Waleed Ajaj
Stefan G. Ruehm
Thomas Lauenstein
Susanne Goehde
Christiane Kuehle
Christoph U. Herborn
Jost Langhorst
Thomas Zoepf
Guido Gerken
Mathias Goyen

Dark-lumen magnetic resonance colonography in patients with suspected sigmoid diverticulitis: a feasibility study

W. Ajaj (✉) · T. Lauenstein ·
S. Goehde · C. Kuehle · C. U. Herborn
Department of Diagnostic
and Interventional Radiology
and Neuroradiology, University Hospital,
Hufelandstrasse 55,
45122 Essen, Germany
e-mail: Waleed.ajaj@uni-essen.de
Tel.: +49-201-7231517
Fax: +49-201-7231548

S. G. Ruehm
Department of Radiology,
David Geffen School of Medicine,
University of California at Los Angeles,
Los Angeles, CA, USA

J. Langhorst · T. Zoepf · G. Gerken
Department of Gastroenterology
and Hepatology, University Hospital,
Hufelandstrasse 55,
45122 Essen, Germany

M. Goyen
Medical Center Hamburg-Eppendorf,
Hamburg, Germany

Abstract To assess dark-lumen magnetic resonance colonography (MRC) for the evaluation of patients with suspected sigmoid diverticulitis. Forty patients with suspected sigmoid diverticulitis underwent MRC within 72 h prior to conventional colonoscopy (CC). A three-dimensional T1-weighted volumetric interpolated breath-hold examination sequence was acquired after an aqueous enema and intravenous administration of gadolinium-based contrast agents. All MRC data were evaluated by two radiologists. Based on wall thickness and focal uptake of contrast material and pericolic reaction including mesenteric infiltration on T1-weighted sequence the sigmoid colon was assessed for the presence of diverticulitis. MRC classified 17 of the 40 patients as normal with regard to sigmoid diverticulitis. However, CC confirmed the presence of light inflammatory signs in four patients which were missed in MRC. MRC correctly identified wall thickness and contrast uptake of the sigmoid colon in the other 23 patients. In three of these patients false-positive findings were observed, and MRC classified the inflammation of the sigmoid colon as diverticulitis whereas CC and histopathology confirmed invasive carcinoma. MRC detected additionally relevant pathologies of the entire colon and could be performed in cases where CC was incomplete. MRC may be considered a promising alternative to CC for the detection of sigmoid diverticulitis.

Keywords Magnetic resonance colonography · Diverticulosis · Diverticulitis · Sigmoid colon · Conventional colonoscopy

Introduction

A true diverticulum is defined as a herniation of the mucous membrane of the colonic wall including mucosa, muscularis mucosae, and submucosa through the circular muscularis propia and is usually located in the central portion of the interhaustral segments [1–5]. Various hypotheses have been suggested regarding the cause of colonic diverticulo-

sis, including advanced age, high pressure within the large bowel, prolonged gastrointestinal transit time, fiber-deficient diet, and hereditary diseases [6, 7]. Diverticular disease (DD) involving the left colon is a common condition in Western countries, affecting 30–50% of adults aged over 60 years [8–13]. The incidence of DD is increasing because of nutritional habits and population aging [1, 7, 11]. DD involves predominantly the sigmoid colon [1, 12, 13]. How-

ever, most patients with diverticulosis are asymptomatic without evidence of complications. Some 10–30% of those aged over 60 years develop an acute diverticulitis [8, 9, 12, 13]. Complications of DD in addition to diverticulitis include stricture, pericolic abscess, bleeding, and perforation [6, 8, 14–16].

Optical endoscopy is considered the gold standard for the detection of colorectal pathologies including diverticulitis [17]. Invasiveness, procedure-related discomfort, and poor patient acceptance have driven the exploration of alternatives to endoscopy for diagnosing large bowel diseases. Computed tomography (CT) and magnetic resonance imaging (MRI) with the administration of contrast agents and postprocessing software paved the way to a new area in the detection of colorectal pathologies [18–25]. Initial studies documented high diagnostic accuracies for both CT- and magnetic resonance colonography (MRC) [18–25] for the detection of colorectal pathologies.

