

GASTROINTESTINAL TRACT WALL VISUALIZATION AND DISTENTION DURING ABDOMINAL AND PELVIC MULTIDETECTOR CT WITH A NEUTRAL BARIUM SULPHATE SUSPENSION: COMPARISON WITH POSITIVE BARIUM SULPHATE SUSPENSION AND WITH WATER

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Objective: When examining patients with contrast-enhanced multidetector-row CT, we determined if the stomach and small bowel were visualized and distended better with a neutral barium sulphate suspension than with positive barium sulphate suspension or water.

Materials and methods: After obtaining approval from our institutional review board, 156 patients (women: 84; mean age: 54 yrs) with no history of gastrointestinal tract disease were randomized prospectively to receive orally either 900 ml of neutral (0.1%w/v) barium sulphate suspension (n = 53), 900 ml of positive (2.1%w/v) barium sulphate suspension (n = 53), or 900 ml of water (n = 50), prior to undergoing contrast-enhanced abdominal and pelvic multidetector-row CT. Two independent radiologists evaluated the stomach, and small bowel, for luminal distension and wall visualization, using a five point scale. Results were compared using Kruskal-Wallis and Mann-Whitney U tests.

Results: The walls of the stomach, and small bowel were visualized better in patients who were administered neutral barium sulphate suspension than those who were administered either positive barium sulphate suspension ($p < 0.01$) or water ($p < 0.01$). In patients who received neutral barium sulphate suspension, the stomach and small bowel were distended better compared to patients administered water ($p < 0.01$); the stomach, duodenum, and ileum were distended better compared to patients administered positive barium sulphate suspension ($p < 0.05$).

Conclusions: When examining patients with intravenous contrast-enhanced abdominal and pelvic multidetector-row CT, orally administered neutral barium sulphate suspension allows the gastrointestinal tract to be visualized and distended better than either positive barium sulphate suspension, or water.

Key-words: Abdomen, CT – Pelvis, CT – Barium.

The stomach and small bowel are two of the most challenging organs to be assessed radiologically. The stomach is variable in shape and is often not distended. The small bowel is a long, tortuous, and tubular organ whose loops often overlap and are variable in their position (1). With the introduction of multidetector-row CT (MDCT), the entire abdomen and pelvis can be scanned during a short breathhold such that blurring due to motion is minimized. Furthermore, spatial resolution is improved and isotropic with the use of thin collimation (2). However, regardless of the technique used, the stomach and small bowel need to be distended for their lumen and walls to be evaluated (1, 3). The stomach can be examined fluoroscopically; and the small bowel with enteroclysis, a relatively invasive method using fluoroscopy or CT, that requires infusing contrast medium directly into the small bowel via a nasojejunal tube (4).

Positive oral contrast material is currently used for abdominal and pelvic CT scans, typically barium sulphate suspension (2.1%w/v). However, it often obscures the bowel wall and does not allow the enhanced bowel wall to be discriminated from dense luminal fluid. Also, positive oral contrast material may obscure other dense structures of interest, such as blood vessels and the urinary tract (2, 5-8). As a result, positive oral contrast material is typically not used during CT angiography and CT urography (9, 10). However, when oral contrast agent is not used, the small bowel is often collapsed and, therefore, the small bowel cannot be evaluated for masses and other abnormalities. At times, collapsed small bowel may mimic or obscure an abdominal mass or an abscess (11).

Water has been used as a neutral oral contrast agent for abdominal and pelvic CT (2, 12, 13). It is safe

and acceptable to patients (2, 10). Because the luminal fluid is hypodense, the enhancing wall can be visualized (2). However, water is absorbed rapidly by the stomach and proximal small bowel; as a result, the distal small bowel is rarely distended (2). A neutral barium sulphate suspension (0.1% w/v BaSO₄- VoLumen[®], EZEM, Lake Success, NY) has been developed for abdominal and pelvic CT with the purpose of providing a solution that results in luminal fluid attenuation that is close to water. Initial study with this agent showed good distention in patients with known or suspected pancreatic or biliary tract disease (14).

