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Quantitative and qualitative bowel analysis using mannitol, water and iodine-based endoluminal contrast agent on 64-row detector CT

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Abstract

Objective: To assess the performance of mannitol as a luminal contrast as compared to water and positive contrast in evaluation of bowel on multidetector computed tomography (MDCT). **Materials and Methods:** Three hundred patients were randomly selected for this study and were divided equally into three groups. Each subject received 1500 ml of oral contrast. Group 1 received 3% mannitol in water, group 2 received diluted iodinated positive contrast, and group 3 received plain water without additives. Qualitative and quantitative analysis for distension, fold visibility, and overall image quality were analyzed by actual diameter measurement and point scale system at different bowel levels. One-way analysis of variance (ANOVA) followed by Tukey's HSD Post-hoc test and Pearson's Chi-square (exact test) test were applied. **Results:** Group 1 showed better results for small bowel distension, intraluminal homogeneity, and visibility of mucosal folds on quantitative and qualitative analysis with statistically significant P value (P<0.001). The ileo-caecal junction distension and mural feature visibility was better with mannitol (P < 0.001). No significant difference in distension of stomach and duodenum was found between the three groups. **Conclusion:** Mannitol as endoluminal contrast increases the diagnostic accuracy of the investigative studies in comparison to water and iodine-based contrast by producing significantly better bowel distension and visibility of mural features with improved image quality without additional adverse effects.

Key words: Bowel distension; iodinated positive contrast; mannitol; mural details; water

Introduction

The small bowel has always been a challenging area to assess for surgeons and gastroenterologists owing to its long length and complexity of the loops. Yesteryear's barium investigations were most often non-specific with a very low diagnostic yield. Technological advances in multidetector computed tomography (MDCT) have revolutionized imaging field and have added new concepts to solid and hollow viscera imaging.[1] The success of accurate interpretation of bowel pathologies requires an optimal preparation and acquisition. Luminal distension and fold visualization are the determining factors in gastrointestinal tract imaging. This requires an oral contrast agent, which should cause uniform intraluminal attenuation, high contrast between luminal content and bowel wall, minimal mucosal absorption leading to maximum distension, absence of artifact formation and no significant adverse effects.[2] In recent years, there has been a gradual trend of using low attenuation contrast agents over positive agents for abdomino-pelvic imaging, as these agents fulfill most of the characteristics of an ideal agent.

We compared the performance of three contrast agents that included water, 3% mannitol solution, and diluted

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angiograffin (65%), an iodinated contrast to assess whether mannitol contrast media improved bowel distension, fold visualization, and intraluminal contrast homogeneity as compared with positive and plain water in abdomino-pelvic imaging on MDCT, as well as whether mannitol assists in improvement of overall image quality by reducing artifacts.

Materials and Methods

Subjects

A total of 300 patients undergoing 64-slice MDCT examination of abdomen and pelvis for various indications were randomly selected. Patients were divided into three groups comprising of 100 patients each. Age and sex matching was done and the subjects were of age 20-70 years.

The first group received 3% mannitol in water; total 45 g of mannitol was dissolved in 1500 ml of water to make a 3% solution.[3,4] The second group received positive contrast containing 65% meglumine diatrizoate (20 ml dissolved in 1500 ml of water). The third group received 1500 ml of plain water without additives. All patients consumed 1500 ml of endoluminal contrast agent; 1200 ml of endoluminal contrast was consumed over a time period of 30-45 min and the remaining 300 ml at 10 min before the scan. For standardization and uniform distension of small bowel, patients were asked to drink 150 ml every 4-5 min for 45-55 min. Imaging was performed 55-60 min after the beginning of contrast agent consumption.