The aim of this study was to assess the diagnostic accuracy of MRC regarding its ability in patients with suspected sigmoid diverticulitis using conventional colonoscopy (CC) as the gold standard.

Materials and methods

Subjects

Over an 18-month period 40 patients (24 women, 16 men; age range 55–77 years, mean 63.6) were been referred to CC due to suspected sigmoid diverticulitis; 23 had known sigmoid diverticulosis, and 5 presented with a history of sigmoid diverticulitis. Beyond the clinical suspicion patients exhibited high inflammatory parameters (leukocytosis >13,000/nl and/or C reactive protein 1.5 mg/dl) and clinical symptoms such as abdominal pain, pararectal bleeding, fever, and diarrhea. Exclusion criteria included high suspicion of perforation and general contraindications to MRI, such as the presence of a pacemaker, metallic implants in the central nervous system, and severe claustrophobia. Written informed consent was obtained from all subjects in accordance with the local institutional review board, which had approved the study.

Bowel preparation

All patients underwent a standardized bowel cleansing procedure with 3000 ml of a polyethylene glycol solution (Golytely sodium chloride 1.46 g, sodium hydrogencarbonate 1.68 g, sodium sulfate 5.68 g, potassium chloride 0.75 g, polyethylene glycol 4000 59 g; Braintree Laboratories, Braintree, Mass., USA), 2000 ml of which was ingested the night before and 1000 ml on the morning of the examination day.

Magnetic resonance scanner

All MR examinations were performed on a 1.5-T MR scanner equipped with high performance gradients characterized by an amplitude of 40 mT/m and a slew rate of 200 mT m^{-1} ms^{-1} (Magnetom Sonata, Siemens Medical Systems, Erlangen, Germany).

Magnetic resonance imaging

Following the bowel preparation MRC was performed in prone position only. Imaging in the prone position reduces breathing artifacts. A combination of two surface coils was used in conjunction with the built-in spine array coil for signal reception to permit coverage of the entire colon. To minimize bowel peristalsis 40 mg scopolamine (Buscopan; Boehringer Ingelheim, Germany) was injected intravenously prior to the rectal filling. Following the placement of a rectal enema tube (E-Z-Em, Westbury, N.Y., USA), the colon was filled with approx. 2000–2500 ml warm tap water. This enema was performed without fluoroscopic guidance as the maximum amount of water that can be administered depends only on the patient's subjective feeling. Following bowel distension, a T1-weighted three-dimensional (3D) gradient-echo dataset was collected in the coronal plane. Sequence parameters included: TR/TE 3.1/1.1 ms, flip angle 12°, field of view 450×450 mm, matrix 168×256 without use of interpolation, receiver bandwidth 490 Hz/Px, number of actual slices 96, and an effective slice thickness of 1.6 mm with a distance factor of 20% but without interpolation. Subsequently paramagnetic contrast (Gd-benzyloxyproprionic-tetraacetic acid, MultiHance, Bracco, Milan, Italy) was administered intravenously at a dose of 0.2 mmol/kg and a flow rate of 3.5 ml/s. Following a delay of 75 s the 3D acquisition was repeated with identical imaging parameters. The 3D data were collected under breath-hold in 22 s. Following completion of the MRC the colonic contents were drained. The water was drained in the enema bag which was placed on the floor.

Conventional colonoscopy procedure

All patients underwent CC within 72 h following MRC. CC was performed using standard equipment (model CFQ 140, Olympus, Tokyo, Japan). The attending gastroenterologist was unaware of the MR findings. All patients obtained sedatives (2.5–5 mg midazolam, Dormicum, Roche, Grenzach-Wyhlen, Germany) or, when necessary, also a low dose of analgesics (Dolantin, Hoechst, Bad Soden, Germany). Location and size of colorectal pathologies were recorded. Signs of sigmoid diverticulitis were swelling and inflammatory signs of the sigmoid wall, loss of folds, and
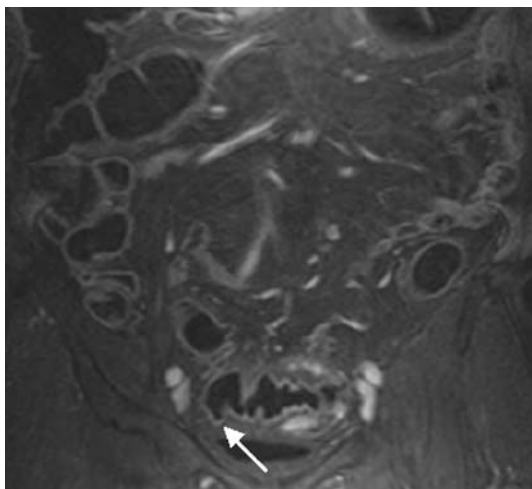
restriction of the sigmoid lumen. All biopsy materials were analyzed by histopathology.

