Hydro-MRI of the Small Bowel: Effect of Contrast Volume, Timing of Contrast Administration, and Data Acquisition on Bowel Distention

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OBJECTIVE. The purpose of this study was to assess oral contrast agents, volumes of the agents, and time points of data acquisition in regard to small-bowel distention and patient acceptance.

SUBJECTS AND METHODS. Six healthy volunteers underwent imaging on 16 different days. Four volumes (450, 900, 1,350, and 1,800 mL) of each of the four contrast compounds (0.2% locust bean gum plus 2.5% mannitol, VoLumen containing 2.0% sorbitol, VoLumen containing 1.4% sorbitol, and tap water) were used. Two-dimensional true fast imaging with steady-state free precession data sets were acquired at 5-minute intervals after contrast ingestion. Distention values for small-bowel segments (duodenum, proximal and distal jejunum, ileum) and occurrence of side effects were documented.

RESULTS. Analysis of bowel distention revealed significantly greater distention for all carbohydrate sugar alcohol–containing solutions compared with water but no significant difference among the three contrast agents. Sufficient duodenal distention was achieved with 900 mL of any of the contrast agents, but imaging had to be performed soon after ingestion. For MRI of the distal jejunum and ileum, a volume of 1,350 mL is preferable, and the time point of data acquisition plays a minor role. Ingestion of 1,800 mL of the carbohydrate sugar alcohol solutions led to a significantly higher rate of side effects such as abdominal cramps than did ingestion of smaller volumes.

CONCLUSION. The data indicate that sufficient contrast consumption and optimal timing of data acquisition are essential to distention of the small bowel. Oral contrast agent protocols should be adapted to the bowel region in question.

Keywords: abdominal imaging, bowel distention, data acquisition, MRI, oral contrast agents, small bowel

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Routine cross-sectional imaging procedures require delineation of the small bowel. Assessment of the pancreatic parenchyma by CT or MRI can be improved by duodenal distention [1, 2]. To that end, oral ingestion of water before the examination has been proposed [1–3]. Furthermore, evaluation of the small bowel itself requires complete distention and delineation of small-bowel loops, which are often collapsed and nondistended in their physiologic state. Various strategies have been used to ensure sufficient small-bowel filling. Administration of contrast agents through a duodenal tube usually leads to homogeneous small-bowel distention [4, 5]. However, this approach makes the procedure invasive, and the fluoroscopic guidance exposes the patient to ionizing radiation.

To avoid the drawbacks, oral administration of liquid contrast medium seems to be an attractive alternative to insertion of a tube. Water, which is ideal in terms of cost and patient tolerance, has been proposed for small-bowel MRI [6, 7]. Use of water, however, has a poor distention rate because water is quickly resorbed in the gastrointestinal tract. Various additives have been shown to decrease water resorption and have been proposed as oral contrast agents for cross-sectional imaging [8–11]. To our knowledge, there is no general agreement regarding required volumes of contrast agents, timing of administration of the agents, or timing of data acquisition to visualize small-bowel loops. Our aim was to assess oral contrast agents, volumes of contrast agents, and time points of data acquisition in regard to small-bowel distention and patient acceptance.

Subjects and Methods

Subjects

Six healthy volunteers (four women, two men; median age, 36 years; age range, 28–47 years; median body mass index, 23.3; body mass index range, 18–28) were included in this study. Any history of gastrointestinal disease or gastrointestinal symptoms (postprandial belching, nausea, early satiety) was excluded with use of a standardized ques-

tionnaire. The study protocol was approved in accordance with the local institutional review board. Written informed consent was obtained from all subjects before they were examined. Each volunteer underwent 16 MRI examinations on separate days. The interval between examinations was at least 24 hours.

Oral Contrast Agents

Four oral contrast agents were tested. In a baseline examination, tap water was used (agent A). The other compounds were a homemade hydrosolution (agent B) containing 0.2% locust bean gum and 2.5% mannitol and two commercially available solutions: VoLumen containing 1.4% sorbitol (E-Z-EM) (agent C) and VoLumen containing 2.0% sorbitol (E-Z-EM) (agent D). To assure homogeneity of bowel activity for all subjects and examinations, MRI was performed after a 4-hour fasting period. Before each examination, the volunteers were asked to ingest 450 mL, 900 mL, 1,350 mL, or 1,800 mL of contrast agent. Ingestion was done at a steady, evenly distributed rate of approximately 40 mL/min. Ingestion time was measured with a stopwatch. After ingestion of the first 100 mL of each solution, 100 mg erythromycin was administered IV to enhance gastric emptying [12, 13]. The examinations were performed in a randomized order regarding type and volume of oral contrast compound.

MRI Examination Protocol

MRI examinations were performed on a 1.5-T MRI system (Magnetom Sonata, Siemens Medical Solutions) equipped with a high-performance gradient system characterized by a maximum gradient amplitude of 40 mT/m and a slew rate of 200 mT/m/ms. For signal reception a set of two large flex surface coils were used to obtain coverage of the entire abdomen and pelvis. Neither a spasmolytic agent nor paramagnetic contrast compound was used. Coronal 2D images were collected with the subject in the prone position and performing a breath-hold. True fast imaging with steady-state free precession sequence parameters were as follows: TR/TE, 4.3/2.15; flip angle, 70°; field of view, 50 cm; slice thickness, 3 mm; intersection gap, 0.3 mm; matrix size, 201 × 256; acquisition time, 20 seconds. Data acquisition was performed seven times: immediately after contrast ingestion (time = 0) and 5, 10, 15, 20, 30, and 45 minutes after ingestion. During this time period, patients stayed in the imager.

Data Analysis

The data sets were evaluated on a postprocessing workstation (Virtuoso, Siemens Medical Solutions). In a first step the small bowel was divided into four segments: duodenum, proximal jejunum, distal jejunum, and ileum. Images were analyzed in a consensus mode by two radiologists blinded to dose and type of oral contrast agent and to data acquisition time. They quantified bowel distention for each segment using a visual 5-grade ranking (5 = very good distention, 1 = collapsed bowel).

Twenty-four hours after each MRI examination, the subjects were questioned about the occurrence of side effects such as diarrhea, flatulence, vomiting, regurgitation, and abdominal spasms. For this purpose, a standardized questionnaire with a 4-point scale (1 = no side effects, 4 = severe side effects) was used. In addition, subject acceptance concerning volume, taste, consistency, and smell of each of the four contrast agents was documented with a 4-point scale (1 = no objections, 4 = severe objections). Results for each contrast agent in regard to distention, side effects, and acceptance were compared by use of a Wilcoxon rank test.

