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MR enterography imaging of Crohn's disease in pediatric patients

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Summary

Background: Crohn disease (CD) is a chronic inflammatory process of gastrointestinal tract, which frequently affects children. Recent advances in Magnetic Resonance Imaging (MRI) technique have made small bowel imaging possible, what is extremely useful in pediatrics.

The purpose of this article is to describe the characteristic MR enterography findings and to present the advantages of this modality in pediatric patients.

Material/Methods: A group of 40 patients referred from the Department of Pediatric Gastroenterology and Nutrition, Medical University of Warsaw was included in the analysis. The patients' age ranged from 7 to 18 years (mean age 14 years). Among the study participants, 28 patients were diagnosed with CD, whereas 12 patients had a history of ulcerative colitis or were strongly suspected of CD based on clinical data.

The examinations were performed on GE Signa HD 1,5 T system. Small bowel distention was achieved by oral administration of 600–1000 ml of hyperosmotic solution of polyetylenglycol (PEG). Prior to the examination, 20–40 mg of a spasmolytic drug, hioscine-N-butylobromide (Buscolysin®), was administrated to reduce peristaltic movements.

Results: The abnormal small bowel segments were found in 21 patients and the features of colonic disease were detected in 5 patients. In 2 patients the lesions involved both small and large bowel. In 16 subjects mural changes were not found. Among studied patients, following signs of small bowel inflammation were fund: bowel wall thickening (n=21), submucosal edema (n=8), segment wall hyperenhancement (n=18), deep ulceration (n=6), fistula (n=3), stenosis (n=7), mesenteric signs such as hyperemia (n=9), fibrofatty proliferation (n=8) and lymphadenopathy (n=28).

Conclusions: MR enterography is an excellent examination, which provides an accurate information about severity and activity of and complications related to CD. It is especially valuable in children, because of lack of the negative consequences of repeated exposure to ionizing radiation.

Keywords: Inflammatory Bowel Diseases • Crohn's Disease • MR Enterography

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Background

Crohn disease (CD) is a chronic inflammatory process of gastrointestinal tract with a relapsing and remitting course. Many patients with CD demand frequently performed diagnostic imaging procedures, because of a specific course of the disease and its multiple complications. Owing to the fact that lesions are often localized in terminal segment of the ileum and the capability of obtaining samples for histopathologic assessment, an endoscopy with biopsy is considered as gold standard in diagnosing CD. However endoscopic techniques have some limitations including poor accessibility to remaining part of the small bowel (except for difficult and time-consuming enteroscopy), risk of bowel perforation and limited ability to evaluate extraluminal structures. Capsule endoscopy, although

attractive, cannot be performed in very young children, does not allow for tissue sampling and is not reimbursed by national health service.

Computed tomography (CT) has a high diagnostic value, because it enables the evaluation of extraluminal lesions and disease complications. However, this technique should not be routinely used in children because of exposure to ionizing radiation.

Due to the reservations described above, until recently no low invasive diagnostic method enabling detailed evaluation of disease severity and monitoring the treatment effectiveness was available. The progress in magnetic resonance (MR) techniques and the development of new sequences with short exposition time, which are less sensitive to motion artifacts, has enabled acquiring good quality images of abdominal organs in children.

MR imaging has many advantages, of which the most important are lack of harmful influence of ionizing radiation and noninvasiveness. Furthermore, this method provides good tissue differentiation within an organ and allows distinguishing between inflamed and normal tissues. There are two methods of MR diagnostic imaging for visualizing small bowel: enterography and enteroclysis. Enteroclysis involves introducing the catheter into distal segment of the duodenum and administration of methylcellulose solution, whereas in enterography osmotically-active contrast agent solution is administered orally, without the necessity of using duodenal catheter. Enteroclysis has proven to be more accurate method for the evaluation of early mucosal lesions, but enterography is markedly more convenient in clinical practice [1]. Therefore, MR enterography is becoming more and more widely used, especially in children. Currently it is considered as the method of choice for the evaluation of CD severity and activity as well as for monitoring treatment effectiveness in children [2]. The aim of our paper was to present findings characteristic of CD in MR enterography observed in our material, as well as to highlight the advantages of this technique in children.

Material and Methods

Study group

The study group consisted of 40 pediatric patients referred from the Department of Pediatric Gastroenterology and Nutrition, Medical University of Warsaw. The patients' age ranged from 7 to 18 years (mean age 14 years). The majority of study participants n=28 (70%) was diagnosed with CD, based on endoscopic and histopathologic examinations. In remaining 12 (30%) patients 3 (7.5%) were diagnosed with ulcerative colitis, remaining patients were suspected of having Inflammatory Bowel Diesease (IBD) based on clinical symptoms (Table 1). In the group of children diagnosed with CD, there were patients with both clinically active disease and long-term remission.

