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Contrast Enhancement of the Gastrointestinal Tract on MR Images Using Intravenous Gadolinium-DTPA

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Abstract. Gadopentetate dimeglumine was administered intravenously to 16 patients undergoing abdominal magnetic resonance (MR) imaging. T1-weighted and fat-suppressed T1-weighted images were acquired before and after intravenous administration of 0.1 mmol/kg gadopentetate dimeglumine. The stomach, small bowel, and colon were analyzed regarding the presence and relative intensity of contrast enhancement. Diffuse enhancement of the gastrointestinal tract wall was observed in all patients following contrast material administration. Such enhancement was most conspicuous on fat-suppressed T1-weighted images. Quantitative measurements indicated that the wall of the gastrointestinal tract enhanced approximately 100% with gadopentetate dimeglumine. This study demonstrates that enhancement of the normal gastrointestinal tract occurs routinely when intravenous gadopentetate dimeglumine is administered, and such enhancement should not be considered indicative of gastrointestinal pathology. Furthermore, it suggests the potential utility for using intravenous rather than orally administered contrast agents to provide enhancement of the gastrointestinal tract on MR images.

Key words: Abdomen, MRI—Intestine, contrast enhancement—Gastrointestinal tract, MRI.

The lack of an effective gastrointestinal contrast agent remains an important limitation of abdominal magnetic resonance (MR) imaging. The need for an effective gastrointestinal contrast agent for abdominal MR imaging relates to two issues. First, enhancement of the gastrointestinal tract is often necessary in order to distinguish stomach and/or bowel from adjacent structures, such as pancreas, lymph nodes, or abdominal masses. Second, a contrast agent is necessary in order to allow for detection of primary abnormalities of the gastrointestinal tract, a challenge which has largely remained elusive for MR imaging to date.

A number of potential gastrointestinal contrast agents for MR imaging have been proposed and investigated, though none has yet achieved widespread clinical use. Limiting factors have included unavailability, safety concerns and/or side effects, difficulty related to administration, or lack of reliable efficacy for producing uniform enhancement of the gastrointestinal tract. While the gastrointestinal contrast agents which have been studied have many differences, they all share one thing in common: each is administered orally and results in enhancement of the gastrointestinal tract lumen.

The objective of this study was to investigate the potential ability to provide enhancement of the gastrointestinal tract through the intravenous rather than oral route of administration. Gadopentetate dimeglumine diethylenetriaminepentacetic acid is currently the only FDA approved MR contrast agent, and has an established safety record and near complete absence of side effects. Moreover, this agent is being used with increasing frequency for evaluation of visceral abdominal lesions. The objective of this study was to determine the enhancement pattern of the normal gastrointestinal tract using intravenous gadopentetate dimeglumine.

Subjects and Methods

Abdominal MR images in 16 patients in whom gadopentetate dimeglumine was administered intravenously were reviewed. MR imaging in these patients (seven men, nine women; 44–84 years,

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mean 70 years) was primarily directed towards evaluation of the kidneys, liver, and pelvis, in nine, five, and two patients, respectively. None of the patients were known or suspected to have abnormalities related to the gastrointestinal tract.

Imaging was performed at 1.5 T (Signa, General Electric) and consisted of conventional T1-weighted, fat-suppressed T1-weighted, and spin density/T2-weighted spin-echo pulse sequences. T1-weighted and fat-suppressed T1-weighted images were usually performed with TR 400–600 ms, TE 11–15 ms, and 2–4 excitations. T1-weighted images were acquired using fat suppression only in three patients. Long TR images were acquired using TR2100–3200 ms, first echo TE 35–45 ms, second echo TE 70–90 ms, and 1–2 excitations. Slice thickness varied from 6–10 mm, with 2-mm interslice gap and 36–44 cm field-of-view. Respiratory-ordered phase encoding and spatial presaturation were used to decrease respiratory motion and flow-related artifacts, respectively. Glucagon (0.1 mg IM) was routinely administered to decrease peristaltic motion of the gastrointestinal tract. Patients were not instructed to fast prior to MR imaging, and no mechanical or medicinal forms of bowel preparation were utilized. Gradient moment rephasing was used during acquisition of T2-weighted images. Fat suppression was accomplished with use of the fat saturation method, which involves selective radiofrequency presaturation of the lipid peak [1]. Fat-suppressed T1-weighted sequences were obtained following slow intravenous administration of 0.1 mmol/kg gadopentetate dimeglumine in all patients. Receiver gain and attenuation factors were not held constant between unenhanced and contrast-enhanced imaging sequences.

