Evaluation of Diffusion-weighted MR Imaging for Detection of Bowel Inflammation in Patients with Crohn's Disease[1]

Aytekin Oto, MD, Fang Zhu, MD, PhD, Kirti Kulkarni, MD, Gregory S. Karczmar, PhD, Jerrold R. Turner, MD, PhD, David Rubin, MD

Rationale and Objectives. The aims of this study were to determine the feasibility of diffusion-weighted magnetic resonance imaging (DWI) in the detection of bowel inflammation and to investigate the changes in apparent diffusion coefficient (ADC) values in the inflamed bowel in patients with Crohn's disease.

Materials and Methods. Eleven patients who underwent magnetic resonance enterography (including DWI) for Crohn's disease and colonoscopy or surgery within 4 weeks of examination were recruited. Two radiologists reviewed diffusion-weighted images and ADC maps to evaluate for inflammation in each bowel segment (terminal ileum, cecum, ascending colon, transverse colon, descending colon, and rectosigmoid colon) and measured the ADC values of each bowel segment. Endoscopic and pathologic results were correlated with DWI findings.

Results. Fifty-three segments (19 with inflammation, 34 normal) were included. DWI detected inflammation in 18 of 19 segments (94.7%) and showed normal results in 28 of 34 segments (82.4%). On diffusion-weighted images, bowel segments with inflammation revealed higher signal compared to normal segments. Artifact levels were none or minimal in 10 of 11 patients (90.9%) and moderate in one patient. On quantitative analysis, ADC values of inflamed and normal bowel were measured as $0.47 - 2.60 \times 10^{-3}$ and $1.39 - 4.03 \times 10^{-3}$ mm^2/s, respectively ($P < .05$).

Conclusion. DWI with parallel imaging is a feasible technique for the detection of inflammation in patients with Crohn's disease. ADC values are decreased in inflamed bowel segments, indicating restricted diffusion.

Key Words. Diffusion-weighted MRI; Crohn's disease; bowel.

Magnetic resonance (MR) imaging has been increasingly used for the diagnosis and follow-up of patients with inflammatory bowel disease. Its lack of ionizing radiation, excellent soft-tissue contrast resolution, and potential to perform real-time and functional imaging are the important advantages of MR imaging that make it well suited for imaging the gastrointestinal tract (1). Currently, evaluation of the bowel wall by MR imaging is based on its signal on T2-weighted images, thickness, and the degree of contrast enhancement (1). Although the results of MR imaging using these criteria are promising, several clinically important issues, such as the accurate estimation of the extent of disease, reliable differentiation between chronic and active inflammation, and monitoring response to treatment, remain as diagnostic challenges.

A new possibility to expand the capability of MR imaging is to apply new MR applications that can give additional information about the structural organization of tissues on bowel imaging. Diffusion-weighted imaging (DWI) reflects the changes in the water mobility caused by interactions with cell membranes, macromolecules, and alterations of the tissue environment. DWI has been widely used for intracranial diseases but has only recently been applied to the abdomen. Initial results suggest that it can be useful for the evaluation of various hepatic, renal, and pancreatic diseases (2–4). The available published descriptions of DWI for the evaluation of

Acad Radiol 2009; 16:597–603

[1] From the Department of Radiology (A.O., F.Z., K.K., G.S.K.), the Department of Pathology (J.R.T.), and the Department of Medicine (D.R.), University of Chicago Medical Center, 5841 South Maryland Avenue, MC 2026, Chicago, IL 60637. Received October 23, 2008; accepted November 14, 2008. **Address correspondence to:** A.O. e-mail: aoto@radiology.bsd.uchicago.edu

doi:10.1016/j.acra.2008.11.009

the bowel are focused on the detection of colorectal cancer (5–7). To our knowledge, the use of DWI for the detection of bowel wall inflammation and its associated features has not been previously described.

Especially after the emergence of nephrogenic systemic fibrosis as a rare but serious complication of gadolinium-based contrast agents, there is less willingness to use intravenous contrast agents in MR imaging, and DWI is becoming important as an alternative method to obtain information that could otherwise be obtained from extracellular contrast enhancement. The purposes of our study were to determine the possibility of a role for DWI in the detection of bowel inflammation and investigate the changes in apparent diffusion coefficient (ADC) values of the inflamed bowel in patients with Crohn's disease (CD).