Table 1. Patients referred for MR enterography – clinical data.

CD disease	28
IBD suspicion	6
Ulcerative colitis	3
Gastrointestinal bleeding or anemia of unknown origin	3
Total	**40**

Examination technique

No special preparation was necessary before the examination. The patients were only recommended to eat light meals in the day before the examination and to avoid foods in the day of the examination.

Small bowel distention was achieved by oral administration of 600–1000 ml of hyperosmotic solution of polyetylenglycol (PEG, trade name Fortrans®). PEG was administered orally to most of the patients, but in some children with poor drug tolerance, it was administered directly to the stomach through enteral feeding tube. Imaging procedure was performed with the patient lying prone. This position of the patient causes that small bowel loops are better separated from each other, they are located closer to the coil and the number of motion artifact is smaller. Furthermore, it also enables to reduce the number of sections required for each coronal acquisition, which in turn leads to reduced time of the examination [3].

Prior to the examination, 20–40 mg of a spasmolytic drug, hioscine-N-butylobromide (Buscolysin), was administrated intramuscularly to reduce motion artifacts caused by peristaltic movements.

The examinations were performed on GE Signa HD 1,5 T system. The study protocol included images of coronal and axial Ultrafast Spin Echo (SSFSE) and Balanced Gradient Echo (FIESTA) sequences, dynamic images of Balanced Gradient Echo (FIESTA CINE) in coronal plane, T1-weighted sequences (LAVA) before and after administration of contrast agent in coronal and axial planes, and diffusion weighted imaging (DWI) in axial plane.

Results

The image analysis focused mainly on the assessment of the small bowel. However, in some patients the colon was also evaluated, if evident changes in morphology or contrast enhancement of the bowel wall were present.

The first step of image analysis was the assessment of small bowel distension. In 3 patients the distension was insufficient.

Among the study participants, in 21 (52.5%) patients lesions were found in small bowel, in 5 (12.5%) patients – in colon, in 2 (5%) patients lesions were present both in small bowel and in colon, and in 16(40%) patients there were no mural changes.

Bowel images were analyzed for following features: bowel wall thickening, submucosal edema, contrast hyperenhancement, deep ulcerations, fistulas, strictures, mesenteric changes, such as hyperemia and fibrofatty proliferation, and lymphadenopathy. Additionally, the signal intensity of

Table 2. Small bowel changes in analyzed material.

Wall thickening	21
Disease extension	2–30 cm
Submucosal edema	8
Contrast enhancement	18
Deep ulceration	6
Fistulas	3
Strictures	7
Mesenteric hyperemia	9
Fibrofatty proliferation	8
Lymphadenopathy	28
Increased signal intensity in DWI	15

affected bowel segments in DWI sequences was assessed. Detailed data are presented in Table 2.

Bowel wall thickening was observed in 21 (52.5%) patients. In almost all of them, lesions were found in terminal segment of ileum, and in one child lesions were also present in more proximal bowel loops. Features of submucosal edema within the thickened bowel wall were observed in 8 (20%) patients. Deep ulcerations were found in 6 (15%) patients. In the study group, in one patient an intestino-intestinal fistula was observed (whose patency was indicated by high signal in T2-weighted sequences), in one patient obstructed ileo-cecal fistula was visualized, and in one patient perianal fistula and blind-ending sinus penetrating from sigmoid colon to presacral area, were detected. In our material, one fibrotic stricture with concomitant features of impaired patency of gastrointestinal tract was found. Remaining six strictures were related to large edema and impairment of affected bowel segment motility. Mesenteric changes, such as hyperemia and fibrofatty proliferation, were detected in 9 (22.5%) and 8 (20%) patients, accordingly. Frequently observed finding in our material was enlargement of mesenteric lymph nodes – it was found in 28 (70%) patients, among whom 4 had no other signs of Inflammatory Bowel Disease (IBD). Out of 5 patients with changes in the large bowel, 2 had fistulas, one had features of inflammation within vermiform appendix, and 2 had edematous changes.

Discussion

Small bowel distension

PEG solution may be poorly tolerated by some patients when administered orally, mainly due to its taste properties. In children in whom PEG intolerance was previously observed, during preparations to colonoscopy a catheter was introduced to the stomach or previously introduced enteral feeding tube was used. Sometimes, the problem was the lack of patient's compliance resulting from young age of the child. In the study group, adequate distension was not achieved in 3 (7.5%) patients: in 2 of them it was caused by poor compliance and in one by vomiting.