The intensity of gastrointestinal tract structures, including the stomach, small bowel, and colon, was visually analyzed on each pulse sequence. Images obtained following intravenous gadopentetate dimeglumine administration were evaluated for the presence and relative intensity of contrast enhancement of gastrointestinal tract structures. Identical window and level settings were used to photograph enhanced and unenhanced T1-weighted images. Quantitative signal intensity (SI) measurements of the gastrointestinal tract wall were performed on enhanced and unenhanced fat-suppressed T1-weighted images. These measurements were used to calculate percent contrast enhancement, which was defined as: [SI (enhanced) − SI (unenhanced)]/SI (unenhanced). Three separate measurements of the stomach, small bowel, and colon wall were acquired in each patient.

Results

Heterogeneous signal intensity was present throughout the gastrointestinal tract on nonenhanced T1-weighted, fat-suppressed T1-weighted, and T2-weighted images. The predominant signal intensity observed within the stomach, small bowel, and colon was hypointense on T1-weighted images, with signal intensity ranging between that of fluid and muscle. On fat-suppressed T1-weighted images, the gastrointestinal tract was primarily isointense to mildly hyperintense, with signal intensity similar to or slightly greater than that of surrounding suppressed mesenteric and omental fat. T2-weighted images demonstrated isointense to markedly hyperintense signal throughout most of the gastrointestinal tract, with signal intensity ranging between that of abdominal fat and fluid. Localized variations of signal intensity ranging from markedly hypointense to markedly hyperintense were present within portions of the gastrointestinal tract on each pulse sequence. Such signal variations were attributable to the presence of air, solid ingested material, or fecal material resulting in areas of decreased signal intensity or ingested food, liquids, and medications, leading to regions of variably increased signal intensity. Heterogeneous suppression of fat signal intensity was frequently observed along the periphery of the abdomen using the fat saturation method.

Diffuse enhancement of the gastrointestinal tract was observed in all patients on T1-weighted and fat-suppressed T1-weighted images obtained following intravenous gadopentetate dimeglumine administration (Fig. 1). Enhancement was of relatively mild intensity on conventional T1-weighted images, whereas marked enhancement was displayed on fat-suppressed T1-weighted images. The signal intensity of the enhanced gastrointestinal tract following gadopentetate administration was intermediate between muscle and fat on conventional T1-weighted images. The gastrointestinal tract demonstrated signal intensity similar to that of the enhanced kidneys on contrast-enhanced fat-suppressed T1-weighted images (Fig. 2).

While enhancement was visualized throughout the gastrointestinal tract, it was usually most apparent in the small bowel and least apparent in the stomach. Enhancement appeared to diffusely occur throughout nondistended portions of the gastrointestinal tract, such as within most of the small intestine. However, in those portions of the gastrointestinal tract which were distended by air and/or fluid, enhancement was noted to be limited to the bowel wall, with no evidence of intraluminal enhancement (Fig. 3). The appearance of diffuse enhancement in collapsed portions of the gastrointestinal tract was attributed to coapted-enhancing mucosal surfaces within the bowel lumen. Enhancement was less readily appreciated within those portions of the gastrointestinal tract which contained intraluminal high signal intensity on nonenhanced images.

The mean percentage enhancement of the stomach, small intestine, and colon was 98%, 109%, and 108%, respectively.

