel but has the added advantage of being non-ionising.
- The ideal MRE oral contrast for assessing endoluminal pathology must produce good bowel distension and image quality by demonstrating good contrast between bowel wall and bowel content.
- 3.3% mannitol concentration solution is the preferred MRE oral contrast agent as it is widely available, produces optimal bowel distension and good image quality with fairly good patient acceptance and moderate side effects.

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