Results

Subjects ingested 450 mL, 900 mL, and 1,350 mL of each contrast compound at the predetermined rate of 40 mL/min. The target time of ingesting 1,800 mL within 45 minutes was achieved by all volunteers for contrast agents A (water) and B (locust bean gum/mannitol). However, consumption of 1,800 mL of hydrosolution agents C and D was prolonged as much as 65 minutes because of higher viscosity and intense taste. Mean bowel distention results for all six volunteers are displayed in Tables 1 and 2.

Distention of Small-Bowel Segments

Average distention values for single bowel segments are shown in Figure 1. Loops of

TABLE 1: Distention Grade of Small-Bowel Segments Over Time for Four Oral Contrast Agents

Segment	Agent	0 min	5 min	10 min	15 min	20 min	30 min	45 min	Mean
Duodenum									
Mean		3.8	3.5	3.2	3.2	3.1	2.6	2.4	3.1
Range	A	3.5	3.2	3.0	2.8	2.7	2.0	1.9	2.7
	B	4.0	3.7	3.5	3.5	3.3	2.8	2.5	3.3
	C	3.8	3.5	3.1	3.0	2.9	2.8	2.5	3.1
	D	3.9	3.6	3.2	3.3	3.1	2.8	2.8	3.2
Jejunum, proximal									
Mean		2.5	2.3	2.3	1.9	1.9	1.7	1.6	2.1
Range	A	2.1	2.0	1.8	1.7	1.7	1.6	1.5	1.8
	B	2.9	2.4	2.5	2.1	2.1	2.0	1.6	2.2
	C	2.7	2.7	2.5	2.2	2.1	1.7	1.8	2.2
	D	2.9	2.6	2.4	2.0	2.0	1.7	1.7	2.2
Jejunum, distal									
Mean		2.8	2.8	2.9	2.7	2.7	2.5	2.4	2.7
Range	A	2.1	2.0	2.0	1.7	1.9	1.9	1.6	1.9
	B	3.1	3.0	3.2	3.2	3.2	2.8	2.6	3.0
	C	2.8	2.9	3.1	3.0	2.9	2.9	3.0	2.9
	D	3.2	3.3	3.3	3.0	2.9	2.6	2.5	2.9
Ileum									
Mean		3.2	3.4	3.5	3.6	3.7	3.7	3.8	3.6
Range	A	2.2	2.4	2.3	2.2	2.3	2.3	2.3	2.3
	B	3.6	3.9	4.1	4.1	4.3	4.5	4.6	4.1
	C	3.4	3.6	3.7	3.8	3.9	4.0	4.0	3.8
	D	3.6	3.9	4.0	4.0	4.1	4.2	4.2	4.0

Note—Distention grades of the four small-bowel segments for 45 minutes after ingestion one of four contrast agents without regard to volume of the agent. A = water, B = locust bean gum with mannitol, C = VoLumen (E-Z-EM) with 1.4% sorbitol, D = VoLumen with 2% sorbitol.

TABLE 2: Distention Grade of Small-Bowel Segments for Four Volumes of Contrast Agents

Segment	Agent	450 mL	900 mL	1,350 mL	1,800 mL	Mean
Duodenum						
Mean		2.7	3.2	3.3	3.1	3.1
Range	A	2.3	3.1	2.8	2.8	2.7
	B	3.2	3.3	3.5	3.2	3.3
	C	2.7	3.2	3.3	3.1	3.1
	D	2.7	3.2	3.7	3.3	3.2
Jejunum, proximal						
Mean		1.9	2.1	2.5	2.2	2.2
Range	A	1.6	2.1	2.0	1.7	1.8
	B	2.0	2.2	3.0	2.7	2.5
	C	2.0	2.3	2.4	2.4	2.2
	D	2.0	2.0	2.6	2.2	2.2
Jejunum, distal						
Mean		2.2	2.7	3.1	2.8	2.7
Range	A	1.3	2.0	1.9	2.2	1.9
	B	2.4	2.8	3.6	3.3	3.0
	C	2.8	2.9	3.5	2.7	2.9
	D	2.5	3.0	3.5	2.9	2.9
Ileum						
Mean		2.8	3.5	4.0	4.0	3.6
Range	A	1.8	2.4	2.5	2.4	2.3
	B	3.2	3.9	4.6	4.9	4.1
	C	2.9	3.7	4.5	4.1	3.8
	D	3.3	3.9	4.3	4.5	4.0

Note—Overall distention grade of the four small-bowel segments for 45 minutes after ingestion of contrast material in four volumes. A = water, B = locust bean gum with mannitol, C = VoLumen (E-Z-EM) with 1.4% sorbitol, D = VoLumen with 2% sorbitol.

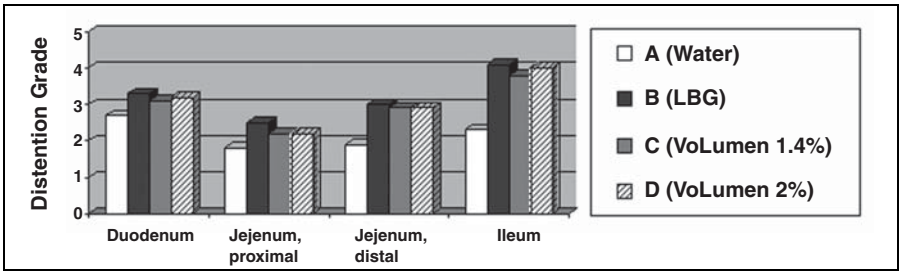


Fig. 1—Graph shows differences in average distention values at all time points of data acquisition for small-bowel segments. Least distention occurred in proximal jejunum (mean grade, 1.8). Most distention occurred in ileum (maximum rating, 4.1). LBG = locust bean gum with mannitol. VoLumen, E-Z-EM.

proximal jejunum had the least distention with a mean value of 1.8. The most distention occurred in the ileum (maximum rating, 4.1).

Influence of Type of Contrast Medium

Mean bowel distention values for all acquisition time points and volumes are shown in Figure 2A. For the duodenum and proximal jejunum, there were no statistically significant differences among the four substances (Figs. 2B–2E). Water, however, proved inferior to all other agents in distention of the distal jejunum (1,350 mL of contrast agent: A over B, $p = 0.028$; A over C, $p = 0.028$; A over D, $p = 0.028$) and ileum (Figs. 2F–2I) (1,350 mL of contrast agent: A over B, $p = 0.028$; A over C, $p = 0.028$; A over D, $p = 0.028$). There was no statistical difference among agents B, C, and D for those small-bowel segments.

