ELSEVIER
SAUNDERS

Magn Reson Imaging Clin N Am
13 (2005) 349–358

MAGNETIC
RESONANCE
IMAGING CLINICS
of North America

MR Imaging of the Large Bowel

Thomas C. Lauenstein, MD*, Christiane A. Kuehle, MD,
Waleed Ajaj, MD

Department of Diagnostic and Interventional Radiology and Neuroradiology, University Hospital Essen, Hufelandstrasse 55, 45122 Essen, Germany

Conventional colonoscopy has a high accuracy for the detection of colorectal masses or inflammatory bowel disease (IBD). Poor patient acceptance, which reflects considerable procedural pain, has limited the use of colonoscopy as a screening method for colorectal cancer [1,2]. In addition, anticipation of an endoscopic study of the colon frequently is associated with unpleasant expectations that focus on disco mfort and the risk of complications, such as perforations [3]. This generally leads to poor patient participation [4]. The presence of stenoses or elongated bowel segments may result in an inability to visualize the entire colon and the ileocecal valve in a considerable number of patients [5]. This has motivated investigators to develop alternative concepts to assess the colon. Main efforts have focused on virtual endoscopy that is based on the acquisition of cross-sectional images; this can be accomplished by using CT or MR imaging. Recent studies have shown that CT and MR colonography (MRC) are effective in the detection of clinically relevant diseases [6–9]. In a study that included more than 100 patients who underwent virtual and conventional endoscopy, virtual endoscopy was favored by 82% of the patients [10]. Similar results were obtained by Angtuaco et al [11]; 77% of 400 potential screening patients preferred virtual endoscopy over conventional colonoscopy. Virtual colonoscopy that is based on the acquisition of CT data sets is associated with considerable doses of ionizing radiation, however [12,13]. This issue plays a mayor role because patients who have IBD often are young. Also, screening examinations for colorectal cancer should be repeated every 3 to 5 years. Therefore, it seems preferable to use MR imaging for virtual colonography.

Technique

Three main requirements need to be fulfilled for MRC:

1. The use of an appropriate hardware system: because data acquisition must be performed under breath-hold conditions, the use of new 1.0 or 1.5 tesla scanners that are equipped with strong gradient systems is mandatory. Whether MRC is possible is determined largely by the minimum repetition time. If it exceeds 5 milliseconds, collection of a three-dimensional (3D) data set that contains the entire colon will take more than 30 seconds—too long for a comfortable breathhold.
2. Distension of the colonic bowel loops: in their physiologic state, parts of the large bowel are collapsed and cannot be assessed properly. Thus, the colon needs to be distended by administering liquid or gasiform-distending media rectally.
3. A high contrast between the bowel wall and the bowel lumen: this feature, which allows the accurate display of the colonic wall, strongly depends on the MR sequences that are applied and the use of intravenous (IV) and rectal contrast agents.

Before the MR examination, patients need to undergo bowel cleansing in a manner which is similar to that required for conventional

* Corresponding author.
E-mail address: thomas.lauenstein@uni-essen.de (T.C. Lauenstein).

1064-9689/05/$ - see front matter © 2005 Elsevier Inc. All rights reserved.
doi:10.1016/j.mric.2005.03.002

colonoscopy. To avoid unnecessary patient discomfort, MRC should be performed in the morning. Administration of sedative or analgesics is not required. Before the examination, patients have to be screened for possible contraindications to MR imaging, such as metallic implants or severe claustrophobia. The presence of hip prosthesis, which generally is not regarded as a contraindication to MR imaging, may lead to avid artifacts in the region of the rectum and sigmoid colon. Hence, these patients should not be examined.

For data acquisition, a combination of two large "flex surface coils" should be used for signal reception to assure the coverage of the entire colon (Fig. 1). To obviate bowel spasms and minimize artifacts that are due to bowel motion, a spasmolytic agent (eg, scopolamine, 20 mg, IV; glucagon, 1 mg, IV) has to be administered. Following the placement of a rectal tube (Fig. 2), the colon is filled, while the patient is in the prone position, with approximately 2000 mL to 2500 mL of tap water using hydrostatic pressure. The filling procedure should be stopped after the application of the entire amount of water or whenever the patient complains about discomfort. Other investigators propose the acquisition of monitoring sequences during the filling process (eg, nonslice select sequences that provide an update image every 1–2 seconds).