Data analysis

Both non-contrast- and contrast-enhanced 3D MRI datasets were transferred to a postprocessing workstation (Virtuoso, Siemens Medical Systems), where they were analyzed in consensus mode by two experienced radiologists (>5 years experience in abdominal MRI). MR data were analyzed in the multiplanar reformation mode, which permitted scrolling through the 3D datasets in all three orthogonal planes. Neither radiologist had knowledge of colonoscopic findings.

For analysis the colon was divided into pre- and postsigmoidal segments. The distension of pre- and postsigmoidal segments was classified in three grades: 1=well distended, 2=moderately distended, 3=poorly distended. Furthermore, image quality of pre- and postsigmoidal segments was evaluated concerning the presence of artifacts including motion and susceptibility artifacts and was graded on a three point scale: 1=no artifacts, 2=moderate artifacts, diagnostic image quality, 3=extensive artifacts, not diagnostic.

Employed criteria for the evaluation of the region of sigmoid colon included bowel wall thickening and increased contrast uptake of this region and pericolic reaction including mesenteric infiltration [24, 26]. Furthermore, all other colonic segments and extraintestinal organs were assessed for the presence of pathologies.
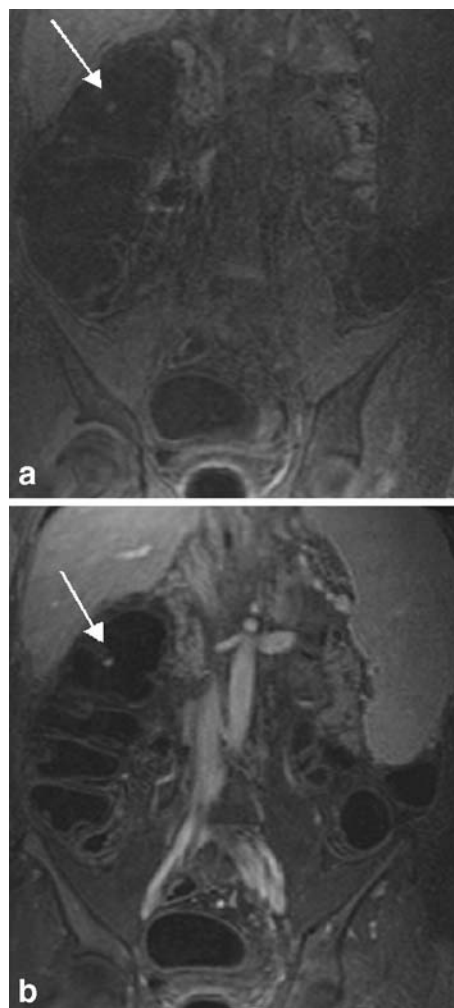
Statistical analysis

Ratings of pre- and postsigmoidal segments were compared by the unpaired Student's t test (Wilcoxon rank test) considering a P value less than 0.05 to indicate statistical significance. Using CC as the standard of reference, the MRC accuracy was assessed by calculating point estimates for sensitivity and specificity.