Timing of Data Acquisition

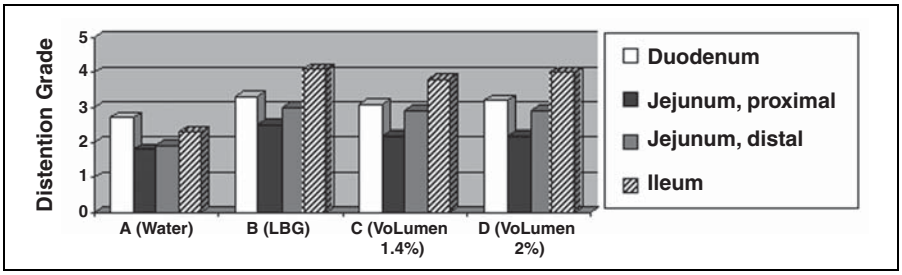
Average distention ratings depending on the time point of image acquisition are displayed in Figure 3A. Data analysis for the duodenum and proximal jejunum showed that prompt data acquisition after ingestion was essential (Figs. 3B–3F). Fifteen minutes after ingestion, distention decreased significantly in these two bowel segments (duodenum: time = 0 over time = 15 minutes, $p = 0.028$; proximal jejunum: time = 0 over time = 15 minutes, $p = 0.028$). For the distal jejunum and ileum, however, distention did not show statistically significant differences for imaging 20–45 minutes after contrast ingestion (Figs. 3G–3K).

Influence of Contrast Volume

Results for the four contrast volumes are shown in Figure 4A. A volume of 1,350 mL gave the best mean results for contrast agents B, C, and D, and these results did not improve with expansion of the volume to 1,800 mL. For the duodenum (Figs. 4B–4F) and the proximal jejunum, the increase in distention with administration of 900 mL, 1,350 mL, and 1,800 mL of agent was only moderate (duodenum: 900 mL over 1,800 mL, $p = 0.674$; proximal jejunum: 900 mL over 1,800 mL, $p = 0.674$). Expanding the dose from 450 mL to 1,350 mL, however, improved distention of the distal jejunum and ileum (Figs. 4G–4K) in a statistically significant different way (distal jejunum: 450 mL over 1,350 mL, $p = 0.028$; ileum: 450 mL over 1,350 mL, $p = 0.028$).

Side Effects and Patient Acceptance

There were no side effects after ingestion of tap water at any of the four doses. The questionnaire results for acceptance of the contrast agents showed no significant difference regarding volumes of 450–1,350 mL, which were associated with no or only mild side effects and no or only mild objections (Fig. 5). Consumption of 1,800 mL of contrast agent, however, led to a significantly higher rate of side effects compared with lower volumes (450 mL, 900 mL, 1,350 mL over 1,800 mL, $p = 0.024$, $p = 0.028$, $p = 0.028$, respectively) because of diarrhea and



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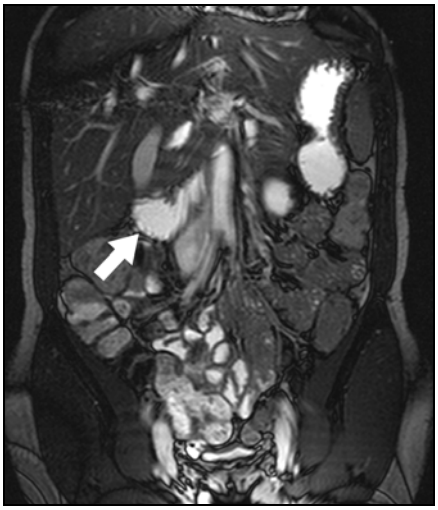

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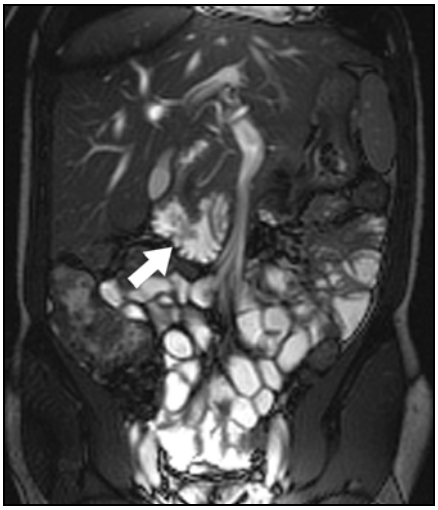

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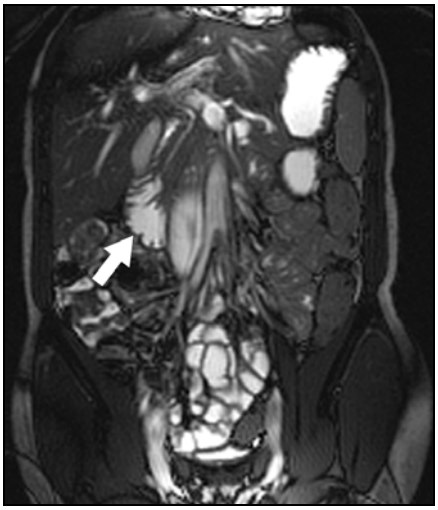

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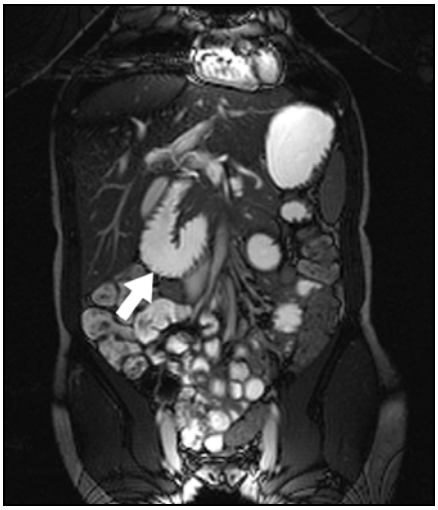

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Fig. 2—Influence of type of contrast medium.
A, Graph shows mean grade of bowel distention after ingestion of one of four contrast media without regard to acquisition time points or volume. For duodenum, there were no statistically significant differences between substances. Water, however, proved inferior to other agents for distention of proximal and distal jejunum and ileum. There was no statistical difference among agents B, C, and D for those bowel segments. LBG = locust bean gum with mannitol.
B–E, 29-year-old woman in good health. MR images show influence of type of contrast medium on duodenum. For duodenum there were no statistically significant differences between substances. All agents administered at volume of 900 mL.
B, Water.
C, Locust bean gum with mannitol.
D, VoLumen (E-Z-EM) with 1.4% sorbitol.
E, VoLumen with 2% sorbitol.
(Fig. 2 continues on next page)

abdominal cramps (mean score: 2.8 for agent B; 3.7 for agent C, and 3.8 for agent D).