Scanning protocol

All examinations were performed on a 64-detector row MDCT scanner (Brilliance, Philips Imaging System, The Netherlands). Using a power injector, 80-100 ml of intravenous contrast was administered at a concentration of 300 mg/ml iodine (Ultravist 300; Bayer-Schering, Germany), with an injection rate of 3-5 ml/s. The administration of contrast was followed by a flush of 40 ml normal saline at the same injection rate. Multiphasic studies were performed depending upon the clinical and radiological indications. Bolus tracking method was used for acquisition of arterial and portovenous phases with a delay of 8 s post-threshold achievement in lower thoracic aorta for arterial phase and a delay of 45 s post-threshold for portovenous phase. Images were reconstructed in axial and coronal planes with a slice thickness and interval of 5 mm.[1] Images were sent to Picture Archiving and Communication System (PACS) for analysis.

Image analysis

Image analysis was done on PACS by two radiologists with an experience of 3 and 6 years in abdominal CT imaging, respectively, and who were blinded to the neutral luminal contrast agents, i.e., mannitol and water. Both qualitative and quantitative analysis was done for distension, delineation of bowel wall and fold pattern, intraluminal content homogeneity, and overall image quality by using actual measurements for quantitative analysis and point scale system for qualitative analysis at different bowel levels.

Quantitative analysis

Quantitative analysis of distension was assessed on axial images by selecting two segments of loops that were maximally distended one each on right and left side of abdomen by taking outer to outer dimensions. To obtain systemized data, measurements were done at following levels: Superior mesenteric artery, renal artery, inferior mesenteric artery levels for jejunum, aortic and common iliac bifurcation, and deep pelvis for ileal loops, following this, the means were calculated. Quantitative analysis of fold and wall visibility was done on axial images at the same above mentioned levels by using 3 grades. Collapsed bowel/poor contrast between the wall and intraluminal contents was graded as grade 0, endoluminal contrast agent seen within the bowel loops with distension of ≤1.5 cm and incomplete fold visibility graded as grade I and distension >1.5 cm and complete visibility of fold was graded as grade II.[5]

Qualitative analysis

Qualitative analysis of individual index-like distension, homogeneity of luminal contents, and wall visibility was done using a continuous 3 point scale (0-2, fair to excellent) using only coronal images. Score 0-fair (<25% of the bowel loops show adequate distension or homogeneity of luminal contents or fold visibility) and score 2-excellent (75-100% of the bowel loops show adequate distension or homogeneity of luminal contents or fold visibility). The presence of artifacts ran from no artifacts (0) to serious image degradation due to artifacts (4) and overall image quality from unreadable (0) to perfect (4). Maximum distension of stomach, pylorus, and small bowel loops was measured by taking outer to outer wall dimension. Ileo-caecal (IC) junction was separately evaluated on coronal planes for distension and mural pattern using same grades and point scale.

Assessment of large bowel was also made by 3-point scale system. Grade 0-2 as no intraluminal contrast and non-visualization of haustra to >75% length of large bowel showing endoluminal contrast with complete visualization of haustra.

Results

Total 300 abdominal MDCT examinations were included in the study, with 100 cases in each group, which included mannitol in water, positive contrast group, and plain water. Of the total, 188 were male and 112 were female patients and they belonged to the age group of 20-70 years (mean age: 48 years). Period over which the contrast media consumed was same for the three contrast group with mean time being 57, 53, and 52 min for mannitol, positive and water contrast group, respectively. Minimum and maximum time period between start of contrast media consumption and start of the scan was 45 and 65 min respectively.

Acceptance of the oral contrast media

All three contrast agents were well tolerated by the patients and considered the taste of mannitol as fine and suitable without any discomfort. No major complications were reported by clinicians. Few patients reported a mild frequency of watery stool following mannitol intake. However, none of them had severe degree of diarrhea or electrolyte imbalance and none required intravenous infusion.