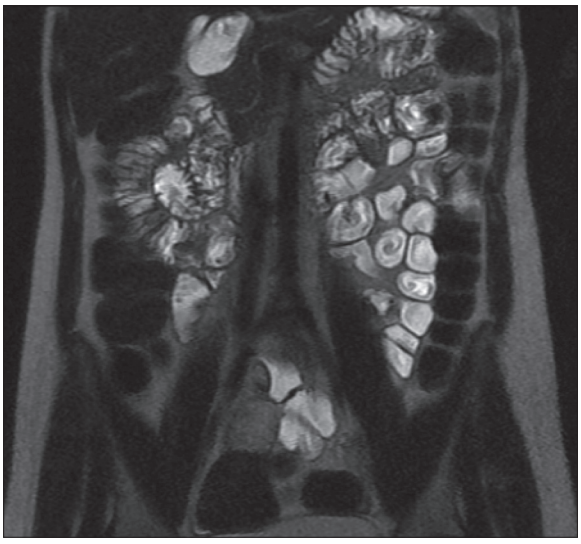

Figure 1. Coronal T2-weighted single-shot fast spin-echo (SSFSE) image shows typical small bowel distention.

Therefore cooperation with a clinician is necessary for optimal preparation of patients for the examination.

Image of normal small bowel in MR enterography

Normal bowel wall is characterized by medium signal intensity in T1- and T2-weighted sequences. The wall thickness is considered normal if does not exceed 3 mm [4]. Visceral lymph nodes are normal size if their short-axis diameter does not exceed 5 mm. In post-contrast sequences moderate mucosal contrast enhancement is observed. There is a distinct border between the bowel wall and mesenteric fatty tissue [5] (Figure 1).

Lesions typical of Crohn disease

Lesions occurring in CD can be divided into several types: active inflammatory (without fistulae and strictures), penetrating, fibrostenotic, and regenerative and reparative lesions [6]. However, it should be noted that different types of lesions may coexist simultaneously in one patient [7]. Findings indicating active inflammatory process include: bowel wall thickening >4 mm, bowel wall and mesenteric edema, contrast enhancement, deep ulceration, hyperemia, and lymph nodes enlargement [1].

Small bowel wall thickening

The increase of small bowel wall thickness exceeding 3 mm is considered abnormal [5]. Thickness assessment depends largely on proper distension of the small bowel. If the bowel is insufficiently distended, mucosal folds may adhere and mimic wall thickening, which may lead to potentially false positive results. Apparent wall thickening may be also caused by bowel constriction. For verification of the cause of the stricture, dynamic cine sequences can be helpful, because they enable the observation of peristaltic wave passage. In analyzed material, wall thickening was found in 21 (52.5%) patients. In almost all subjects the lesions were located in terminal ileum. In one child the lesions were also detected in more proximal segments of ileum.