Discussion

MRI of the small bowel in conjunction with oral administration of a contrast agent is feasible, and there are various methods of optimizing this imaging technique. Administration of water alone leads to significantly less bowel distention than the use of an oral contrast agent containing osmotic or nonosmotic additives, which reduce resorption of water in the gastrointestinal tract. In addition, there is no linear correlation between the volume of contrast agent used and the corresponding bowel distention. Rather, a certain amount of contrast agent gives peak bowel distention, which cannot be increased with a larger volume of contrast agent. Imaging techniques should be adapted to the bowel segments in question in terms of contrast dose and timing of data acquisition.

Luminal distention is key to diagnostic imaging of the small bowel [14–16] because collapsed bowel loops can hide even large lesions and give the false appearance of wall thickening [4, 17, 18]. For cross-sectional bowel imaging with CT or MRI, distention can be achieved with a technique analogous to conventional enteroclysis [19–22]. After insertion of a duodenal tube, large amounts of a contrast agent such as methylcellulose can be administered within a relatively short time. This technique results in excellent bowel distention and high sensitivity and specificity in the detection of inflammatory lesions [23]. However, the practicability of MR and CT enteroclysis is restricted because of patient discomfort and technical complexity. The nasojejunal tube must be inserted under fluoroscopic guidance. This procedure requires the use of two diagnostic rooms and movement of the patient between examinations. In addition, the procedure is associated with exposure to ionizing radiation. This limitation is particularly undesirable in examinations of young patients, who often need several imaging examinations for therapeutic monitoring. Finally, many patients consider nasojejunal intubation unpleasant and invasive [24]. Thus strategies have been evaluated for obviating nasojejunal intubation for MRI of the small bowel.

The first approaches without intubation were based on oral administration of tap water alone. Lomas and Graves [7] performed small bowel MRI on eight volunteers who had ingested of 1–2 L of water. Rapid acqui-

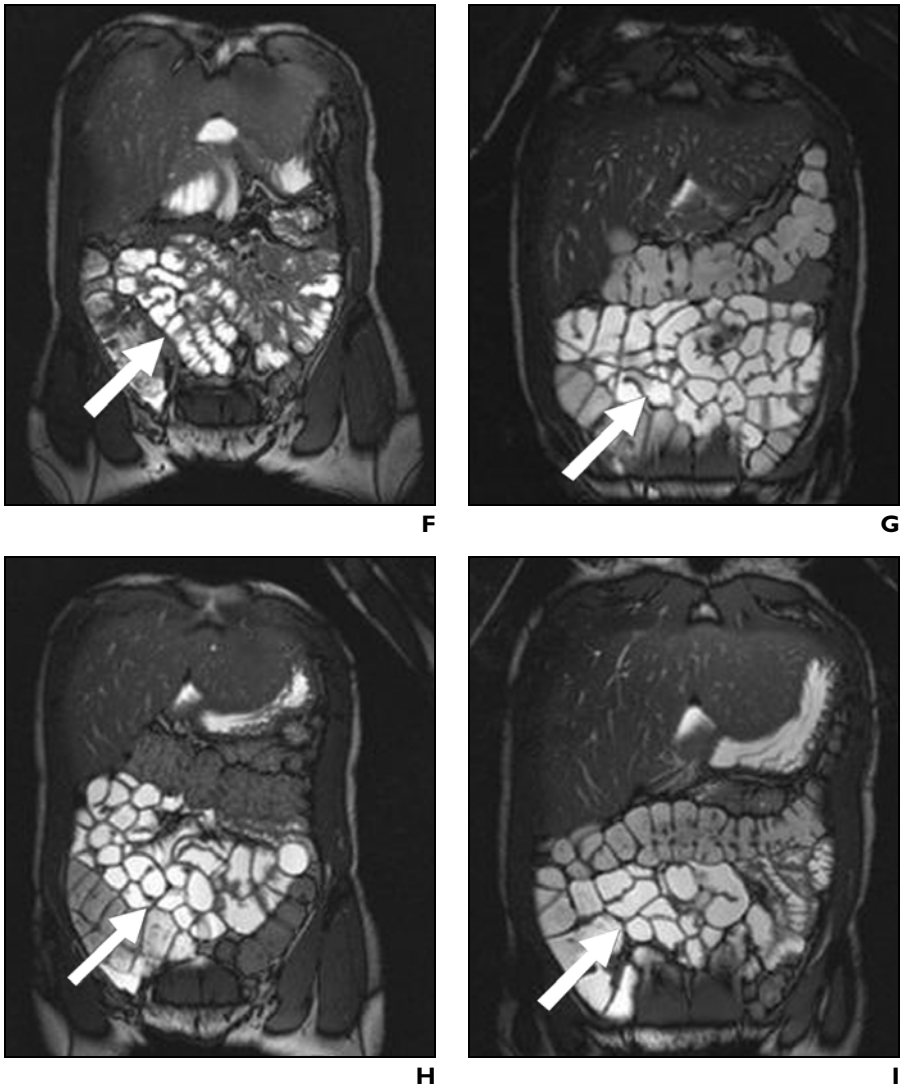


Fig. 2 (continued)—Influence of type of contrast medium.
F–I, 28-year-old man in good health. MR images show influence of type of contrast medium on ileum (*arrow*). There was no statistical difference among agents in regard to ileal distention. All agents administered at volume of 1,350 mL.
F, Water.
G, Locust bean gum with mannitol.
H, VoLumen with 1.4% sorbitol.
I, VoLumen with 2% sorbitol.

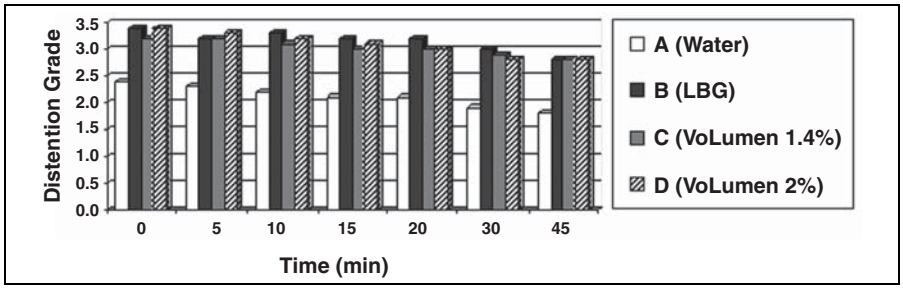


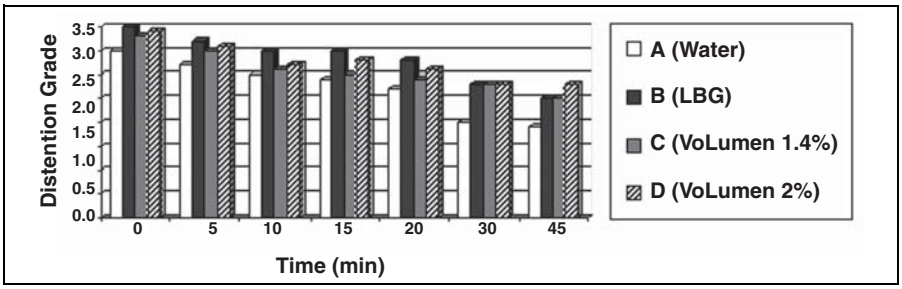
Fig. 3—Timing of data acquisition.
A, Graph shows mean distention values of all bowel segments depending on time point of image acquisition. LBG = locust bean gum with mannitol.
(Fig. 3 continues on next page)