Quantitative analysis of bowel distension and fold visibility

Bowel distension

Quantitative assessment of bowel distension at various levels with a mean distension and standard deviation was calculated. The mean distension of stomach, pylorus, and second and third part of duodenum (D2 and D3) did not show any statistically significant ($P > 0.05$) difference between the three groups [Figure 1A-C]. Mean distension of jejunum and ileum with mannitol was 1.97 and 2.1 cm, with positive contrast 1.70 and 1.71 cm, and with water 1.60 and 1.62 cm. One-way analysis of variance (ANOVA) followed by Tukey's HSD Post-hoc test showed significant difference between mannitol and other two groups ($P < 0.001$) for jejunal and ileal distension. The mean distension achieved at the IC junction was 1.4, 1.34, and 1.16 cm with mannitol, positive contrast, and water, respectively, achieving a statistically significant difference ($P < 0.001$) between mannitol and water group, whereas no clinical or statistical difference was found between mannitol and positive contrast group [Table 1].

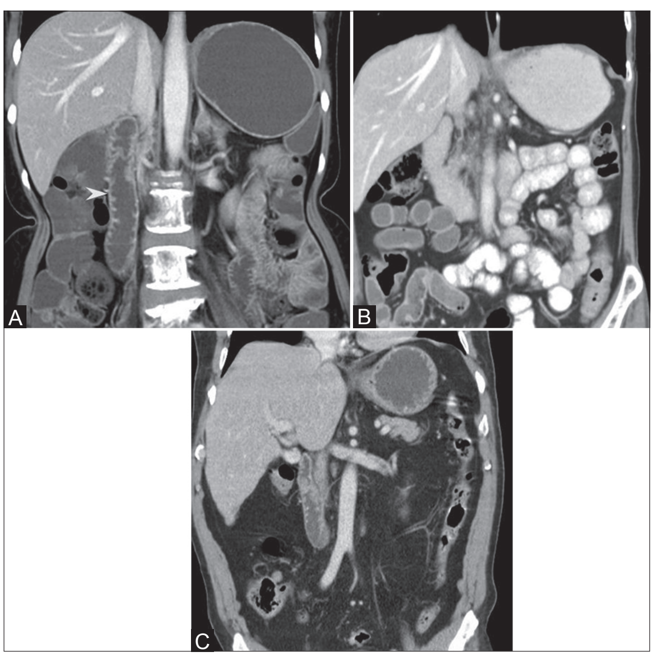

Figure 1 (A-C): Similar degree of duodenal distension achieved with 3% mannitol (A), iodinated contrast (B), water without any additives (C)

Fold visibility and details of mural features

Fold visibility and details of mural features were better delineated with mannitol as compared to positive or water endoluminal contrast group; 62% of cases showed distension >1.5 cm with complete fold visibility at the level of jejunum with mannitol, whereas it was only 34% and 39% with iodinated contrast and water, respectively. Improved visualization of mural details were seen in ileum and IC junction with mannitol in 88% and 71% cases, respectively. There was superior definition of the internal feature of the small bowel wall at IC junction in the mannitol group as compared to water and positive contrast groups. Statistical analysis showed strong association between the fold visibility grading and the contrast groups. Pearson's Chi-square (exact test) showed significant P value ($P = 0.001$) [Tables 2-4].

Qualitative analysis of image quality with respect to overall distension, fold visibility, and homogeneity

Overall qualitative assessment of distension, fold visibility, and homogeneity of intraluminal content was significantly better with mannitol group, with significant number of cases put under the category "good" and "excellent." More than 25% cases were graded as "excellent" with mannitol, whereas only 0-10% cases with positive and water group were graded so. There was statistically significant difference with good association between the groups (Pearson's Chi-square (exact test): $P = 0.001$) [Table 5].

Large bowel distension and fold visibility was also excellent with mannitol group as compared to the other two contrast groups. Mannitol contrast group could produce adequate distension and allowed haustral visibility in 61% subjects without additional per rectal infusion, which was not seen in water or positive groups [Figure 2].