Different 3D sequence types can be acquired. For T1-weighted MR imaging (dark-lumen MRC), the IV administration of gadolinium is mandatory. After a first "precontrast" T1-weighted 3D gradient echo data set, paramagnetic contrast should be administered IV at a dosage of 0.2 mmol/kg using an automatic injector. The paramagnetic contrast application should be followed by rapid injection of normal saline. After a delay of 75 seconds, the "precontrast" 3D acquisition has to be repeated (Fig. 3). Imaging parameters are listed in Table 1. In case of insufficient image quality (eg, due to patient's movement or technical problems), the postcontrast scan can be repeated over a long time period after contrast injection because of a stable contrast enhancement of the colonic wall. Furthermore, T1-weighted data should be amplified by 3D fast imaging with steady-state precession sequences. Different vendor-specific names for these sequences have been introduced: FIESTA (General Electric Medical Systems, Milwaukee, Wisconsin), TrueFISP (Siemens Medical Solutions, Erlangen, Germany), and Balanced Fast Field Echo (Philips Medical Systems, Best, The Netherlands). Image features are characterized by a mixture of T1- and T2-contrast which leads to a homogenous bright signal of the colonic lumen filled with water (bright-lumen MRC). The colonic wall and masses that arise from are seen as dark filling defects (Fig. 4). After data acquisition, the enema bag is placed on the floor for draining the water and the patient is removed from the scanner.

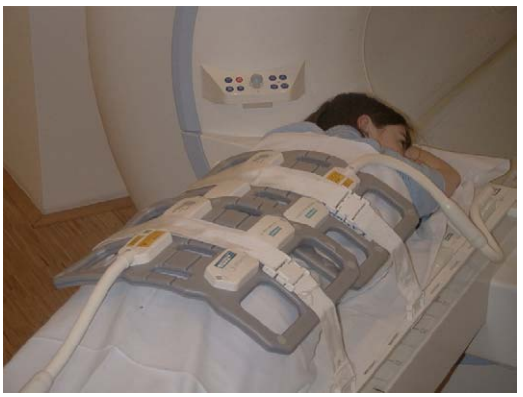

Fig. 1. Clinical setup for MRC. The patient is placed in a prone position on the scanner table. A combination of two surface coils is used to permit coverage of the entire abdomen.

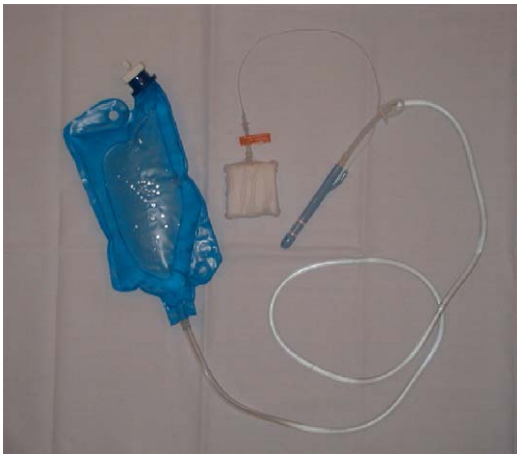

Fig. 2. The water-containing enema bag is connected by way of a catheter with a rectal tube. The tube may be blocked at its tip with a balloon.

Data interpretation

All 3D data sets should be transferred to a postprocessing workstation. A special software

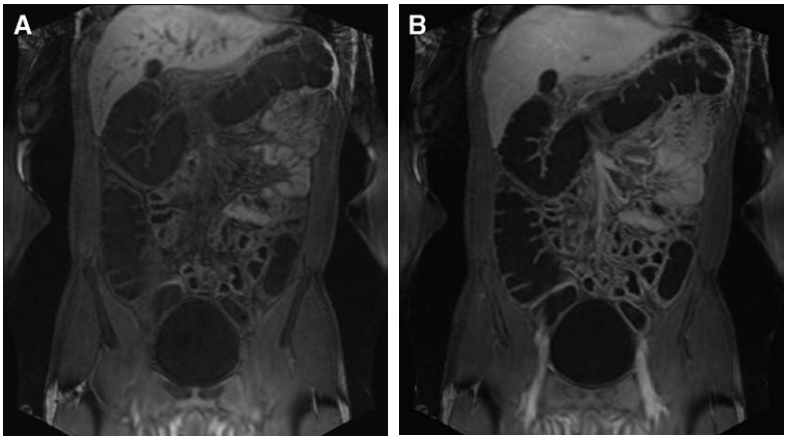

Fig. 3. Pre- (*A*) and postcontrast (*B*) T1-weighted sequence. The colonic lumen is rendered dark because of the water enema. An avid contrast enhancement leads to a high signal of the colonic wall on the postcontrast scan.

tool should be used to enable the perception of the MR source data as well as virtual endoscopic views of the colon (Fig. 5). Initially, however, MRC should be interpreted in the multiplanar reformation mode by scrolling through the T1-weighted contrast-enhanced 3D data set in all three orthogonal planes. Whenever a mass that arises from the colonic wall is detected, the identical part of the colon should be analyzed on the precontrast scan. Thus, a contrast enhancement value can be determined by measuring signal intensities of the mass in native and postcontrast scans. This method assures a reliable discrimination between residual stool particles and real colorectal masses. Although residual stool does not show any contrast enhancement (Fig. 6), colorectal lesions always do (Fig. 7). Scar tissue (eg, after appendectomy) may mimic polypoid lesions (Fig. 8).