sition with relaxation enhancement sequences (half-Fourier single-shot rapid acquisition with relaxation enhancement) were acquired at 15-minute intervals until the terminal ileum was visualized. Although the proximal parts of the small bowel could be assessed in all subjects, the water column reached only the terminal ileum in six of the eight subjects because of fast intestinal resorption. This drawback can be considered serious because inflammatory bowel disease is predominantly found in this part of the small intestine [25]. These results were confirmed by our findings: oral water administration led to the worst distention of all tested contrast solutions, and the greatest discrepancy was in the ileum.

Contrast compounds should contain additives that bind intraluminal liquid. Various solutions have been evaluated and are in clinical use. Sood et al. [26] compared the effects of polyethylene glycol solutions on bowel distention with the effects of water. Twenty-two volunteers were examined on 2 days. Ingestion of polyethylene glycol resulted in significantly better visualization of the distal small bowel segments. The usefulness of polyethylene glycol as an oral contrast compound has been confirmed in several clinical studies [27, 28] involving patients with Crohn's disease or celiac disease. Other authors have shown the value of contrast solutions containing osmotic carbohydrate sugar alcohols such as sorbitol and mannitol [29]. Our results showed that any of the three contrast compounds containing sorbitol or mannitol had higher distention values than the baseline examination with water. Although the results were not statistically significant for all bowel segments, the mannitol solution tended to give the most distention.

Although the benefit of solutions containing carbohydrate sugar alcohols or similar substances has been proved in several clinical trials, one study showed controversial results with water. Wold et al. [30] assessed two CT enterography protocols: a noninvasive technique with water administered orally and CT enteroclysis in conjunction with duodenal intubation. Twenty-three patients with known or highly suspected Crohn's disease were included. Results of the CT examinations were compared with those of fluoroscopic examinations and endoscopic findings. The noninvasive oral water CT protocol turned out to provide the same level of bowel distention as CT entero-

clysis. These results may appear to be surprising and discordant with those of other studies showing no practicability of oral water administration. The study by Wold et al. was conducted with a highly selected patient cohort, mainly of patients with severe active inflammation. The presence of inflammatory bowel stenosis resulting in prestenotic bowel dilatation may explain



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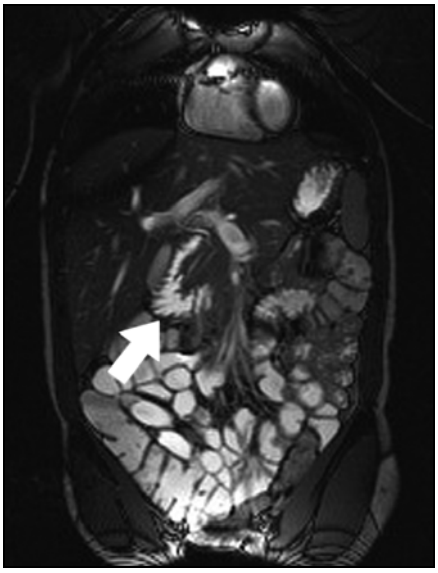

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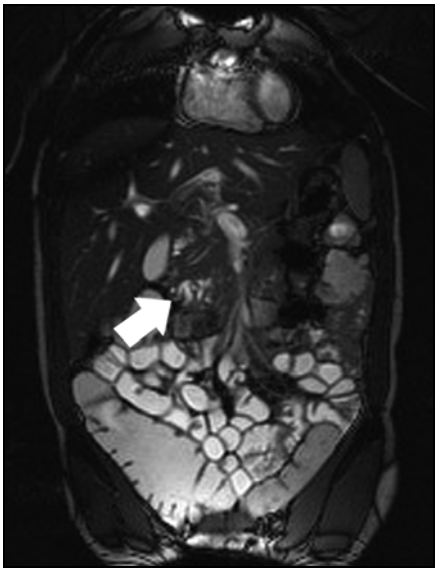

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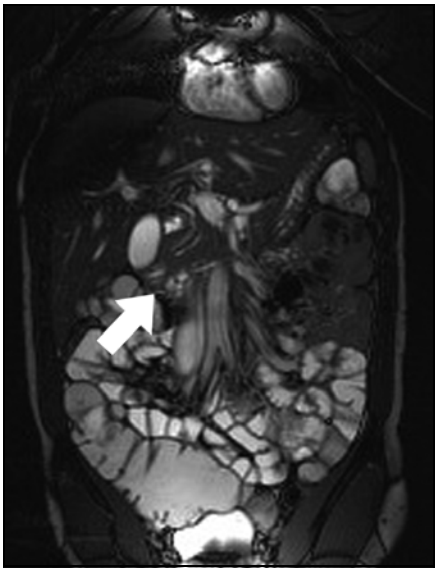

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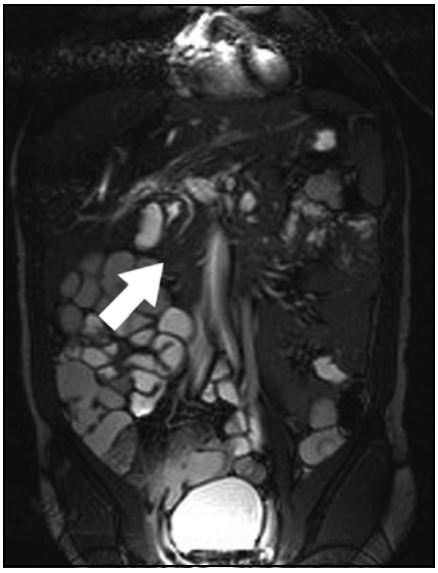