MATERIALS AND METHODS

A retrospective search of the institutional computer database was performed for all patients who had undergone MR enterography for the indication of suspected or known CD and who also underwent subsequent colonoscopy or bowel resection within 4 weeks of MR enterography between July 2007 and February 2008. Institutional review board approval was obtained, and informed consent was waived for this retrospective study, which was compliant with the Health Insurance Portability and Accountability Act.

A total of 32 MR enterographic examinations were performed for suspected or known CD during the specified time. Eleven patients (seven women, four men; mean age, 36.8 years; range, 21–74 years) who also underwent subsequent colonoscopy or bowel resection within 4 weeks of MR enterography were included in the study to undergo either endoscopy or pathology as the gold standard. Two patients had partial colectomy (one right hemicolectomy and one cecectomy) and ileal resection prior to MR enterography.

MR Imaging Protocol

The MR imaging examinations were performed with a 1.5-T GE Signa unit (GE Healthcare, Milwaukee, WI). Patients fasted for 6 hours before the MR imaging examinations. VoLumen 1350 mL (E-Z-EM Inc, Lake Success, NY) was administered orally to every patient over 45 minutes before the study. Glucagon 1 mg (Glucagen; Bedford Laboratories, Bedford, OH) was administered intramuscularly when the patient was placed in the scanner, immediately before starting the examination.

After acquiring a standard three-plane scout image, the following sequences were obtained through the abdomen and pelvis using a four-channel, phased-array body coil: (1) axial and coronal fast imaging employing steady-state acquisition with and without fat suppression (repetition time [TR], 3.4 ms; echo time [TE], 1.4 ms; matrix, 224 × 224; flip angle, 45°; slice thickness, 7 mm; gap, 0 mm); (2) axial and coronal T2-weighted single-shot fast spin echo with and without fat suppression (TR, infinite; TE, 90 ms; matrix, 256 × 256; slice thickness, 6 mm; gap, 0 mm); (3) pre- and postcontrast T1-weighted liver acquisition with volume acceleration, with additional dynamic postcontrast images (TR, 3.5–3.9 ms; TE, 1.6–1.9 ms; matrix, 192 × 256; flip angle, 10°; interpolated slice thickness, 2.2 mm); and (4) axial and/or coronal diffusion-weighted images (b values, 0 and 600 s/mm^2; TR, 8000 ms; TE, 75 ms; matrix, 128 × 128–224; slice thickness, 7 mm; gap, 0 mm; number of signals acquired, 4). The upper abdomen and pelvis were scanned separately. The field of view ranged between 32 and 40 cm, and an ASSET factor of 2 was used in all sequences. Acquisition time for the DWI sequences covering the abdomen and pelvis ranged from 5 to 8 minutes.

Image Analysis

The bowel was divided into six segments: terminal ileum, cecum, ascending colon, transverse colon, descending colon, and rectosigmoid colon. In patients who had previous ileocolectomy and ileocecal anastomosis, the small-bowel loop segments (up to 10 cm) anastomosed to the colon (neoterminal ileum) was regarded as the ''terminal ileum.'' The perianal region and small-bowel loops other than terminal ileum were not specifically assessed in this study.

Qualitative Analysis

DWI of the bowel (b values, 0 and 600 s/mm^2) was retrospectively evaluated by two radiologists (with a combined 12 years of body MR experience) who were blinded to the clinical and endoscopic examination and surgical results. Pixelwise ADC maps were generated using a commercially available software workstation system (Advanced Workstation; GE Medical Systems, Milwaukee, WI).

Each segment was graded for the presence of inflammation on a four-point confidence scale on the basis of wall thickening and wall signal on DWI and the ADC map as follows: 0 = definitely absent (imperceptible wall, both in signal and in thickness), 1 = probably absent (normal thickness, signal intensity and thickness are similar to the surrounding bowel segments), 2 = probably present (normal wall thickness, but signal intensity is increased on DWI and decreased on ADC map), and 3 = definitely present (thick bowel wall, and signal intensity is increased on DWI and decreased on ADC map). The bowel wall was considered to be thickened when it was >3 mm. Grading scores of 0 and 1 were regarded as indicating normal bowel wall, and scores of 2 and 3 were regarded as indicating bowel wall inflammation on DWI.