The purpose of this study was to determine if, when examining patients with abdominal and pelvic contrast-enhanced multidetector-row CT, the stomach and small bowel are visualized and distended better with a neutral barium sulphate suspension than with positive barium sulphate suspension or water.

Materials and methods

Patients and oral contrast media

From September 2004 to September 2005, outpatients scheduled for intravenous contrast-enhanced abdominal and pelvic MDCT were asked to participate in

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this study. Written informed consent was obtained from each enrolled patient. Inclusion criteria included patients who were 18 years of age or older, and without a history of gastrointestinal tract disease. The exclusion criteria included women known to be pregnant or lactating, patients known to be allergic to barium sulphate suspension, or patients on a restricted fluid diet or unable to drink fluid.

One hundred and fifty six consecutive patients who met the eligibility criteria were randomized prospectively to drink either 900 ml of low attenuation barium sulphate suspension (VoLumen[®], EZEM, Lake Success, NY) (n = 53), 900 ml of high attenuation barium sulphate suspension (ReadCat[®], EZEM, Lake Success, NY) (n = 53), or 900 ml of filtered tap water (n = 50) over approximately one-hour time period, prior to the multidetector-row CT scan. The initial randomization list included a larger number of patients to be examined. However, due to significant results on our periodic assessment the study was terminated earlier. At this time there was a smaller number of patients in the water group, which explains the small discrepancy between the 3 groups.

Both barium sulphate suspensions were fully prepared by the manufacturer in advance of the day of the scan, this including dilution with citric acid, natural gum, benzoic acid, sodium citrate, artificial blueberry flavor, potassium sorbate, purified water, saccharin sodium, simethicone emulsion, sodium benzoate, and sorbitol.

Patients who received neutral barium sulphate solution included 28 women and 25 men; 45 patients were white, 5 were black, and 3 were from other racial backgrounds. Indications for the MDCT scan included: staging cancer (n = 42), suspected liver lesion (n = 6), abdominal pain (n = 2), and 3 were performed for other indications (suspected pancreatic lesion, gluteal mass, and trauma). Mean age was 53 years (range: 21-80 years); mean weight was 78 kg (range: 43-127 kg, standard deviation: 19 kg); and mean height was 171 cm (range: 150-191 cm, standard deviation: 9 cm).

Patients who received high-density barium sulphate suspension included 31 women and 22 men; of whom 46 were white, 3 were black, and 4 were from other racial backgrounds. Indications for the study included: staging cancer (n = 36),

suspected liver lesion (n = 4), abdominal pain (n = 10), and 3 were performed for other indications (suspected pancreatic lesion, pancreatitis, and follow-up of enlarged perihepatic lymph nodes). Mean age was 53 years (range: 27-77 years); mean weight was 78 kg (range: 41-147 kg, standard deviation: 21 kg); and mean height was 169 cm (range: 150-191 cm, standard deviation: 11 cm).

Patients who received water included 25 women and 25 men; 43 of whom were white, 5 were black, and 2 were from other racial backgrounds. Indications for the study included: staging cancer (n = 37), abdominal pain (n = 4), hematuria (n = 3), follow-up of renal mass (n = 2), suspected liver lesion (n = 1), and in 3 patients there were other indications (suspected pancreatic lesion, splenic lesion, and lymphadenopathy). Mean age was 57 years (range: 28-78 years); mean weight was 78 kg (range: 39-125 kg, standard deviation: 19 kg); and mean height was 172 cm (range: 157-198 cm, standard deviation: 11 cm). Adverse reactions to one of the 3 oral contrast agents used were documented if reported by the patients.

Abdominal and pelvic MDCT scan technique

Patients underwent MDCT scans of the abdomen and pelvis with commercially available multidetector-row CT scanners (Sensation 4 and Sensation 16; Siemens Medical Solutions, Erlangen, Germany). All scans were performed 70 seconds after the IV administration of 100 ml of iopromide 300 mg I/mL (Ultravist 300[®], Berlex, Wayne, NJ), at a flow rate of 2-3 ml/sec using a mechanical power injector. Images were reconstructed as five mm axial sections with no overlap.