Results

All MR examinations were completed without complications. Similarly, there were no complications associated

Fig. 1 Coronal source image of a T1-weigted gradient-echo three-dimensional MR image from 60-year-old woman with suspected sigmoid diverticulitis. Dark lumen MRC using a volumetric interpolated breath-hold examination sequence (TR/TE 3.1/1.1 ms, flip angle 12°, matrix 168×256) was acquired after intravenous administration of contrast medium showing multiple diverticula of the sigmoid colon (*arrow*)

Fig. 2 a Coronal MR source image from a 59-year-old man with known liver cirrhosis who underwent MRC due to positive hemoccult test and suspected diverticulitis. On the coronal T1-weighted precontrast phase a hypointense lesion (*arrow*) is shown in the ascending colon. **b** Dark lumen MRC after intravenous injection of paramagnetic contrast. The coronal source image shows a contrast-uptake within the lesion. Conventional colonoscopy confirmed the presence of an ascending polyp (*arrow*)
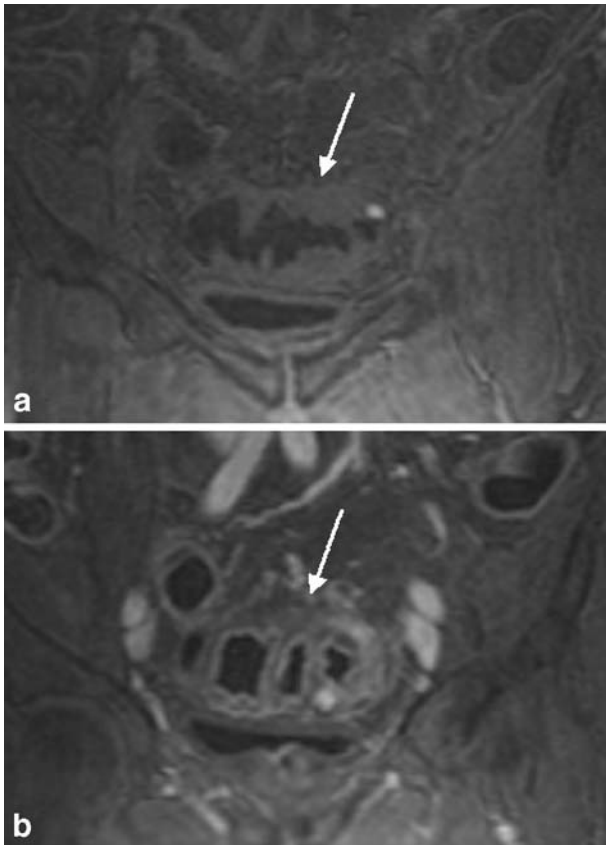
with CC or endoscopic biopsy. In four patients CC was incomplete due to high-grade stenoses of the sigmoid colon. In all other 36 cases the CC was complete.
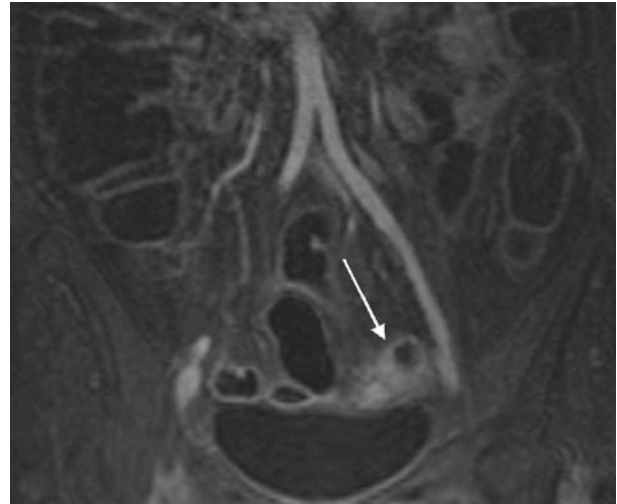
Image quality

MR image quality was sufficient for diagnosis in all patients. Colonic distension proved robust, with a statistically significant difference between pre- and postsigmoidal segments (distension value 1.3 vs. 1.8). Also, the assessment for artifacts failed to show a statistically significant difference between pre- and postsigmoidal segments (1.3 and 1.9, respectively).

MR findings

In 17 patients neither a wall thickening nor a contrast uptake within the colonic wall of the sigmoid was seen in MRC.