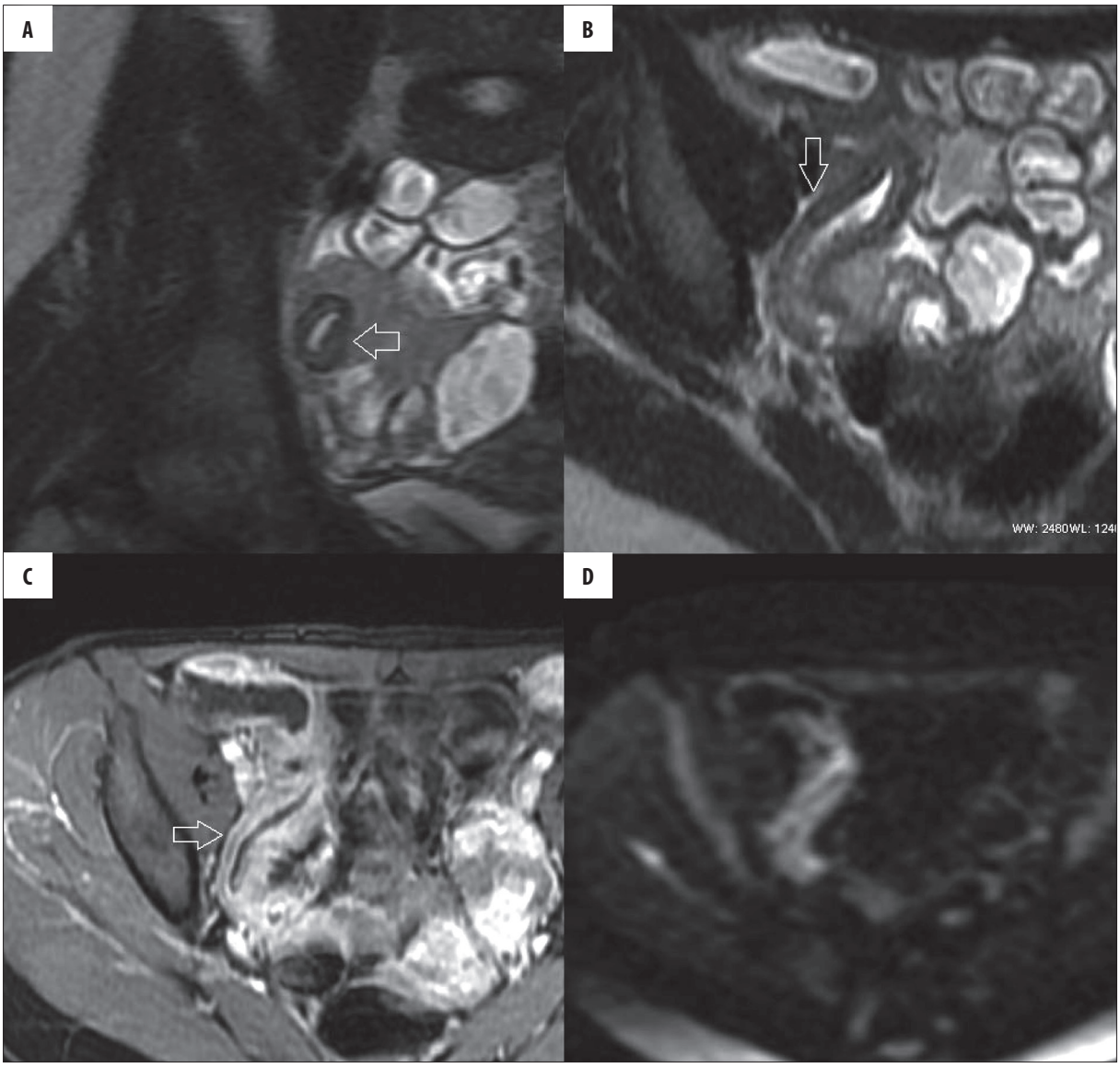

Figure 2. Submucosal edema in the terminal ileum. (**A, B**) Coronal and axial single-shot turbo spin-echo (SSFSE) images show high signal intensity of submucosa (arrows). (**C**) Axial contrast-enhanced fat-suppressed T1-weighted gradient-echo (LAVA) image shows stratified mural enhancement (arrow). (**D**) Axial diffusion-weighted image (b=1000 sec/mm^2) shows restricted diffusion in the affected ileal loop.

The image of small bowel wall layers

Increased signal intensity, reflecting submucosal edema, may be visualized within thickened bowel wall in T2-weighted sequences. In the analyzed material, this feature was observed in 8 patients with small bowel wall thickening (Figure 2). In transverse sections of bowel loops a "target" sign can be seen – two rings of low intensity signal corresponding to mucosa and muscle layer are separated by high-signal-intensity submucosa. An analogous picture can be also seen in post-contrast T1-weighted sequences with hyperenhanced mucosa and muscle layer and edematous submucosa that does not show contrast enhancement. However, similar image can be observed in fat hypertrophy and fibrosis of bowel wall, which is typical of chronic lesions both in CD and ulcerative colitis. This sign should be differentiated, taking into account other features of disease activity, such as mesenteric hyperemia, intense contrast enhancement [7], or lymphadenopathy. Moreover, the images obtained with and without fat suppression should be compared. However, no such case was observed in our material.

Ulceration

The presence of mucosal ulceration is indicative of high activity of CD. Two types of ulcerations are distinguished: shallow ulceration referred as aphtous ulceration and deep ulceration exceeding mucosal membrane and involving deeper layers of bowel wall. Deep ulceration may present as point-like or longitudinal fissuring ulcers. Some authors have questioned the utility of MR enterography for detecting shallow ulcerations [5]. Deep ulcerations are usually well visible in T2-weighted sequences as excess contrast collection penetrating into bowel wall [6]. In our material such changes were found in 6 patients (Figure 3).