Image analysis

Images were evaluated independently by two radiologists with 18 and 7 years of experience in reading abdominal and pelvic CT scans, respectively; they were not informed about the type of oral contrast agent administered. Using a picture archiving and communication system (PACS) workstation (AGFA-Gevaert AG, Belgium) with monitor resolution of 1280 × 1024 pixels, wall visualization and distension of the stomach, duodenum, jejunum and ileum, were assessed using a qualitative five point scoring scale. Prior to the image analysis, a test session

with the readers was conducted by the study coordinator to review classification criteria and practice reading 10 cases that were not used for the study. Anatomic landmarks were used to define stomach, duodenum, and small bowel.

Bowel wall visualization and bowel distention were estimated. Bowel wall visualization (identification of bowel wall as a separate structure from the lumen content and adjacent structures) was graded as: 1.0 = not identified; 1.5 = identified in < 30% of the assessed segment; 2.0 = identified in 30-60% of the segment; 2.5 = identified in 61-80% of the segment; 3.0 = identified in > 80% of the segment. Distension was defined as separation of the lumen and was graded based on an estimate of both the amount of distention and the length of the distended segment. Bowel distention was graded as: 1.0 = no distention (lumen not visible in any portion of the segment); 1.5 = distended lumen identified in < 30% of the segment; 2.0 = distended lumen identified in 30-60% of the segment; 2.5 = distended lumen identified in 61-80% of the segment; 3.0 = distended lumen identified in > 80% of the segment.

Statistical analysis

Differences in demographic information between the groups were evaluated with chi-square test (gender and race) and ANOVA (age, weight, and height). Differences were considered statistically significant if $p < 0.05$. ANOVA was also employed to analyze differences in mean time interval between the MDCT scan and the start of ingestion.

For each reader, statistical analyses of the differences in mean scores for wall visualization and distention were performed using Kruskal-Wallis and Mann-Whitney U tests for each segment. Differences were considered significant if $p < 0.05$. Interobserver agreement for wall visualization and distention of each segment was evaluated using linear-weighted kappa statistics. Kappa statistics results were classified as: less than chance agreement (< 0), slight agreement (0.01-0.20), fair agreement (0.21-0.40), moderate agreement (0.41-0.60), substantial agreement (0.61-0.80), and almost perfect agreement (0.81-0.99) (15).

Results

There were no significant differences among the three groups



Fig. 1. — 22-year-old man with prior history of testicular cancer. Intravenous contrast-enhanced transverse CT scans of the abdomen and pelvis after oral administration of neutral barium sulphate suspension. Both readers graded the stomach (A) wall visualization and distention as 3.0. Jejunal (B) wall visualization was graded as 2.5, and distention as 2.5 and 2.0. Ileal (C) wall visualization was graded as 2.5, and distention as 2.5 and 2.0.



Fig. 2. — 51-year-old woman with prior history of lymphoma. Intravenous contrast-enhanced transverse CT scans of the abdomen and pelvis after oral administration of positive barium sulphate suspension. Both readers graded the stomach (A) wall visualization as 1.5, and distention as 2.0. Jejunal (B) wall visualization was graded as 1.5, and distention as 2.0. Ileal (C) wall visualization was graded as 1.0, and distention as 1.5.



Fig. 3. — 48-year-old woman for follow-up of suspected splenic lesion. Intravenous contrast-enhanced transverse CT scans of the abdomen and pelvis after oral administration of water. Both readers graded the stomach (A) wall visualization and distention as 2.0 and 1.5. Jejunal (B) wall visualization was graded as 2.0 and 1.5, and distention as 1.5. Ileal (C) wall visualization and distention were graded as 1.0.

regarding patients' gender and race, mean age, weight, and height. Using ANOVA, mean time interval between the MDCT scan and the start of ingestion of neutral barium sulphate (81 min), positive barium sulphate (91 min), and water (84 min) were not significantly different. None of the patients reported adverse reaction to the oral contrast media administered.