Fig. 4 A 55-year-old woman with abdominal pain underwent MRC due to suspected sigmoid diverticulitis. On the postcontrast scan a contrast uptake in the colonic wall and high stenosis of the sigmoid colon were seen (*arrow*). The following conventional colonoscopy was incomplete because of a stenotic lesion. However, subsequent biopsy confirmed the presence of diverticulitis. Additionally, MRC assessed other in conventional colonoscopy not seen colonic segments due to optimally distension of the colon

These examinations were therefore classified as normal with regard to sigmoid diverticulitis. However, in nine of these patients sigmoid diverticulosis (Fig. 1) and in four ascending diverticula were seen. MRC showed no other pathologies in these 13 patients. Additionally, in three patients colorectal polyps with diameters of 6, 9, and 11 mm were seen in MRC (Fig. 2). In one patient no colorectal pathology was detected.
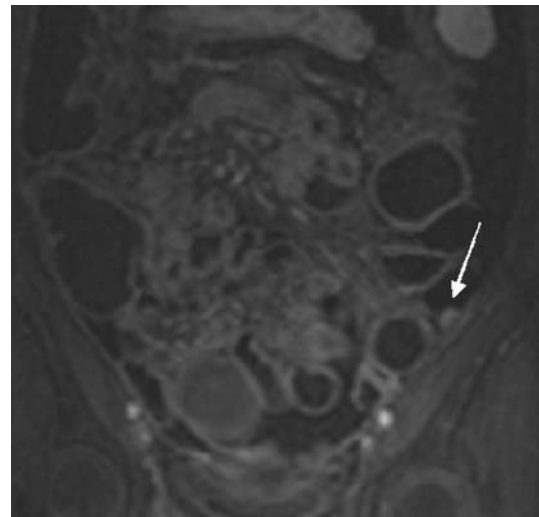

Fig. 3 **a** Coronal MR source image from a 66-year-old woman with known diverticulosis of the sigmoid colon. The patient was transferred to the department of gastroenterology because of acute abdominal pain. The precontrast study shows a wall thickening of the sigmoid colon (*arrow*). **b** On the postcontrast study an increased contrast uptake of the sigmoid bowel wall could be seen (*arrow*), and the patient was diagnosed with diverticulitis. This suspicion was subsequently confirmed by endoscopy

Fig. 5 A postcontrast T1-weighted coronal source image from a 65-year-old woman with sigmoid diverticulitis. In the descending colon a contrast enhancing lesion (*arrow*) with a diameter of 10 mm is seen which was confirmed by CC
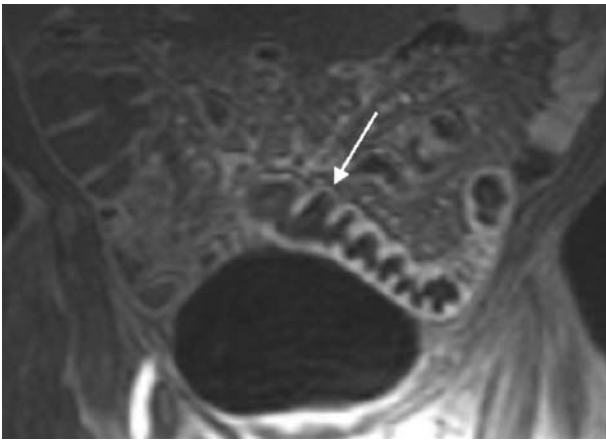
Fig. 6 A 56-year-old man underwent MRC due to diarrhea and abdominal pain. On the postcontrast MRC source image a sigmoid diverticulosis (*arrow*) was confirmed, and the patient was classified without diverticulitis. However, conventional colonoscopy confirmed the presence of light signs of diverticulitis which was missed in MRC

In the other 23 patients wall thickening and high contrast uptake of the sigmoid colon was seen and classified as sigmoid diverticulitis (Fig. 3). Four of these patients presented with high-grade stenosis of the sigmoid colon (Fig. 4) and five with pericolic abscesses. In five patients six colorectal lesions with diameters between 6 and 15 mm were additionally seen (Fig. 5).

Additional findings by MRC

MRC permitted the assessment of extracolonic parenchymal organs. Multiple mesenteric lymph nodes were identified in 12 patients. Liver and renal cysts and osteochondrosis were seen in 15.

CC findings

In the 17 patients without MR signs of sigmoid diverticulitis CC confirmed the sigmoid diverticulosis in 9, ascending diverticula in 3, three colorectal polyps in 3, and the absence of any colorectal pathologies in 1. However, CC confirmed the presence of light inflammatory signs in 4 patients (in MRC missed, Fig. 6). Additionally, CC detected 10 colorectal lesions less than 5 mm in diameter in 8 of these 17 patients, and in 2 patients unspecific rectosigmoiditis was diagnosed which was missed on MRC.