F

Fig. 3 (continued)—Timing of data acquisition.
B, Graph of results of data analysis for duodenum shows prompt data acquisition after ingestion was essential. Fifteen minutes after ingestion, distention decreased significantly in duodenum and proximal jejunum.
C–F, 29-year-old woman in good health. MR images of duodenum (*arrow*) obtained with 1,350 mL locust bean gum with mannitol. Data analysis showed prompt data acquisition after ingestion was essential in duodenum and proximal jejunum.
C, Time zero.
D, Fifteen minutes after contrast ingestion, distention is significantly decreased.
E, Thirty minutes after contrast ingestion.
F, Forty-five minutes after contrast ingestion.
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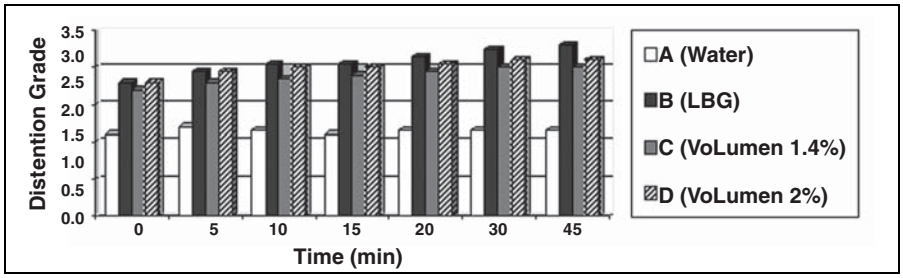

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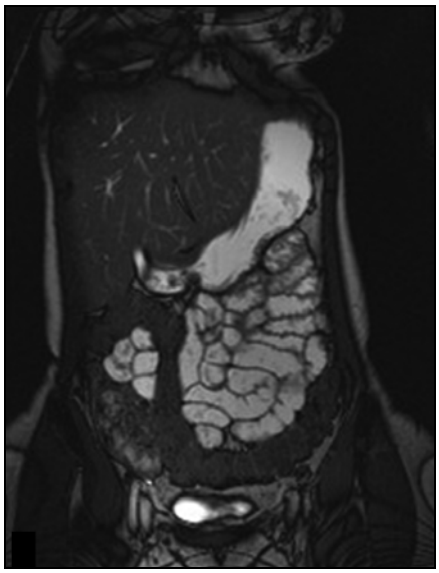

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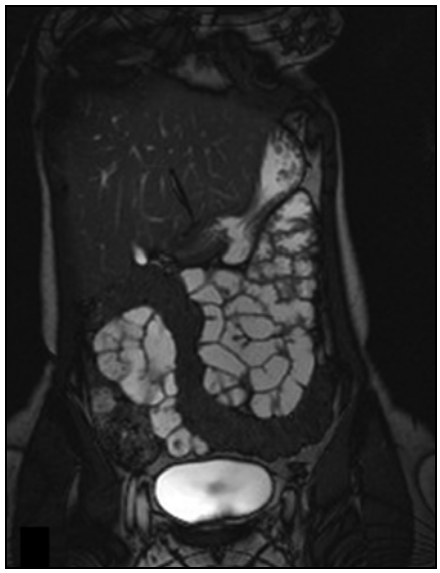

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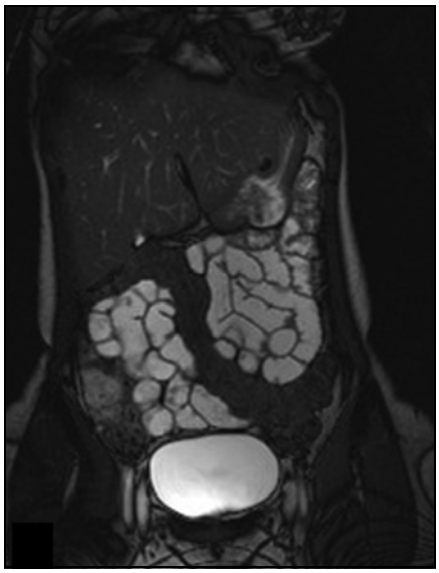

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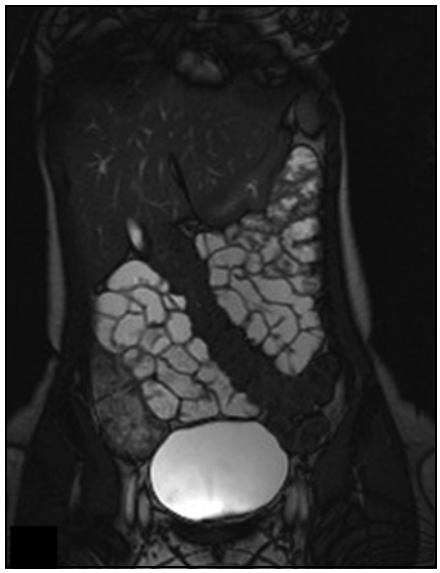
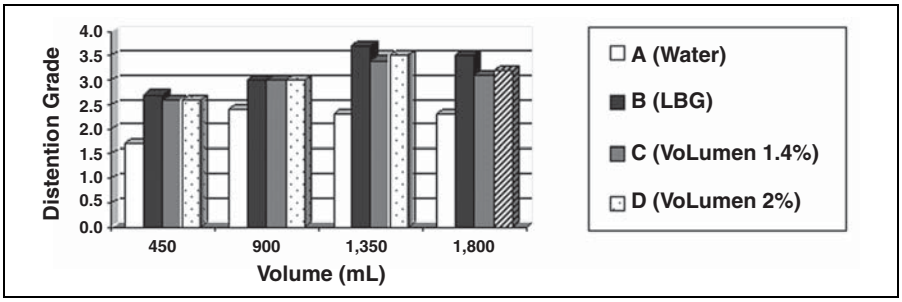


K

Fig. 3 (continued)—Timing of data acquisition.
G, Graph shows ileal distention had no statistically significant differences for imaging between time zero and 45 minutes after contrast ingestion.
H–K, 29-year-old woman in good health. MR images obtained with 1,350 mL VoLumen (E-Z-EM) with 1.4% sorbitol show ileum. Ileal distention had no statistically significant differences for imaging between time zero and 45 minutes after contrast ingestion.
H, Time zero.
I, Fifteen minutes after contrast ingestion.
J, Thirty minutes after contrast ingestion.
K, Forty-five minutes after contrast ingestion.

why both CT protocols had comparable distention ratios. Oral water administration may provide only moderate distention in patients with slight or no inflammatory bowel disease, thereby leading to false-negative or false-positive results.