In addition, MR data should be evaluated based on virtual endoscopic renderings. A virtual endoscopic fly-through facilitates the depiction of small lesions. In addition, the 3D depth perception allows the evaluation of haustral fold morphology, which enhances the observer's ability to distinguish polyps from haustra. To visualize both sides of haustral folds and to minimize the risk of missing relevant lesions, the virtual fly-through should be performed in an antegrade and a retrograde direction.

Because the quality of fast imaging with steady-state precession data is superior as a result of the high contrast and relative motion

Table 1
Sequence parameters of T1-weighted gradient echo data for MR colonography

Repetition time (ms)	3.1
Echo time (ms)	1.1
Flip (degrees)	12
Slice thickness (mm)	1.8
No. of slices	96
Matrix	180 × 256
Acquisition time (s)	22
Acquisition plane	Coronal

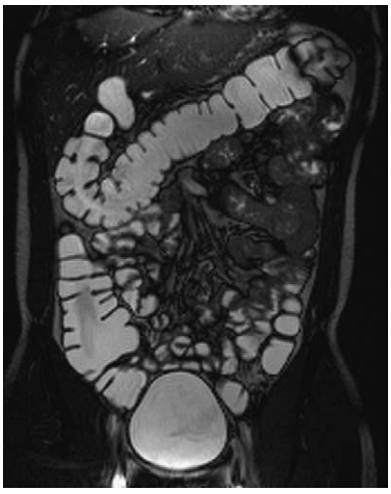

Fig. 4. Fast imaging with steady-state precession sequence of the colon. The contrast mechanism is different compared with the T1-weighted images; the colonic lumen is rendered bright, whereas the colonic wall is seen as a dark filling defect.

Fig. 5. Software platform for the evaluation of MR colonography. The T1-weighted data sets are displayed simultaneously in different manners: a virtual endoscopic view, the coronal source data, and axial and sagittal reconstructions are shown (Viatronix, Stony Brook, NY).

insensitivity, the analysis should be repeated with these data sets as well (Fig. 9). No information about perfusion of the bowel wall is available, however, which may complicate the differentiation between polyps and residual fecal material in these sequences.

Indications of MR colonography

Detection of colorectal masses

Most colorectal cancers develop over a period of several years from adenomatous polyps [14]. This pathogenesis makes colorectal cancer preventable to a large extent. Detection and removal of polyps eliminates the risk of subsequent malignant degeneration. Thus, implementation of screening programs can reduce the incidence of colorectal cancer by more than 80% [15,16].

Ajaj et al [17] evaluated the impact of MRC for the detection of colorectal polyps in a high-risk population. One hundred and twenty-two subjects who had suspected colorectal diseases were studied. A contrast-enhanced T1-weighted 3D volumetric interpolated breath-hold examination

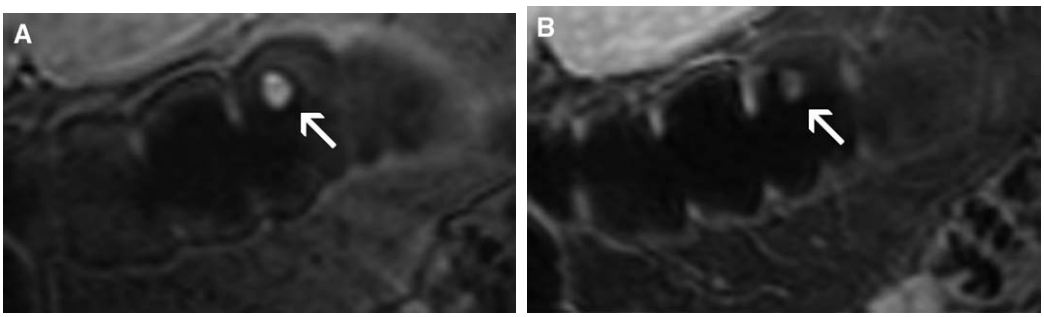

Fig. 6. The acquisition of pre- (*A*) and postcontrast-enhanced (*B*) T1-weighted data allows a reliable differentiation between residual stool and polyps, because stool particles (*arrow*) already are of high signal intensity on the native scan and do not show any contrast uptake.