In the remaining 23 patients CC confirmed the wall thickening; however, CC was incomplete in four patients due to nonpassable stenosis of the sigmoid colon. The histopathological results confirmed the presence of invasive carcinoma of the sigmoid colon in 3 of these 23 patients (Fig. 7). In the remaining 20 patients sigmoid diverticulitis was classified histologically. Thus sensitivity and specificity of MRC for the detection of sigmoid diverticulitis wer 86% and 92%, respectively.

Additionally, CC confirmed four of the six colorectal lesions (one of the three patients with nonpassable stenosis had two lesions with diameters of 12 and 13 mm in MRC). In these 23 patients CC detected 14 colorectal lesions less than 5 mm in diameter which were missed on the MRC datasets.

Discussion

The findings presented here carry two messages we believe to be important: (a) MRC is accurate for the detection of sigmoid diverticulitis and (b) MRC cannot differentiate between diverticulitis and invasive carcinoma of the sigmoid colon.
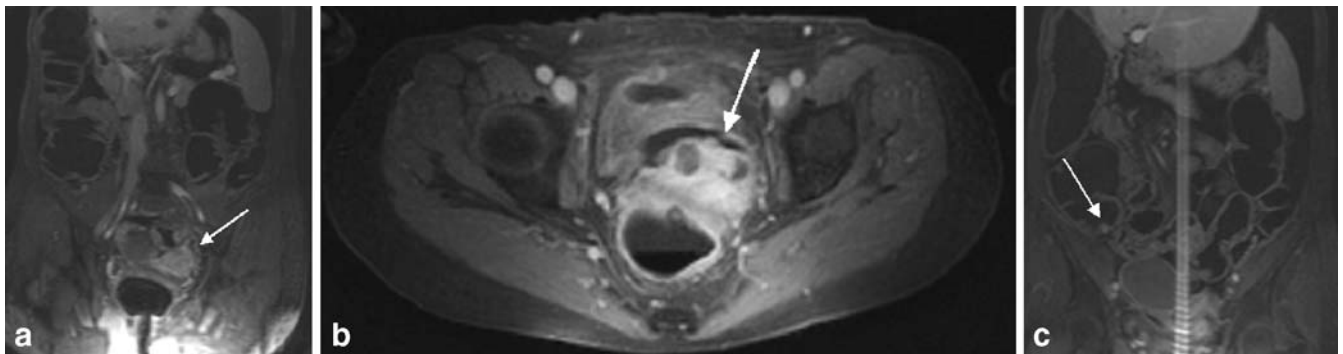
Fig. 7 a A 60-year-old patient with positive hemoccult test and abdominal pain underwent MRC due to suspected sigmoid diverticulitis. On the postcontrast coronal source image a wall thickening and high contrast uptake was seen on MRC (*arrow*). **b** The transversal source image confirmed the contrast uptake and the narrowing of the sigmoid colon (*arrow*). MRC classified the result as sigmoid diverticulitis. However, conventional colonoscopy and histopathology confirmed the presence of invasive carcinoma of the sigmoid colon. **c** Due to the high-grade narrowing of the sigmoid colon conventional colonoscopy was incomplete. On the coronal source image a contrast enhancing lesion in the cecum is seen (*arrow*)

DD of the right colon is the most common colonic disease in Western countries, affecting 10–50% of those aged over 60 years [1–5]. The pathophysiology of DD varies in a complex relationship between age, fiber diet, and transit time of the feces [1, 7]. Patients with DD are usually asymptomatic, and only 10–30% develop acute diverticulitis. Additionally, patients with a history of diverticulitis have a risk of 7–35% for recurrence of diverticulitis [8–13]. Acute diverticulitis is predominantly an extramucosal inflammation with wall thickening. In suspected acute diverticulitis a reliable imaging technique is needed for the initial therapeutic decision as to whether to employ medical or surgical treatment because clinical data or laboratory parameters are frequently inconclusive or unspecific [27].