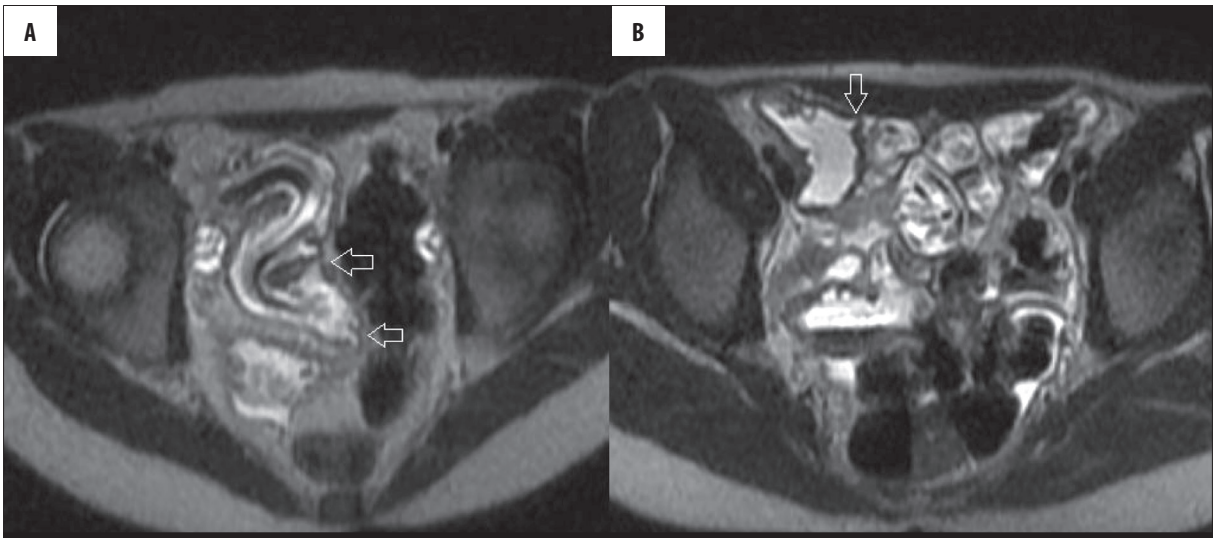

Figure 3. (**A, B**) Axial SSFSE images show deep ulcerations in the affected ileal loop (arrows).