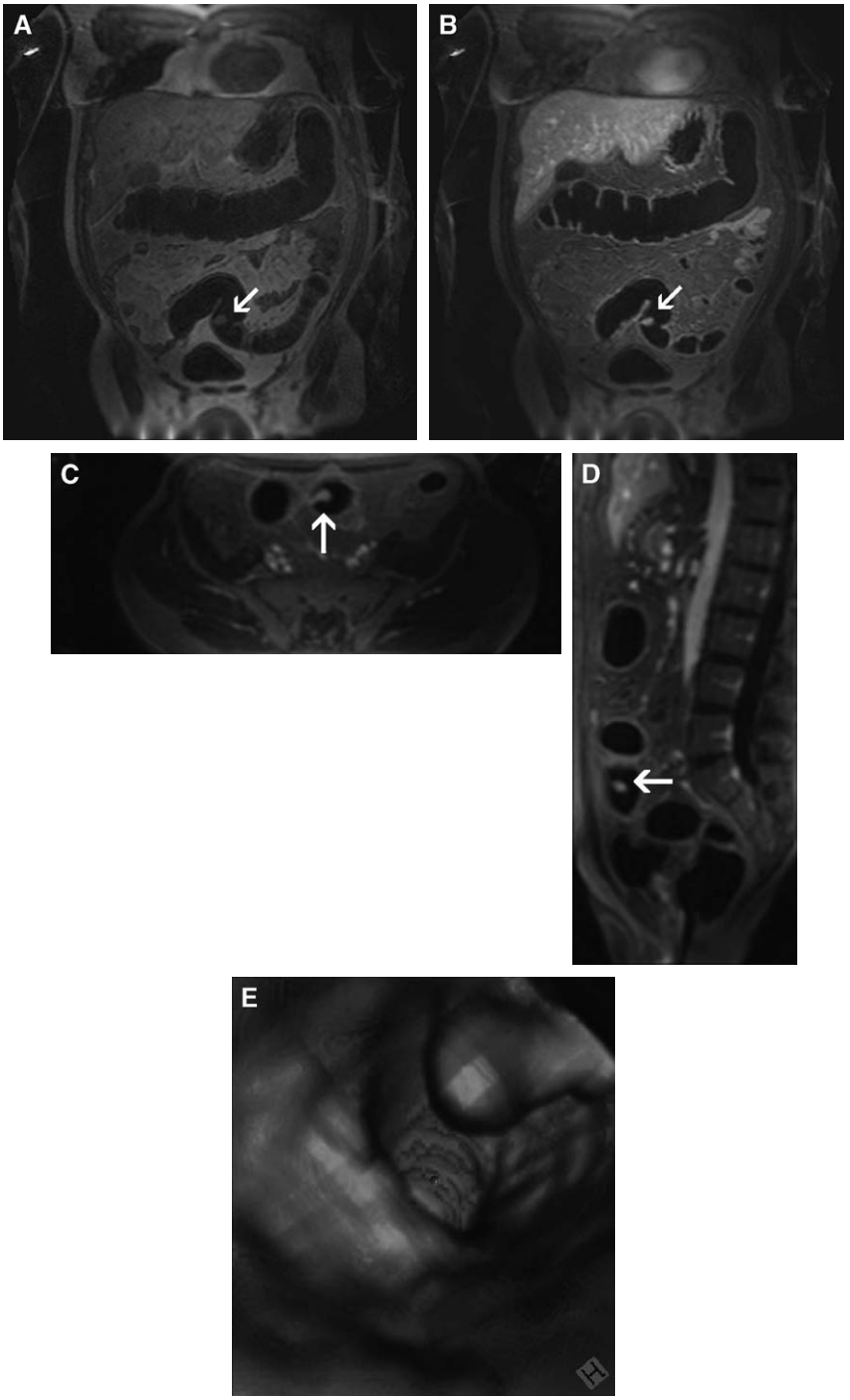

Fig. 7. Colorectal lesions (*arrow*) always show a contrast enhancement when comparing the native (*A*) and postcontrast scan (*B*). Furthermore, pathologies (*arrow*) can be displayed in an axial (*C*) or sagittal (*D*) reformation or as a virtual endoscopic view (*E*).

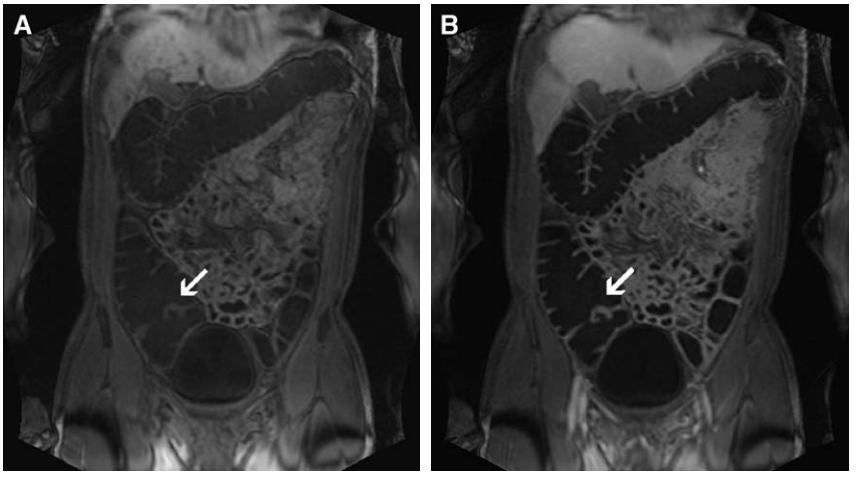

Fig. 8. (*A, B*) Scar tissue after appendectomy may mimic a colorectal mass (*arrow*) by showing a contrast enhancement.