The walls of the stomach, duodenum, jejunum, and ileum were visualized better in patients who were administered neutral barium sulphate suspension than in patients who were administered either positive barium sulphate suspension or water (Fig. 1-3). Stomach and small bowel were also distended better in patients who were administered neutral barium sulphate suspension

compared to patients administered water; stomach, duodenum, and ileum were distended better compared to patients administered positive barium sulphate suspension (Tables I and II).

For reader 1, when comparing patients who were administered neutral barium sulphate suspension with those who were administered positive barium sulphate suspen-

Table I. — Comparison of mean scores for wall visualization and distention of anatomic segments assessed with contrast enhanced MDCT for reader 1.

CT Images Assessment		Barium Sulphate Suspensions		Water	p value #		
		0.1%	2.1%				
Wall visualization	Stomach	2.60	1.99	1.98	< 0.01	< 0.01	0.88
	Duodenum	2.31	1.87	1.85	< 0.01	< 0.01	0.83
	Jejunum	2.36	2.05	1.92	< 0.01	< 0.01	0.07
	Ileum	2.46	2.07	1.96	< 0.01	< 0.01	0.21
Distention	Stomach	2.48	2.10	1.95	< 0.01	< 0.01	0.24
	Duodenum	2.22	1.97	1.87	0.01	< 0.01	0.39
	Jejunum	2.25	2.07	1.84	0.09	< 0.01	0.01
	Ileum	2.32	2.15	1.87	0.03	< 0.01	0.01

Note. - Mean values of a 5-point scoring scale (1.0 = not identified; 1.5 = < 30%; 2.0 = 30-60%; 2.5 = 61-80%; 3.0 = > 80%)
p values comparing neutral 0.1% barium sulphate suspension with positive 2.1% barium sulphate suspension; neutral 0.1% barium sulphate suspension with water; and positive 2.1% barium sulphate suspension with water, respectively.

Table II. — Comparison of mean scores for wall visualization and distention of anatomic segments assessed with contrast enhanced MDCT by reader 2.

CT Images Assessment		Barium Sulphate Suspensions		Water	p value #		
		0.1%	2.1%				
Wall visualization	Stomach	2.57	1.89	1.94	< 0.01	< 0.01	0.76
	Duodenum	2.36	1.89	1.80	< 0.01	< 0.01	0.32
	Jejunum	2.33	2.00	1.93	< 0.01	< 0.01	0.23
	Ileum	2.38	1.94	1.90	< 0.01	< 0.01	0.42
Distention	Stomach	2.56	2.05	1.91	< 0.01	< 0.01	0.31
	Duodenum	2.36	2.02	1.86	< 0.01	< 0.01	0.16
	Jejunum	2.35	2.17	1.93	0.47	< 0.01	< 0.01
	Ileum	2.41	2.11	1.91	< 0.01	< 0.01	0.01

Note. - Mean values of a 5-point scoring scale (1.0 = not identified; 1.5 = < 30%; 2.0 = 30-60%; 2.5 = 61-80%; 3.0 = > 80%)
p values comparing neutral 0.1% barium sulphate suspension with positive 2.1% barium sulphate suspension; neutral 0.1% barium sulphate suspension with water; and positive 2.1% barium sulphate suspension with water, respectively.

sion, the wall of all segments (stomach, duodenum, jejunum, and ileum) were visualized better, and the stomach, duodenum and ileum distention were superior in patients who were administered neutral barium sulphate suspension. When comparing patients who were administered neutral barium sulphate suspension with those who were administered water, the walls of the stomach, duodenum, jejunum and ileum were visualized better, and there was improved distention of the stomach, duodenum, jejunum and ileum with neutral barium sulphate suspension. There were no differences for jejunal

distention between patients administered neutral and positive barium sulphate suspensions. When comparing patients who were administered positive barium sulphate suspension with those who were administered water, jejunal and ileal distention were better in patients who received positive barium sulphate suspension; and no differences were demonstrated in stomach and duodenum distention, and in wall visualization of all segments assessed.