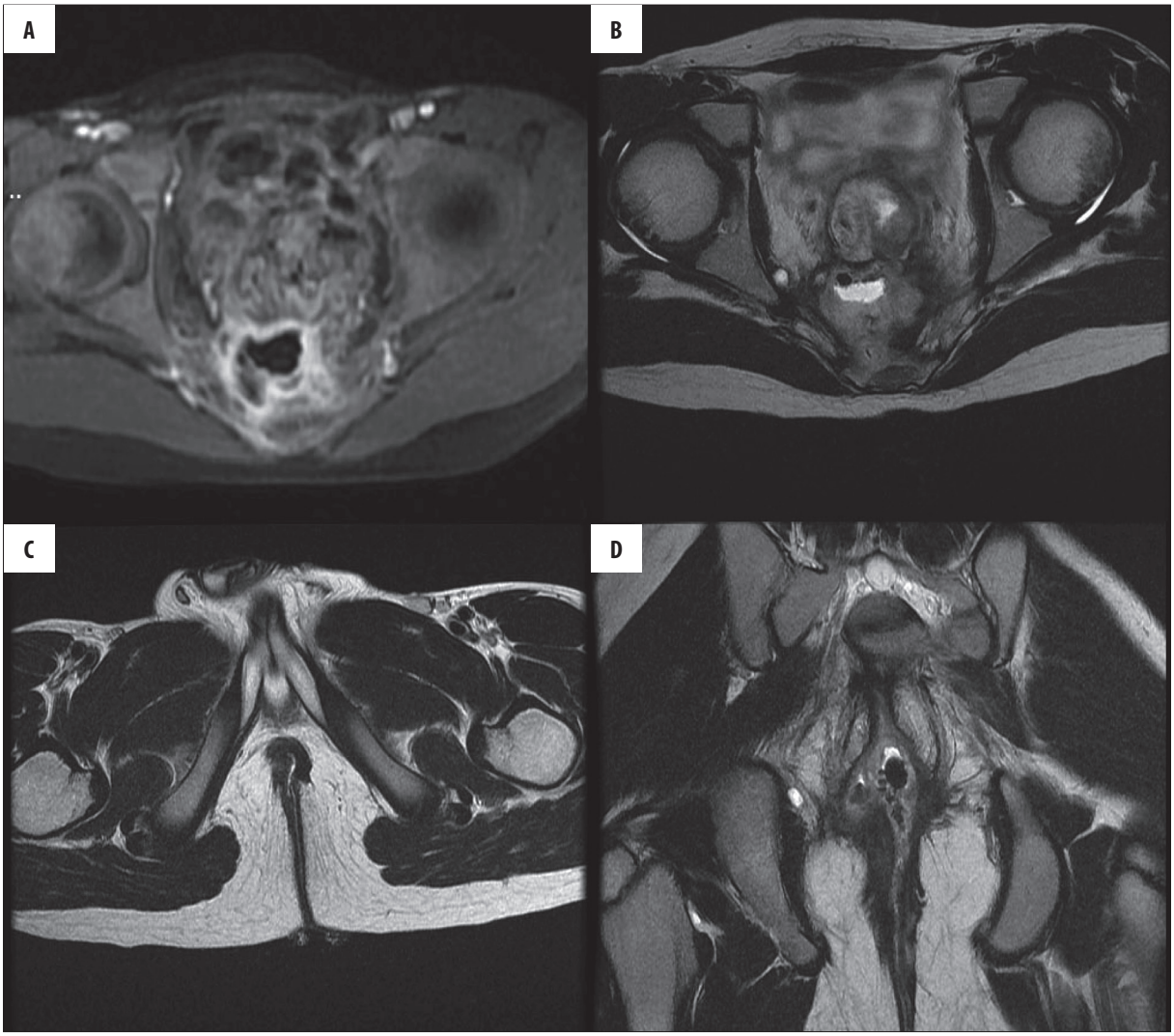

Figure 4. (**A, B**) Axial contrast-enhanced fat-suppressed T1-weighted gradient-echo (LAVA) and axial T2-weighted images show a perianal abscess formation. (**C, D**) Axial and coronal T2-weighted images – perianal fistula.

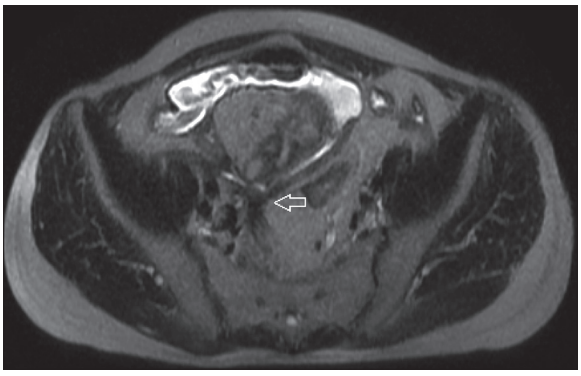

Figure 5. Axial single-shot turbo spin-echo (SSFSE) image shows a stellate pattern of bowel loop retraction to a central point(arrow) associated with complex ileal fistula.

Fistulas

Deep ulcerations lead to expansion of inflammation into deeper layers of alimentary tract wall and adjacent structures, resulting in the development of fistulas. When perianal fistula is suspected, it is reasonable to extend the diagnostic protocol or perform separate examination of the pelvis, including perianal area, aimed at detailed assessment of the course of fistula track in relation to sphincter muscles [8] (Figure 4). In analyzed material, in one patient the diagnostics had been extended to include additional pelvis sequences. Fistulas of other locations can be well visible in MR enterography. Typically, fistula tracks show strong contrast enhancement and connect adjacent bowel loops. Another types of fistulas that may develop in patients with CD include: intestino-cutaneous, intestino-vaginal and intestino-vessical fistulas as well as blind-ending sinuses penetrating to surrounding tissues. Fistula track may be filled with liquid content, which is indicated by high signal intensity in T2-weighted sequences. However the lack of fulfillment is not an evidence that fistula is not patent, because its lumen may be collapsed and timely occluded (Figure 5). In the study group, in one patient patent intestino-intestinal fistula was observed (its patency was indicated by high signal intensity in T2-weighted sequences) and in one patient occluded ileocecal fistula was found. Additionally, in one patient clinical data were suggestive of perianal fistula, therefore diagnostic protocol was expanded to include pelvis examination, which revealed perianal fistula and blind-ending sinus track penetrating from sigmoid colon to presacral area.