(VIBE) sequence was collected after the rectal administration of water. The presence of colorectal masses was documented. Results were compared with those of a subsequently performed colonoscopy. None of the polyps that measured less than 5 mm that were detected by colonoscopy was identified based on MRC images. In the size group that ranged between 5 mm and 10 mm, MRC correctly detected 16 of 18 lesions and two polyps that were larger than 10 mm also were seen correctly on MRC images. Two of three patients who had documented polyposis coli were diagnosed correctly on MRC (Fig. 10). Furthermore, all nine colorectal carcinomas were seen correctly on MRC images.

Thus, one major concern relates to the inability of the MR technique to identify colorectal lesions that are smaller than 5 mm. The significance of this limitation is equivocal because of the direct observational data on growth rates which indicate that small polyps (<10 mm) tend to remain stable over a time range of 36 to 48 months. Furthermore, these small lesions are not prone to malignant degeneration [18]. Nevertheless, small colorectal lesions probably will become detectable by MRC as technical refinements, including

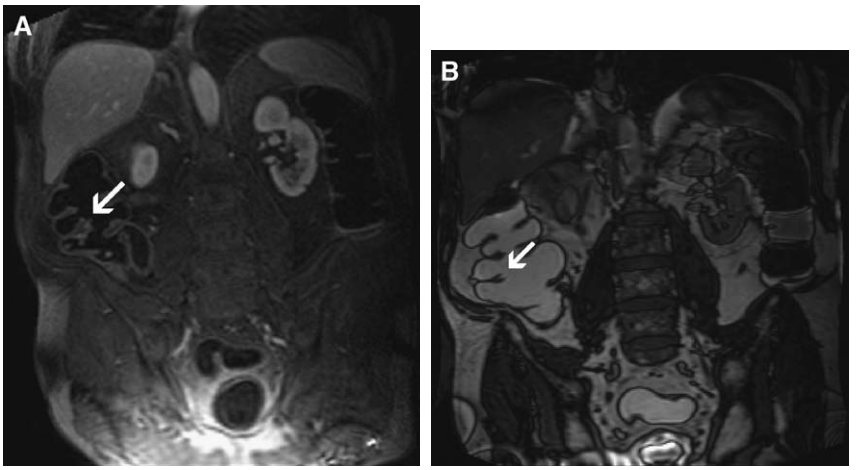

Fig. 9. Fast imaging with steady-state precession sequences may provide useful information. (*A*) On the T1-weighted image, a thickened haustral fold is shown (*arrow*). (*B*) This turns out to be a motion artifact (*arrow*), because the TrueFISP scan shows no abnormality.

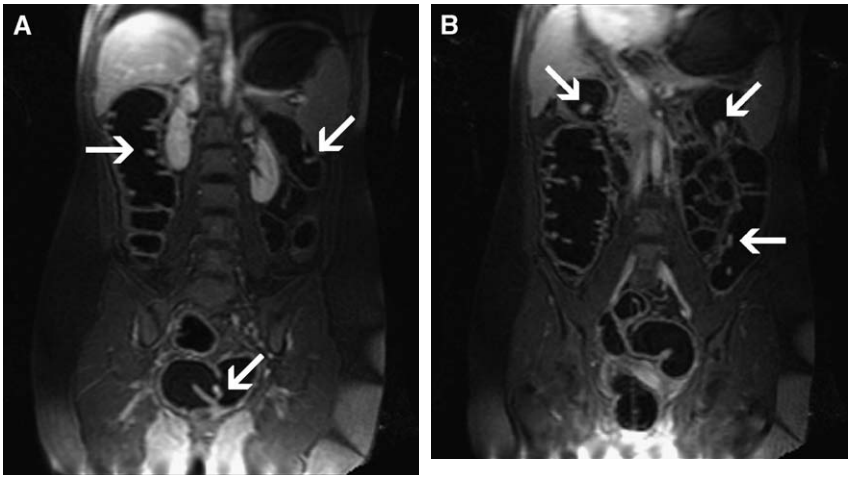

Fig. 10. (*A, B*) Patient who has polyposis coli. Multiple colorectal polyps (*arrows*) are shown on the contrast-enhanced T1-weighted data sets.

parallel acquisition techniques, are implemented [19]. Flat adenomas, however, are likely to remain elusive.

In another trial, the diagnostic accuracy of contrast-enhanced T1-weighted data was compared with 3D fast imaging with steady-state precession sequences [20]. Thirty-seven patients who had suspected colorectal lesions were included. MRC was performed as described earlier. The detection rate of colorectal masses and inflammatory lesions was determined for T1-weighted data and TrueFISP sequences separately. Image quality also was assessed. All patients underwent conventional colonoscopy as the standard of reference. Sensitivity of dark lumen T1-weighted MRC was 78.9%. There were no false positive results; residual stool could be differentiated from colorectal masses. The TrueFISP-based MRC, however, failed to detect two polyps which resulted in a sensitivity of 68.4%. Furthermore, false positive results were seen in five patients; however, image quality of TrueFISP was rated superior to that of dark lumen MRC because of less motion artifacts.