Although CT and MRI techniques for small-bowel imaging are increasingly used and various oral contrast agents have been



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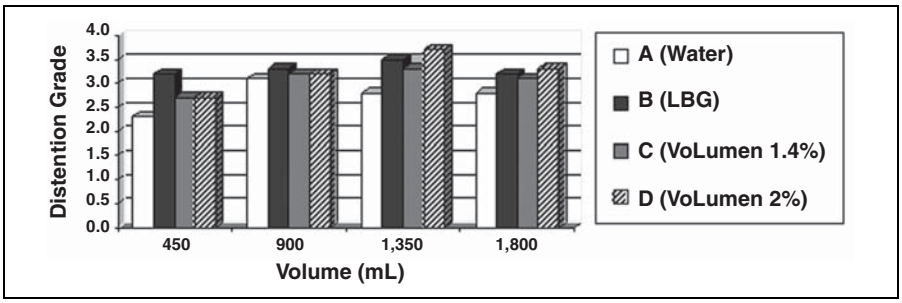

B

Fig. 4—Influence of contrast volume.
A, Graph shows results for all small-bowel segments. Volume of 1,350 mL had best mean results for contrast agents B, C, and D. Results did not improve with increase in volume to 1,800 mL. LBG = locust bean gum with mannitol.
B, Graph shows moderate increase in duodenal distention with administration of 450 mL, 900 mL, and 1,350 mL of contrast agent.
(Fig. 4 continues on next page)

propagated, there are no general guidelines for the required contrast dose or timing of administration and imaging. Some authors recommend that contrast ingestion take as long as 4 hours [9]. In other protocols, the solutions are ingested as fast as possible. Patients than stay in the imager, and imaging is repeated until the terminal ileum is appropriately visualized [7]. The latter strategy decreases the practicability of small-bowel imaging, because imagers may have to be scheduled for larger blocks of time. Our findings can facilitate imaging protocols for both CT and MRI examinations. The contrast media and data acquisition times used depend on the bowel segment being explored. Distention of the duodenum is adequate with only a small amount of contrast agent (450 mL). However, data acquisition should be performed immediately after oral contrast administration, because bowel distention decreases rapidly. For more distal parts of the small bowel, larger contrast volumes are preferable, but bowel distention is fairly stable at a high level for 45 minutes. This fact may be explained by the physiologic processes of small-bowel motility: distention of distal small-bowel segments induces a decrease in bowel motility by neuronal and hormonal feedback mechanisms [31]. Once marked distention is achieved, the effect is twofold: distention is fairly constant, and a further increase in contrast volume does not improve bowel distention. This effect may be why the contrast dose of 1,800 mL did not improve image quality. Lack of patient acceptance and occurrence of side effects may be additional arguments for not using larger contrast volumes. Except for the water-based examination, there was a high incidence of side effects such as diarrhea and abdominal spasms after ingestion of 1,800 mL of the contrast agents.

The present study was not without limitations. Data were acquired for a population of healthy volunteers. We do not know whether conclusions drawn from our results are transferable to patients with inflammatory or other bowel diseases. It is debatable whether a patient with symptoms such as abdominal pain and nausea would be able to ingest a contrast volume greater than 1,000 mL. However, patients should be motivated to reach the target and ingest more than 1,000 mL of the agent for sufficient visualization of distal small-bowel segments. Successful results with the proposed small-bowel imaging strategy will have to be proved with larger cohorts of patients with inflammatory or noninflammatory bowel disease. We tested only specific formulas of contrast agents. Although all of these compounds contained osmotic carbohydrate sugar alcohols, which are mainly used for CT and MRI of the small bowel, validation of our findings for every contrast formula cannot be guaranteed. We are convinced, however, that our proposed protocols may help to establish guidelines for any kind of oral contrast agent: sufficient duodenal distention with a small amount of contrast agent and imaging performed soon after ingestion of the contrast agent. For MRI of more distal parts of the small bowel, a higher volume (e.g., 1,350 mL) is preferable, but the time point of data acquisition plays a minor role.