Discussion

Advancement in CT technology, especially with the advent of MDCT, has resulted in improved spatial and contrast resolution, helping in a better diagnosis. Small bowel has been an obscured area owing to its long length and inability

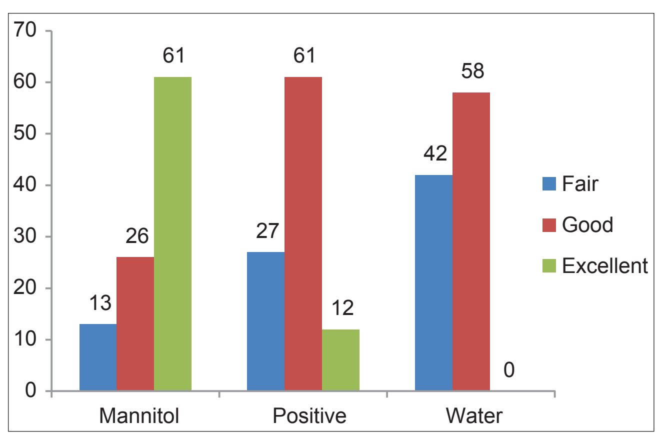

Figure 2: Comparison of large bowel distension

Table 1: Quantitative comparison of mean distension (in centimeters with two standard deviation) of bowel loops at various levels

	Stomach	Pylorus	D2	D3	Jejunum	Ileum	IC junction
Mannitol	8.4±1.20	3.37±0.67	1.84±0.39	1.66±0.34	1.93±0.36	2.11±0.25	1.42±0.45
Positive	7.8±0.96	3.17±0.62	1.83±0.35	1.64±0.28	1.70±0.34	1.71±0.23	1.34±0.52
Water	7.5±1.0	3.11±0.59	1.81±0.41	1.62±0.31	1.60±0.46	1.62±0.23	1.16±0.36

IC: Ileo-caecal

Table 2: Quantitative comparison of fold visibility in jejunum

	Grade 0 (%)	Grade I (%)	Grade II (%)
Mannitol	10	28	62
Positive	18	48	34
Water	18	43	39

Table 3: Quantitative comparison of fold visibility in ileum

	Grade 0 (%)	Grade I (%)	Grade II (%)
Mannitol	0	12	88
Positive	0	34	66
Water	17	40	43

Table 4: Quantitative comparison of fold visibility in IC junction

	Grade 0 (%)	Grade I (%)	Grade II (%)
Mannitol	10	19	71
Positive	34	31	35
Water	52	35	13

IC: Ileo-caecal

of the earlier imaging modalities in diagnosing various bowel conditions.[3,6] The combination of rapid image acquisition and widespread use of 64-slice CT scanners, which provide high quality multiplanar and three-dimensional volume-rendered images in any conceivable plane, produce remarkable images of a wide variety of intestinal abnormalities. The ability to visualize the bowel wall and to distend the lumen adds to the diagnostic capabilities of current abdominal CT examinations.

Since 1980's, there has been a constant debate on optimal bowel contrast media. All these years, positive intraluminal contrast media has dominated the scenario. The major limitation of positive contrast agent is obscuration of mucosal details, especially the distal small bowel and IC junction, which is the target of most small bowel pathologies.[4,5] Hence, an ideal endoluminal contrast agent should be of low attenuation, provide optimal luminal distension, and allow visualization of mural details. Various neutral and negative contrast media have been used in diagnostic imaging, which include mannitol, milk, PEG, water, and Volumen. The use of neutral luminal oral contrast agents combined with the volume capabilities of MDCT scanners allow radiologists to routinely visualize the bowel and its vascular supply and accurately diagnose ischemic, inflammatory, and neoplastic pathologies.[4,7-10]

Several landmark studies have proven that neutral contrast media are more advantageous than positive contrast media in MDCT evaluation of abdomino-pelvic pathologies.[4,11,12] The limitations of neutral contrast agents are encountered in patients with cystic tumors and abdomino-pelvic fluid collections, where distinguishing between the bowel loops and pathology might be a difficulty. In such a scenario, positive agents hold an advantage.[13] With the availability of advanced state-of-the-art systems and workstations, multi-planar reconstruction has permitted a better visualization of lesion in relation to other structures.