Detection of bowel inflammation

Crohn's disease and ulcerative colitis are the most frequent specific IBDs, with a prevalence of approximately 1 in 500 [21–23]. Diagnostic procedures in IBD serve to validate the diagnosis and to optimize treatment. Endoscopic biopsy is considered the gold standard for the detection and quantification of IBDs [24,25]. Several studies reported on the ability of MR imaging to detect IBD [26,27]. Ajaj et al [28] examined 15 normal subjects and 23 patients who had suspected IBD of the large bowel by means of MR imaging. The presence of inflammatory changes was documented based on four criteria: bowel wall thickness, bowel wall contrast enhancement, loss of haustral folds, and presence of perifocal lymph nodes. All results were quantified relative to data that were obtained from normal subjects and summarized in a single score. This MRC-based score was compared with endoscopic and histopathologic data. MRC correctly identified 93% of the segments that were found to reveal IBD changes by histopathology. All severely inflamed segments were identified correctly and there were no false positive findings. Thus, MRC may be used for monitoring IBD activity or assessing therapeutic effectiveness.

Patients who have incomplete colonoscopy

The diagnostic impact of conventional colonoscopy is linked with the ability to reach the ileocecal valve; however, incomplete conventional colonoscopy can be observed in 5% to 26% of colonoscopic examinations that are performed, even by experienced endoscopists [29,30]. There are several reasons for incomplete colonoscopy, including severe procedure-related abdominal discomfort and technical challenges that are due to elongated bowel segments or the presence of intraluminal stenosis. In patients who have known IBD or colorectal carcinoma, the failure rate of conventional colonoscopy may reach 50% [31]. Virtual colonography is associated with significantly

higher completion rates; considerably less abdominal pain enhances patient compliance and only a high-grade stenosis prohibits the passage of water that is required for distending prestenotic segments. Furthermore, bowel elongation does not harm the visualization of colonic segments.

In a recent study, 37 subjects who had an incomplete endoscopy underwent MRC [32]. Contrast-enhanced T1-weighted 3D VIBE images were acquired, and the presence of colorectal pathologies was assessed on a segmental basis. Conventional colonoscopy failed to evaluate almost 50% of the potentially visible colonic segments, whereas 96% of the bowel segments were assessable by means of MR imaging. Beyond stenoses and poststenotic lesions, MR-based assessment of prestenotic segments revealed two carcinoma-suspected lesions, five polyps, and four colitis-affected segments.

Extraintestinal findings

In contrast to a conventional colonoscopic analysis, virtual colonoscopy is not limited to endoscopic viewing. Analysis of the acquired source data allows the simultaneous depiction of the colon and all surrounding abdominal structures. Especially in the case of patients who have a suspected colorectal tumor, imaging of the liver is a benefit. Because of the acquisition of pre- and postcontrast T1-weighted data and TrueFISP sequences, MRC is reliable for the identification and characterization of hepatic lesions, including metastases, hepatocellular carcinoma, and hemangiomas. Other relevant pathologies also can be detected, such as bone metastases, renal cell cancer, or aortic aneurysms. Similarly, MR imaging may provide useful additional information in patients who have IBD. Beyond the depiction of inflammatory processes in the bowel wall, extramural abscesses can be seen. Furthermore, pathologies, such as interintestinal fistulae or conglomerate tumor formations, can be detected easily by means of MR imaging, whereas most of these extraintestinal findings often are not suspected by endoscopy.

Further developments

Fecal tagging

MRC still requires bowel purgation, which negatively impacts patient acceptance. One can overcome bowel cleansing by modulating the signal characteristics of fecal material (fecal tagging). By adding contrast agents to regular meals, the signal intensity of stool can be adapted to the signal properties of the rectal enema.

For dark lumen MRC without bowel cleansing, a highly concentrated, barium sulfate–containing contrast agent has been proposed for fecal tagging [33,34]. Barium sulfate is administered in a volume of 200 mL with each of four principle meals beginning 36 hours before MRC. Barium sulfate has an excellent safety profile; it is not absorbed, it mixes well with stool, and allergic reactions after the ingestion are not known. The barium-based approach of fecal tagging was applied successfully in a volunteer study [33]. Ingestion of barium sulfate before the MR examination leads to a decreasing signal of stool on heavily T1-weighted 3D gradient echo images; this renders fecal material virtually indistinguishable from the administered water enema. Although the concept of fecal tagging with barium sulfate resulted in diagnostic image quality for dark lumen MRC, a recent study revealed that patient acceptance was not increased [35]; ingestion of the barium sulfate compound was considered almost as unpleasant as the bowel-cleansing protocols. A new approach is based on the administration of oral or rectal stool softener; their effect on the signal intensity of fecal material was assessed in another volunteer study [36]. Oral administration of lactulose before the MRC, in combination with a rectal enema that contained ducosate sodium, resulted in low signal intensity values of feces and high image quality (Fig. 11A). In addition, the ingestion of lactulose or the rectal enema that contained ducosate sodium did not impact patients' acceptance negatively. This combination of oral and rectal stool softener may evolve as a promising technique for dark lumen MRC without bowel cleansing; however, data analysis of simultaneous bright lumen MRC is limited (Fig. 11B).