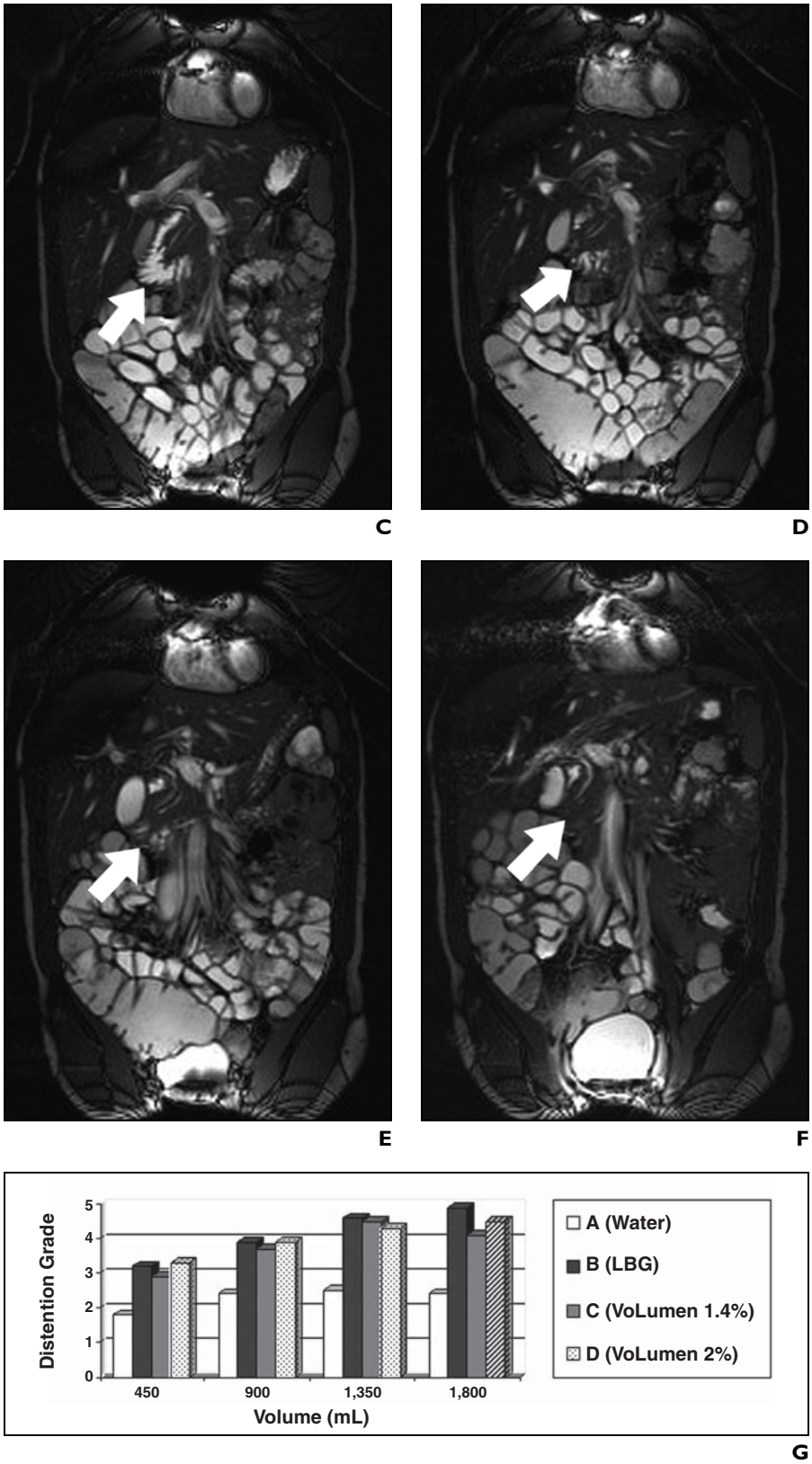

Fig. 4 (continued)—Influence of contrast volume. **C**–**F,** 29-year-old woman in good health. MR images 5 minutes after ingestion of water show distention of duodenum (*arrows*).
C, Moderate increase at 450 mL.
D, Moderate increase at 900 mL.
E, Moderate increase at 1,350 mL.
F, No increase at 1,800 mL.
G, Graph shows distention of ileum. Expanding dose from 450 to 1,350 mL led to statistically significant improvement in distention of ileum.

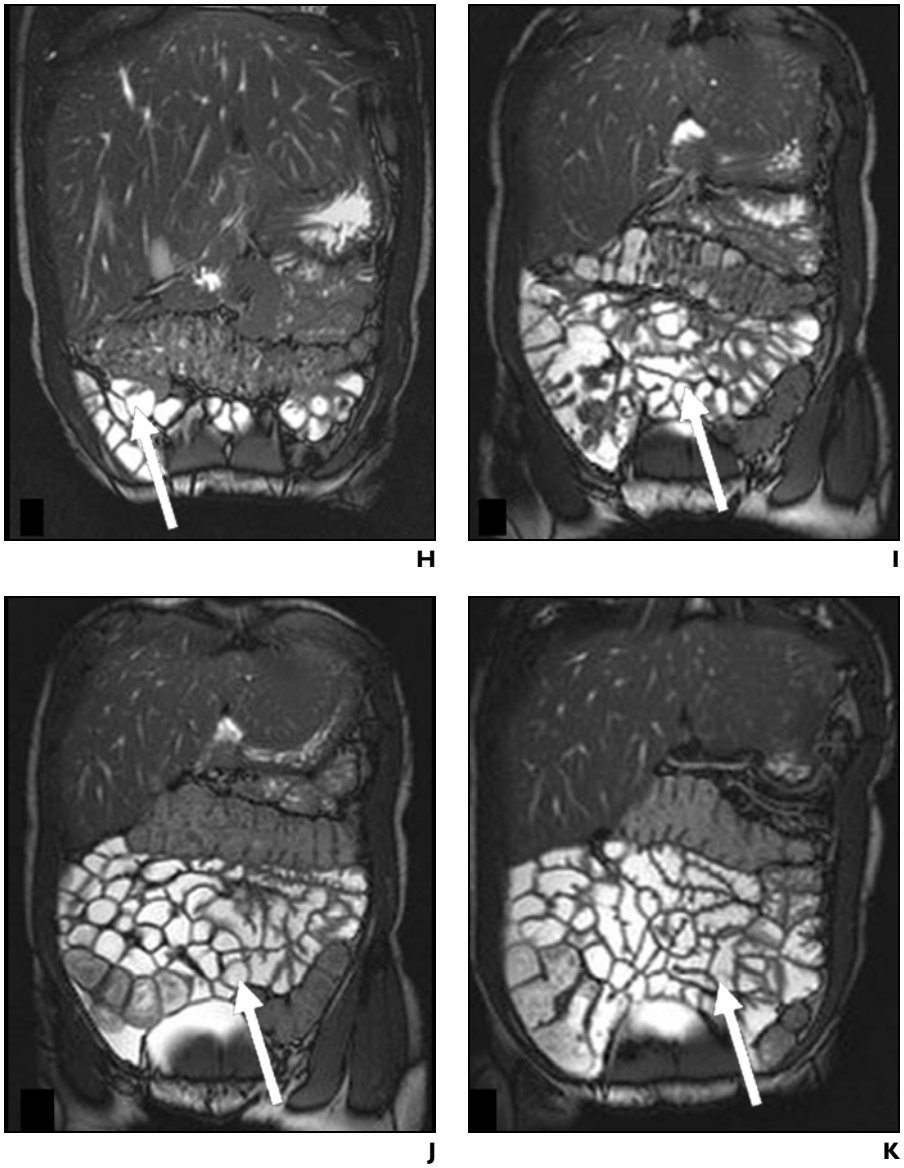

Fig. 4 (continued)—Influence of contrast volume. **H**–**K,** 29-year-old woman in good health. MR images obtained 45 minutes after ingestion of VoLumen (E-Z-EM) with 1.4% sorbitol show ileum. Expanding dose of agent from 450 to 1,350 mL led to statistically significant improvement in distention of ileum (*arrows*).
H, 450 mL.
I, 900 mL.
J, 1,350 mL.
K, 1,800 mL.

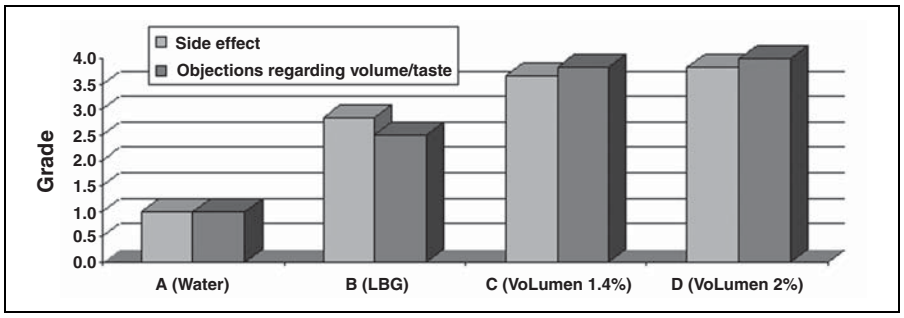

Fig. 5—Graph shows side effects and subject acceptance at volume of 1,800 mL. Consumption of 1,800 mL of contrast agents B, C, and D led to rate of side effects significantly higher than that with water (mean score, agent A, 1; agent B, 2.8; agent C, 3.7; agent D, 3.8).
LBG = locust bean gum with mannitol. VoLumen, E-Z-EM.

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