Strictures

Bowel segment involved in inflammatory process may be narrowed. There are two types of strictures: functional strictures, resulting from reduced and abnormal peristalsis, and anatomical strictures. Typical feature of a stricture is lack of complete distention of the bowel with the contrast agent, which does not change during the examination (despite good distention of remaining bowel loops), and dilation of bowel loops (greater than 3 cm in size) that are proximal to stenosis. In collected material one fibrotic stricture causing significant obstruction of gastrointestinal tract was found (Figure 6). Remaining strictures were related to large edema and impaired peristalsis of affected bowel segments. Dynamic FIESTA CINE sequences are particularly useful in the assessment of strictures and the impairment of small bowel peristalsis. It is important to identify the location of fibrotic stricture of bowel wall, because such changes are not susceptible to conservative treatment. In FIESTA CINE sequences they can be seen as motionless segments of stenosed bowel with thickened wall that does not show increased signal intensity in T2-weighted sequences, because its thickening is not caused by edema [5].

Mesenteric lesions

The expansion of the inflammatory process beyond the mucosal membrane, which is typical of CD, leads to hyperemia and reactive mesenteric fat hypertrophy. The evaluation of mesenteric structures should be performed on FIESTA sequence images that allow for considerably more accurate assessment compared to SSFSE sequences [9]. Post-contrast T1-weighted fat-suppressed images are also useful.

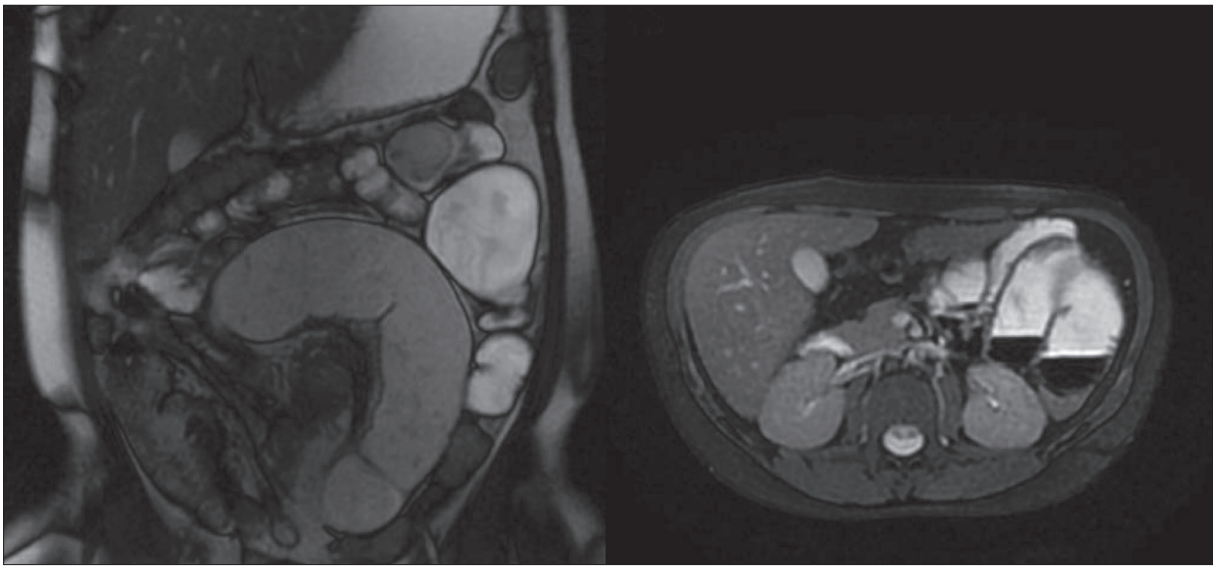

Figure 6. (**A, B**) Coronal and axial SSFSE images show jejunal obstruction with an abrupt transition from dilated to collapsed distal jejunum.