Combined small and large bowel MR imaging

MRC is a reliable method for the assessment of inflammatory diseases of the large bowel; however, IBD often affects the small and large bowel at the same time. Therefore, new approaches have focused on displaying the small bowel and colon simultaneously. An initial study included 18 patients who had IBD [37]. In addition to the rectal administration of water, patients ingested 1.5 L of a hydro solution that contained mannitol before the MR examination. The latter resulted in

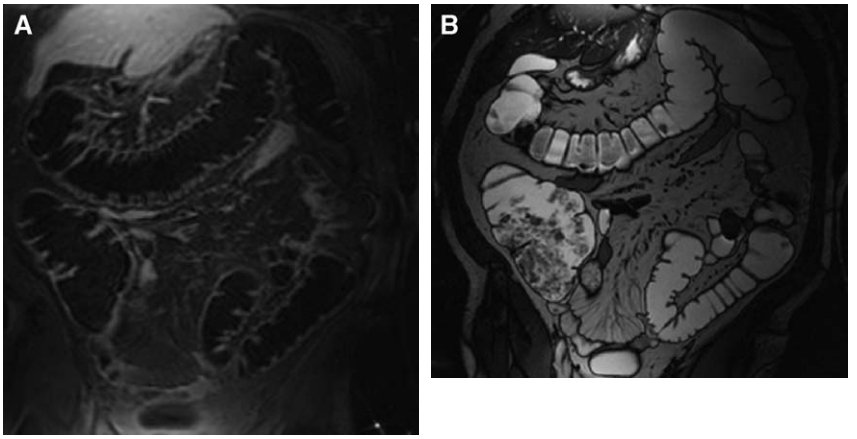

Fig. 11. Using a combination of oral and rectal stool softener, signal intensity of fecal material can be adapted to the low signal of the rectal enema on the T1-weighted sequences (*A*). Thus, stool becomes virtual invisible and a diagnostic image quality can be achieved; however, diagnostic accuracy of TrueFISP images is limited because stool impresses as dark-filling defects on the bright colonic lumen (*B*).

a good distension of small bowel loops, whereas the rectal administration of water allowed the visualization of the colon at the same time. Thus, inflammatory lesions in the colon and terminal ileum and affected bowel segments in the upper small bowel could be detected.

References

[1] Lieberman D. Colon cancer screening: beyond efficacy. Gastroenterology 1994;106:803–7.
[2] Frommer DJ. What's new in colorectal cancer screening? J Gastroenterol Hepatol 1998;13:528–33.
[3] Gatto NM, Frucht H, Sundararajan V, et al. Risk of perforation after colonoscopy and sigmoidoscopy: a population-based study. J Natl Cancer Inst 2003; 95:230–6.
[4] Rex DK, Rahmani EY, Haseman JH, et al. Relative sensitivity of colonoscopy and barium enema for detection of colorectal cancer in clinical practice. Gastroenterology 1997;112:17–23.
[5] Bowles CJ, Leicester R, Romaya C, et al. A prospective study of colonoscopy practice in the UK today: are we adequately prepared for national colorectal cancer screening tomorrow? Gut 2004;53:277–83.
[6] Pickhardt PJ, Choi JR, Hwang I, et al. Computed tomographic virtual colonoscopy to screen for colorectal neoplasia in asymptomatic adults. N Engl J Med 2003;349:2191–200.
[7] Furukawa A, Saotome T, Yamasaki M, et al. Cross-sectional imaging in Crohn disease. Radiographics 2004;24:689–702.
[8] Saar B, Rosch T, Rummeny EJ. Colorectal cancer screening: a challenge for magnetic resonance colonography. Top Magn Reson Imaging 2002;13: 427–34.
[9] Schreyer AG, Furst A, Agha A, et al. Magnetic resonance imaging based colonography for diagnosis and assessment of diverticulosis and diverticulitis. Int J Colorectal Dis 2004;19:474–80.
[10] Svensson MH, Svensson E, Lasson A, et al. Patient acceptance of CT colonography and conventional colonoscopy: prospective comparative study in patients with or suspected of having colorectal disease. Radiology 2002;222:337–45.
[11] Angtuaco TL, Banaad-Omiotek GD, Howden CW. Differing attitudes toward virtual and conventional colonoscopy for colorectal cancer screening: surveys among primary care physicians and potential patients. Am J Gastroenterol 2001;96: 887–93.
[12] Hara AK, Johnson CD, Reed JE, et al. Reducing data size and radiation dose for CT colonography. AJR 1997;168:1181–4.
[13] Sosna J, Morrin MM, Copel L, et al. Computed tomography colonography (virtual colonoscopy): update on technique, applications, and future developments. Surg Technol Int 2003;11:102–10.
[14] Stryker SJ, Wolff BG, Culp CE, et al. Natural history of untreated colonic polyps. Gastroenterology 1987;93:1009–13.
[15] Winawer SJ, Zauber AG, O'Brien MJ, et al. The National Polyp Study. Design, methods, and characteristics of patients with newly diagnosed polyps. The National Polyp Study Workgroup. Cancer 1992; 70:1236–45.
[16] Winkleman BJ, Matthews DE, Wiebke EA. Colorectal cancer screening at a Veterans Affairs hospital. Am J Surg 2003;186:468–71.
[17] Ajaj W, Pelster G, Treichel U, et al. Dark lumen magnetic resonance colonography: comparison with conventional colonoscopy for the detection of colorectal pathology. Gut 2003;52:1738–43.