For reader 2, when comparing patients who received neutral barium sulphate suspension with

patients who were administered positive barium sulphate suspension, the walls of the stomach, duodenum, jejunum, and ileum were visualized better; moreover there was improved distention of the stomach, duodenum, and ileum in patients who received neutral barium sulphate suspension. When comparing patients who were administered neutral barium sulphate suspension with those who received water, the wall of all segments (stomach, duodenum, jejunum, and ileum) were visualized better, and there was improved stomach, duodenal, jejunal and ileal distention

with neutral barium sulphate suspension. When compared to patients who received water, those administered positive barium sulphate suspension showed better jejunal, and ileal distention. No differences were demonstrated between patients administered positive barium sulphate suspension and water for stomach and duodenum distention, as well as for wall visualization of the stomach, duodenum, jejunum, and ileum.

Interobserver agreement for distention and wall visualization ranged from substantial to almost perfect between both readers ($\kappa = 0.63$ to 0.83).

Discussion

Our results show that the walls of the stomach and small bowel were visualized better in patients who were administered neutral barium sulphate suspension than those who were administered either positive barium sulphate suspension or water. The results of our study are in accordance with previous investigators who demonstrated that bowel wall was visualized better with other neutral oral contrast agents, such as lactulose (16), mannitol (17, 18), cellulose (19), methylcellulose (20), mucofalk diluted in water (Falk, Feiburg, Germany) (1, 21), and polyethylene glycol (2, 22). Some of these solutions are widely used, particularly in Europe. However, unlike the neutral barium sulphate suspension used on our study, these agents caused either side effects such as abdominal cramping, gas and diarrhea, or tasted poorly (2).

Our results showed that the stomach, duodenum, and ileum were distended better in patients who received neutral barium sulphate suspension, compared to patients administered positive barium sulphate suspension. Similar results were found in a recent study of patients with known or suspected pancreatic or biliary tract disease, in which patients received neutral barium sulphate suspension, water with methylcellulose and positive barium sulphate suspension (14). However, this study had some important limitations. First, patients who received positive barium sulphate suspension were not enrolled in a randomized fashion at the time the other two groups were enrolled. Furthermore, patients who ingested positive barium sulphate suspension ingested the contrast material over a longer period of time, and received water in addition

to the oral contrast media; both factors may have interfered with gastrointestinal tract distention and wall visualization in the positive barium sulphate group. In our study, all patients were randomized, and all patients received the same amount of oral contrast material over the same period of time prior to scanning. Our results therefore validate that neutral barium sulphate suspension improves bowel distention.

Our results also demonstrated that barium sulphate suspensions (neutral and positive) are better than water in distending the small bowel. Stabilizing agents within the barium sulphate suspensions improve transit and limit absorption across the intestinal wall (14), leaving more contrast material to distend the distal small bowel.

The stomach and small bowel walls were visualized poorly with positive barium sulphate suspension and water. Positive barium sulphate suspension does not allow the enhanced bowel wall to be discriminated from dense luminal fluid. The stomach and small bowel walls were not visualized well with water because of the lack of distention.

Our study was limited because the readers could not be blinded to all types of contrast agents used; the positive barium sulphate suspension could be identified by its appearance. However, the readers were not able to differentiate neutral barium sulphate suspension from water. Furthermore, our assessment was semi-quantitative. However, our study included 2 blinded independent readers and interobserver agreement was substantial to almost perfect. Also, bowel diameters typically vary in each patient due to peristalsis making a quantitative analysis inaccurate to some degree too.

In summary, when examining patients with intravenous contrast-enhanced abdominal and pelvic multidetector-row CT, orally administered neutral barium sulphate suspension allows the gastrointestinal tract to be visualized and distended better than either water, or positive barium sulphate suspension.

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