CC performed by experienced gastroenterologists accompanied by biopsy is the most accurate initial diagnostic imaging tool to examine the entire colon including early signs of colorectal inflammation or cancer [17, 28]. However, CC may be contraindicated in acute diverticulitis and can be incomplete by high-grade stenoses.

Transabdominal ultrasonography is an inexpensive and useful emergency procedure in patients with suspected diverticulitis especially in women to exclude other abdominal or pelvic pathologies. Based on hypoechoic wall thickness and visualization of sigmoid wall ultrasonography has a high accuracy in detecting sigmoid diverticulitis [16, 29]. Schwerk et al. [14] examined 161 patients with suspected acute diverticulitis, and only 46% had a diverticulitis. This study showed a sensitivity and specificity of 98.6% and 96.5%, respectively. However, transabdominal ultrasonography cannot assess the colonic wall segments proximal to the area of diverticulitis and has a sensitivity of only 12% for perforation and 39% for abscess or peridiverticulitis. A barium rectal enema may be performed for a variety of reasons, including to aid in the diagnosis of colorectal cancer, but barium enema is contraindicated when suspecting acute diverticulitis, perforation, or prior to any surgical procedure because of potential hazards to develop a peritonitis [30, 31]. Therefore in suspected acute diverticulitis a water-soluble contrast enema using Gastrografin is the most commonly used radiological examination and can assess proximally or distally colonic areas of sigmoid diverticulitis especially in cases with high-grade stenoses in the affected area [32–34].

CT can be applied for the diagnosis of sigmoid diverticulitis including infectious complications. Additionally, CT has the ability simultaneously to detect extraintestinal lesions affecting the parenchymal abdominal organs, representing a considerable advantage over rectal enema and opitcal colonoscopy. Therefore CT is recommended for assessing severe episodes, failing to clearly improve after medical treatment and most practically when an abscess is suspected [35, 36]. A study including 420 patients with suspected diverticulitis found the performance of CT significantly superior to that of contrast enema in terms of sensitivity (98% vs. 92%, P=0.01), which was calculated from patients who had their colon removed, and whose diverticulitis was confirmed histologically, and in the evaluation of the severity of the inflammation (26% vs. 9%, P=0.02). Moreover, only 20 of 69 patients (29%) who had an associated abscess on CT had indirect signs of this complication on contrast enema [35].

Virtual colonography is based on the acquisition of 3D CT or MRI datasets [16–24]. Initial studies documented high diagnostic accuracies for both CT colonographyand MRC [19–25] and has become as an attractive alternative to CC for the detection of colorectal pathologies including diverticulitis [37, 38]. Lefere et al. [37] examined 160 patients with diverticular disease in CT colonography using CC as standard reference and had found a high accuracy of CT colonography compared to CC.

CT has some advantages regarding spatial resolution, examination costs, and scanner availability. However, lack of harmful side effects, safe contrast agents, and unsurpassed soft tissue contrast render MRI an attractive alternative imaging modality. Schreyer et al. [38] examined 14 consecutive patients with clinically suspected diverticulitis examined by MRC using a 3D fast low-angle shot sequence. Having CT as standard of reference, all sigmoid diverticula were diagnosed based on MRI. Inflammation as judged by CT was assessed identically on MRI. MRC revealed the same diagnosis as CT in all patients without ionizing radiation [38].

In our study dark-lumen MRC using a T1-weighted volumetric interpolated breath-hold examination sequence and combining a rectal water enema with intravenous administration of gadolinium-based contrast agents is based on focal uptake of contrast material in pathologies of colonic wall which are displayed as bright areas while the lumen is rendered totally dark due to water. Based on wall thickness and contrast uptake MRC has shown a sensitivity and specificity of 86% and 92%, respectively, for the detection of sigmoid diverticulitis. In three cases MRC led to false-positive results, and the differentiation between carcinoma and diverticulitis of the sigmoid colon was impossible. It is well known that many CT studies have confirmed the high association between sigmoid diverticulitis and left colon cancer [39, 40].

In conclusion, our results indicate that dark-lumen MRC is an alternative to CC for the detection of sigmoid diverticulitis and can detect other relevant pathologies of the entire colon and can be performed in incomplete CC. However, CC accompanied by biopsy is necessary to exclude carcinoma of the in patients with sigmoid diverticulitis.

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