[18] Villavicencio RT, Rex DK. Colonic adenomas: prevalence and incidence rates, growth rates, and miss rates at colonoscopy. Semin Gastrointest Dis 2000;11:185–93.
[19] Steidle G, Schafer J, Schlemmer HP, et al. Two-dimensional parallel acquisition technique in 3D MR colonography. Rofo 2004;176:1100–5.
[20] Lauenstein TC, Ajaj W, Kuehle CA, et al. Magnetic resonance colonography: comparison of contrast-enhanced three-dimensional vibe with two-dimensional FISP sequences: preliminary experience. Invest Radiol 2005;40(2):89–96.
[21] Ochsenkuhn T, Sackmann M, Goke B. Inflammatory bowel diseases (IBD): critical discussion of etiology, pathogenesis, diagnostics, and therapy. Radiologe 2003;1:1–8.
[22] Schneider W. Epidemiology of chronic inflammatory intestinal diseases. Z Gesamte Inn Med 1981; 3:228–30.
[23] Karlinger K, Gyorke T, Mako E, et al. The epidemiology and the pathogenesis of inflammatory bowel disease. Eur J Radiol 2000;3:154–67.
[24] Fiocca R, Ceppa P. The diagnostic reliability of endoscopic biopsies in diagnosis colitis. J Clin Pathol 2003;56:321–2.
[25] Nahon S, Bouhnik Y, Lavergne-Slove A, et al. Colonoscopy accurately predicts the anatomical severity of colonic Crohn's disease attacks: correlation with findings from colectomy specimens. Am J Gastroenterol 2002;12:3102–7.
[26] Kettritz U, Isaacs K, Warshauer DM, et al. Crohn's disease. Pilot study comparing MRI of the abdomen with clinical evaluation. J Clin Gastroenterol 1995;3: 249–53.
[27] Koh DM, Miao Y, Chinn RJ, et al. MR imaging evaluation of the activity of Crohn's disease. AJR Am J Roentgenol 2001;6:1325–32.
[28] Ajaj W, Lauenstein TC, Pelster G, et al. Magnetic resonance colonography for the detection of inflammatory diseases of the large bowel: quantifying the inflammatory activity. Gut 2005;54(2): 257–63.
[29] Cirocco WC, Rusin LC. Factors that predict incomplete colonoscopy. Dis Colon Rectum 1995;389: 964–8.
[30] Marshall JB, Barthel JS. The frequency of total colonoscopy and terminal ileal intubation in the 1990s. Gastrointest Endosc 1993;39:518–20.
[31] Rottgen R, Schroder RJ, Lorenz M, et al. CT-colonography with the 16-slice CT for the diagnostic evaluation of colorectal neoplasms and inflammatory colon diseases. Rofo 2003;175:1384–91.
[32] Ajaj W, Lauenstein TC, Pelster G, et al. MR colonography in patients with incomplete conventional colonoscopy. Radiology 2005;234(2):452–9.
[33] Lauenstein T, Holtmann G, Schoenfelder D, et al. MR colonography without colonic cleansing: a new strategy to improve patient acceptance. AJR Am J Roentgenol 2001;177:823–7.
[34] Lauenstein TC, Goehde SC, Ruehm SG, et al. MR colonography with barium-based fecal tagging: initial clinical experience. Radiology 2002; 223:248–54.
[35] Goehde SC, Descher E, Boekstegers A, et al. Dark lumen MR colonography based on fecal tagging for detection of colorectal masses: accuracy and patient acceptance. Abdom Imaging, in press.
[36] Ajaj W, Goehde SC, Ruehm SG, et al. MR colonography without bowel cleansing: impact of an oral and rectal softener. Presented at the 12th Scientific Meeting of the International Society for Magnetic Resonance in Medicine. Kyoto (Japan), May 15–21, 2004.
[37] Narin B, Ajaj W, Gohde S, et al. Combined small and large bowel MR imaging in patients with Crohn's disease: a feasibility study. Eur Radiol 2004;14:1535–42.