In our study, we found mannitol in water was the best agent for bowel distension, fold visualization, and homogeneity of the CT images [Figure 3A-C]. $P < 0.001$ was obtained with mannitol in all the aspects on overall comparison of different contrast agents. Achievement of optimal distension was the major aim of our study, and we observed that mannitol showed the best distension among the three agents. The fold visualization and mucosal details were best seen with mannitol. Water showed suboptimal distension, predominantly in the distal bowel loops due to its rapid absorption by the bowel mucosa. The better distension of bowel is due to higher osmotic effect of mannitol as compared with iodinated positive contrast media and water. High osmolarity of an oral contrast media is the most important and decisive factor for bowel distension.[14] Adequate distension was observed with positive contrast media also; however, loss of mucosal details was encountered.

Better homogeneity of the images was observed with mannitol due to similar attenuation of mannitol with the gastrointestinal (GI) secretions. This feature helps in better mucosal and wall delineation. Contrary to neutral contrast agents, positive agents result in obscuration of wall and mucosa predominantly in distal ileal loops due to increasing concentration resulting in artifacts. Appreciation of mucosal enhancement following intravenous contrast was unparalleled between neutral and positive contrast agent. This feature is of diagnostic importance in ischemic and inflammatory bowel disease.

Visualization and distension of IC with mannitol solution was unparalleled as compared to plain water or positive contrast agents. Delineation of wall and folds were much better with mannitol with $P < 0.005$ as compared to the plain water or ionic contrast agents. This feature is clinically significant as IC valve and terminal ileum is the target region of major infective/inflammatory diseases. It is a well-known

Table 5: Comparative table for qualitative analysis of overall bowel distension, fold visibility, and intraluminal homogeneity

	Distension (%)			Fold visibility (%)			Intraluminal homogeneity (%)		
	Fair	Good	Excellent	Fair	Good	Excellent	Fair	Good	Excellent
Mannitol	10	64	26	8	58	34	6	63	31
Positive	56	36	8	43	57	0	37	52	11
Water	49	51	0	56	44	0	55	45	0

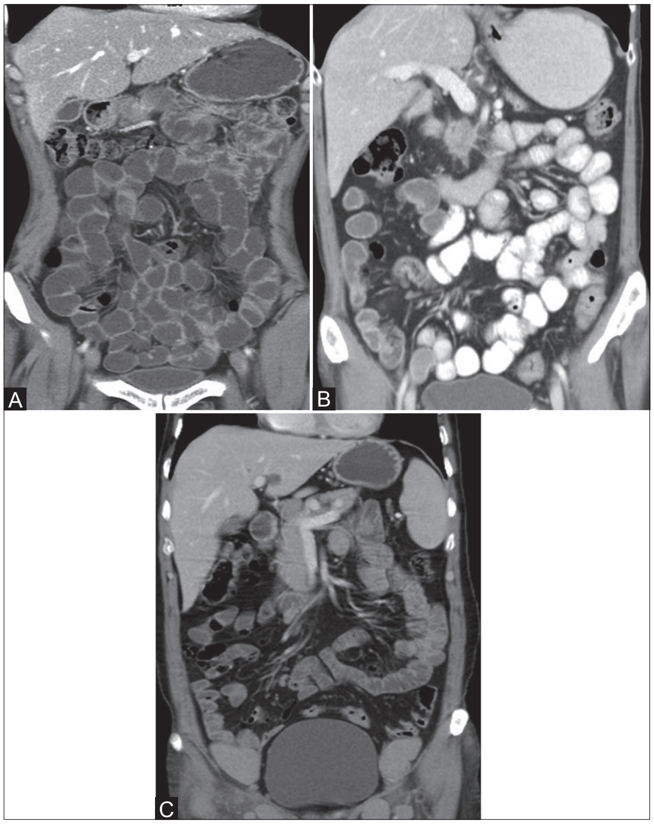

Figure 3 (A-C): Excellent and uniform small bowel distension with good small bowel wall/fold visualization and homogeneity of intraluminal content achieved by mannitol as compared to other two contrast agents. 3% mannitol (A), iodinated contrast (B), water without any additives (C)