Discussion

Administration of intravenous gadopentetate dimeglumine resulted in mural enhancement throughout the gastrointestinal tract. The consistency of this observation throughout our series of patients without gastrointestinal abnormalities indicates that this is a normal phenomenon, and its observation should not

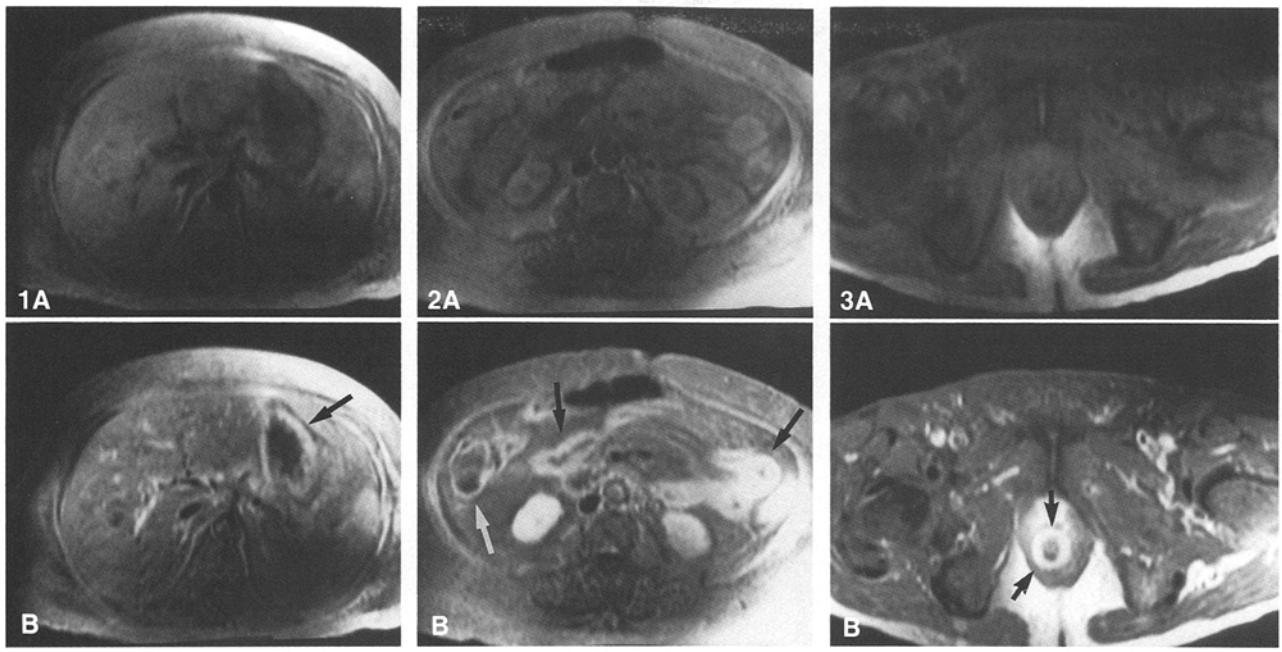

Fig. 1. T1-weighted fat-suppressed images obtained before **(A)** and following **(B)** intravenous gadopentetate dimeglumine injection. Diffuse mural enhancement is demonstrated throughout the stomach which is mildly distended by fluid (*arrow*).

Fig. 2. T1-weighted fat-suppressed images obtained before **(A)** and following **(B)** intravenous gadopentetate dimeglumine injection. Intense mural enhancement is present throughout visualized portions of the duodenum, proximal jejunum (*black arrows*), and ascending colon (*white arrow*). The intensity of the enhanced gastrointestinal tract is similar to that of the kidneys.

Fig. 3. T1-weighted fat-suppressed images obtained before **(A)** and following **(B)** intravenous gadopentetate dimeglumine injection. Intense mural enhancement is demonstrated throughout the rectal wall (*arrows*).

be interpreted as evidence of inflammatory, ischemic, or neoplastic gastrointestinal tract disease.

The conspicuity of gastrointestinal tract enhancement was considerably greater on T1-weighted images obtained with fat suppression. This is attributed to the suppression of high signal intensity from omental and mesenteric fat which surrounds the gastrointestinal tract, to the improved dynamic range for tissue contrast display enabled by fat suppression, and to reduced motion and chemical shift misregistration artifacts on fat-suppressed images [2, 3].

The most obvious method for providing enhancement of the gastrointestinal tract is to administer a contrast agent orally in order to enhance the gastrointestinal lumen, as is routinely done during abdominal CT imaging. A variety of oral contrast agents have been found to enhance the gastrointestinal tract lumen on MR images. Positive contrast agents leading to increased intraluminal signal intensity include ferric ammonium chloride and other paramagnetic metals [4, 5], fats and oils, and orally administered gadopentetate dimeglumine [6, 7]. Negative contrast agents which result in reduced intraluminal signal intensity include air and carbon dioxide effervescent granules [8], perflourooctylbromide [9, 10], clays [11], and superparamagnetic iron oxide particles [12–14].