fact that bowel wall delineation, both inner and outer wall of the bowel, depends on the content within the lumen, density of the content as well as on the amount of distension[15]. With positive contrast, bowel wall demonstration is poor because of high density causing artifacts and also because of partial volume averaging. Ileo-ceacal wall delineation, fold visualization, and enhancement were better appreciated in a group of patients who received mannitol, followed by plain water [Figure 4A-C].

Colonic distension [Figure 4D] was a feature that was achieved with mannitol due to its rapid transit and non-absorbable nature. This stood out as a distinctive feature and may have been due to be alteration of the time interval over which the contrast is given and volume alteration thus helped in achieving an optimal large bowel distension also. The colonic distension with this contrast agent can be extremely useful in assessment of pathologies

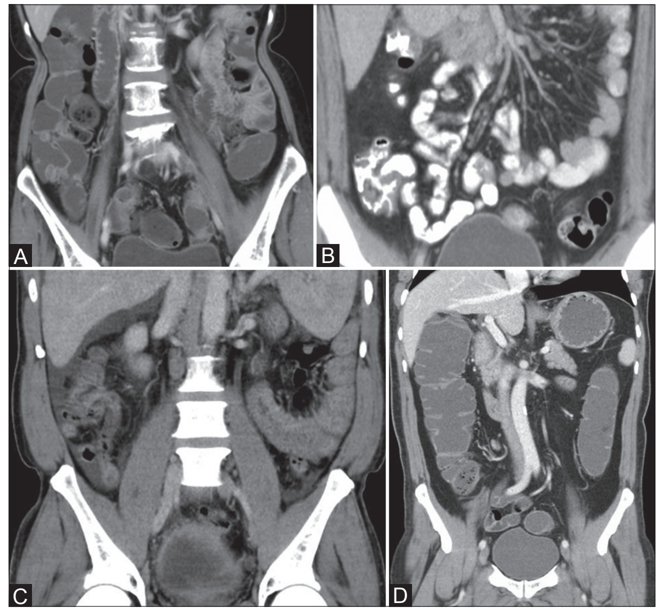

Figure 4 (A-D): Ileo-ceacal region distension obtained was comparable between mannitol (A) and iodinated contrast (B), but poor with water (C). Also, note the good large bowel distension achieved with mannitol (D)

like Crohn's disease and IC tuberculosis, especially in Indian subcontinent where it is rampant.

Mannitol-related bowel alteration was observed in few patients, which is a known effect of this agent due to its high osmolarity. Similar trends have been observed by previous authors, but this minimal discomfort should not be considered as the determining factor for using mannitol.[5,16]

To conclude, achieving uniform small bowel distension by using an hypodense intraluminal contrast, thereby allowing the visualization of internal mural features of small bowel wall, was the aim of this study. Small bowel distension till the jejunal loops was comparable with all three contrast group; however, the distal ileal, IC junction, and large bowel distension was better with mannitol, which is the basic requirement in most of bowel pathology. In addition to the distension, the visualization of mucosal features and homogeneity in the overall luminal content was significantly better with mannitol solution, a neutral contrast agent.

Hence, mannitol is an excellent endoluminal contrast agent in comparison to water and positive contrast agent. Mannitol proved to be better both quantitatively and qualitatively in bringing out small and large bowel distension, delineation of wall, IC valve visualization, and in providing improved overall image quality. It is also a cheap, effective, and well-tolerated endoluminal contrast agent with minimal adverse effects and could produce CT enteroclysis equivalent bowel distension.

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