Despite the large number of oral contrast agents which have been developed, no single agent has proven entirely successful. Most of the difficulties encountered have related to inability to achieve consistent and uniform enhancement throughout the gastrointestinal tract. Nonuniform enhancement may occur because of immiscibility of the agent with bowel contents or due to erratic delivery and absorption of the agent throughout the gastrointestinal tract. In an effort to improve the uniformity of enhancement, some investigators have administered osmotic agents, such as mannitol, in conjunction with these agents, though diarrhea has been encountered as a side effect [6].

Our findings indicate that enhancement of the gastrointestinal tract can be achieved not only through oral contrast administration, but also as a result of intravenous administration of contrast material (Figs. 1–3). There are a number of potentially significant advantages to the latter method. Delivery of contrast material to the gastrointestinal tract via the

bloodstream insures that the agent will simultaneously reach all vascularized portions of the gastrointestinal tract. Use of an intravenous contrast agent also eliminates the considerable time delay which is needed to allow for bowel filling between ingestion of an oral contrast agent and commencement of MR imaging. Intravenous contrast enhancement does not have the detrimental effect of increasing peristaltic motion which may occur with oral contrast, particularly when osmotic agents are also used. Intravenous administration of gadopentetate dimeglumine has established a proven safety record over a considerable time period [15], and it also provides enhancement of other abdominal viscera which has been found to improve detection of a variety of pathologic conditions throughout the abdomen [16–19].

The use of intravenous gadopentetate dimeglumine also presents a number of potential limitations for use as a means of providing gastrointestinal tract enhancement. For example, this method does not result in distention of the gastrointestinal tract lumen, which may limit detection of some types of pathology. Administration of carbon dioxide granules or even water in conjunction with intravenous gadopentetate dimeglumine would be expected to improve bowel distention. Increased intraluminal signal intensity on T1-weighted images may occur due to ingestion of materials which contain protein, fat, or paramagnetic substances. The presence of such materials limits clear visualization of bowel wall enhancement with intravenous gadopentetate dimeglumine. Therefore, it would be desirable to evaluate patients in a fasting state, in order to improve depiction of mural enhancement and to assist in reducing peristaltic motion. Another limitation presented by intravenous gadopentetate dimeglumine is that adequate gastrointestinal tract enhancement is not provided on all pulse sequences. The dominant effect of gadopentetate dimeglumine is to shorten T1 relaxation, thereby increasing signal intensity on T1-weighted images. While contrast-enhanced T2-weighted images were not acquired in this study, gadopentetate dimeglumine would not be expected to provide effective enhancement on T2-weighted images. In addition, gastrointestinal tract enhancement with intravenous gadopentetate dimeglumine is considerably more apparent when fat suppression techniques are used in conjunction with T1-weighted pulse sequences. Fat suppression imaging has been shown to have other benefits over conventional T1-weighted imaging in the abdomen, including improved detection of both hepatic and renal lesions [2, 3, 20]. However, there are several limitations of the fat saturation method. These include an approximately 30% reduction in number of imaging slices as compared to conventional T1-weighted images using similar parameters. Effective fat saturation is dependent on a high degree of magnetic field homogeneity throughout the region of imaging. Field inhomogeneities related to the patient and/or environment may lead to incomplete fat suppression in portions of the image. This is particularly prominent when large field-of-view images are acquired. Finally, many normal abdominal structures and lesions also enhance with gadopentetate dimeglumine, and difficulty may be encountered in distinguishing these structures from bowel when they are in contiguity. While these issues are suggested by the results of our preliminary study, further investigation is necessary.

In summary, we have observed prominent enhancement of the normal gastrointestinal tract following intravenous administration of gadopentetate dimeglumine on fat-suppressed T1-weighted MR images. This contrast agent results in uniform mural enhancement throughout the gastrointestinal tract. Such enhancement should be recognized as a normal phenomenon.

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