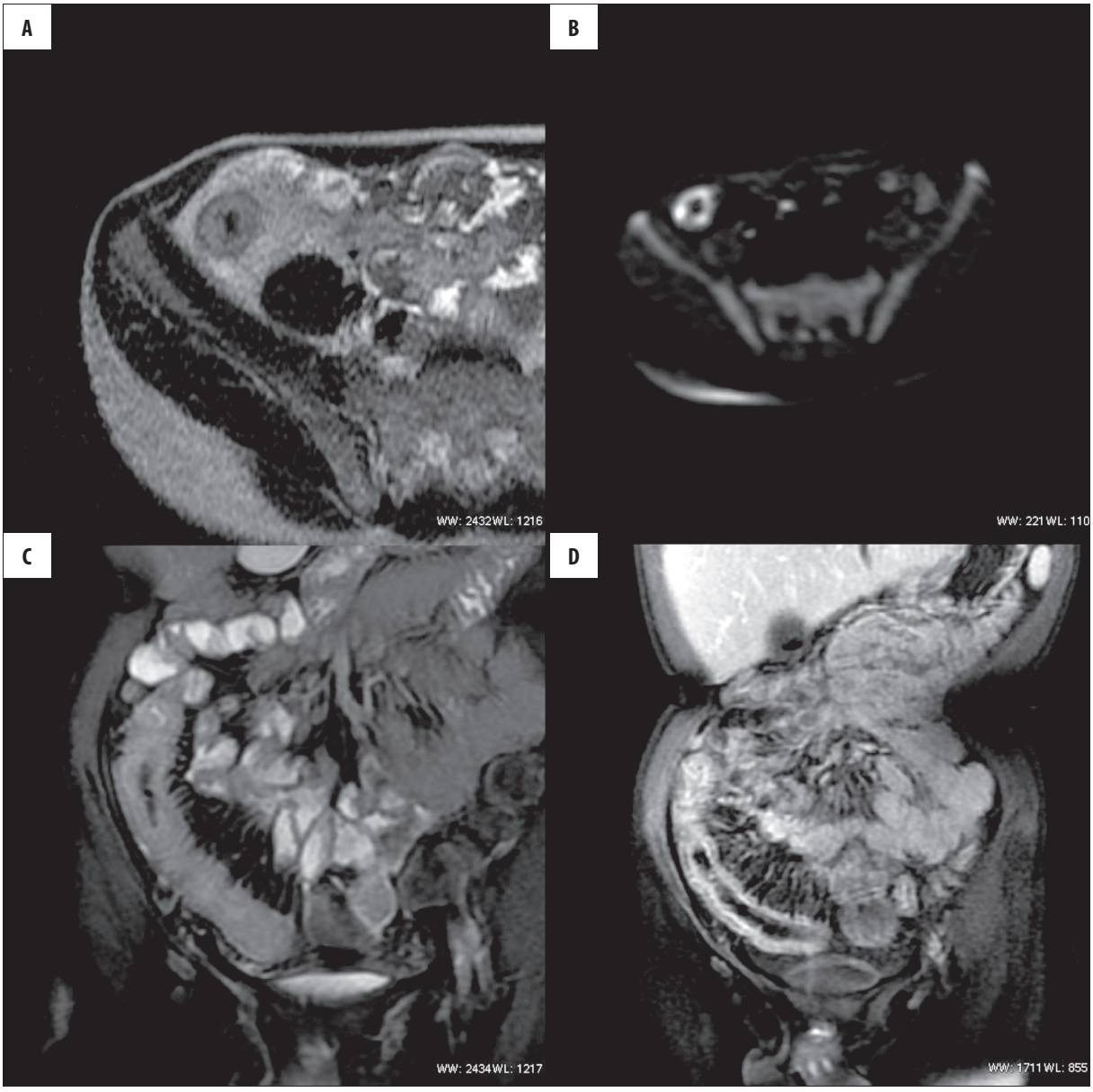

Figure 7. (**A**) Axial SSFSE image show markedly thickened ileal wall with surrounding fat proliferation. (**B**) Axial diffusion-weighted image (b=1000 sec/mm^2) shows restricted diffusion in the affected ileal segment. (**C, D**) Coronal FIESTA and contrast-enhanced fat-suppressed T1-weighted gradient-echo (LAVA) images show increased vascularity adjacent to a hyperenhancing segment of ileum.

Increased vascularization is depicted as typical comb-like picture of parallel vessels of small bowel mesentery, which are best visible in T1-weighted fat-suppressed sequences after intravenous administration of contrast agent and in FIESTA sequences (Figure 7). In our material, this feature was found in 9 patients. Fibrofatty proliferation of mesentery in fat-suppressed images is visible as an area of low signal intensity separating and modeling adjacent bowel loops. This sign is particularly typical of children [2] – in our material it was found in 8 patients. Both described above features coexisted with other signs of acute inflammation.

Mesenteric lymph nodes enlargement is another feature characteristic of CD (although it is much less specific). In our analysis, lymphadenopathy was found in 28 patients, in 4 of whom there were no other symptoms of CD. Mesenteric lymph nodes are well visible in coronal sequences, both T1-weighted and FIESTA. Lymph nodes with short axis longer than 5 mm are considered as abnormal [2]. Packet formation and strong contrast enhancement suggest active inflammation.

Large bowel lesions

The large bowel does not distend sufficiently with a contrast agent, therefore MR enterography is not suitable method for its assessment. However, intramural lesions, fistulas and contrast enhancement of the bowel wall are well visible, despite the lack of distension. Significant problem is the assessment of contrast enhancement of the mucosal membrane, due to high intensity of the stool at T1-weighted sequences. In analyzed material, changes in

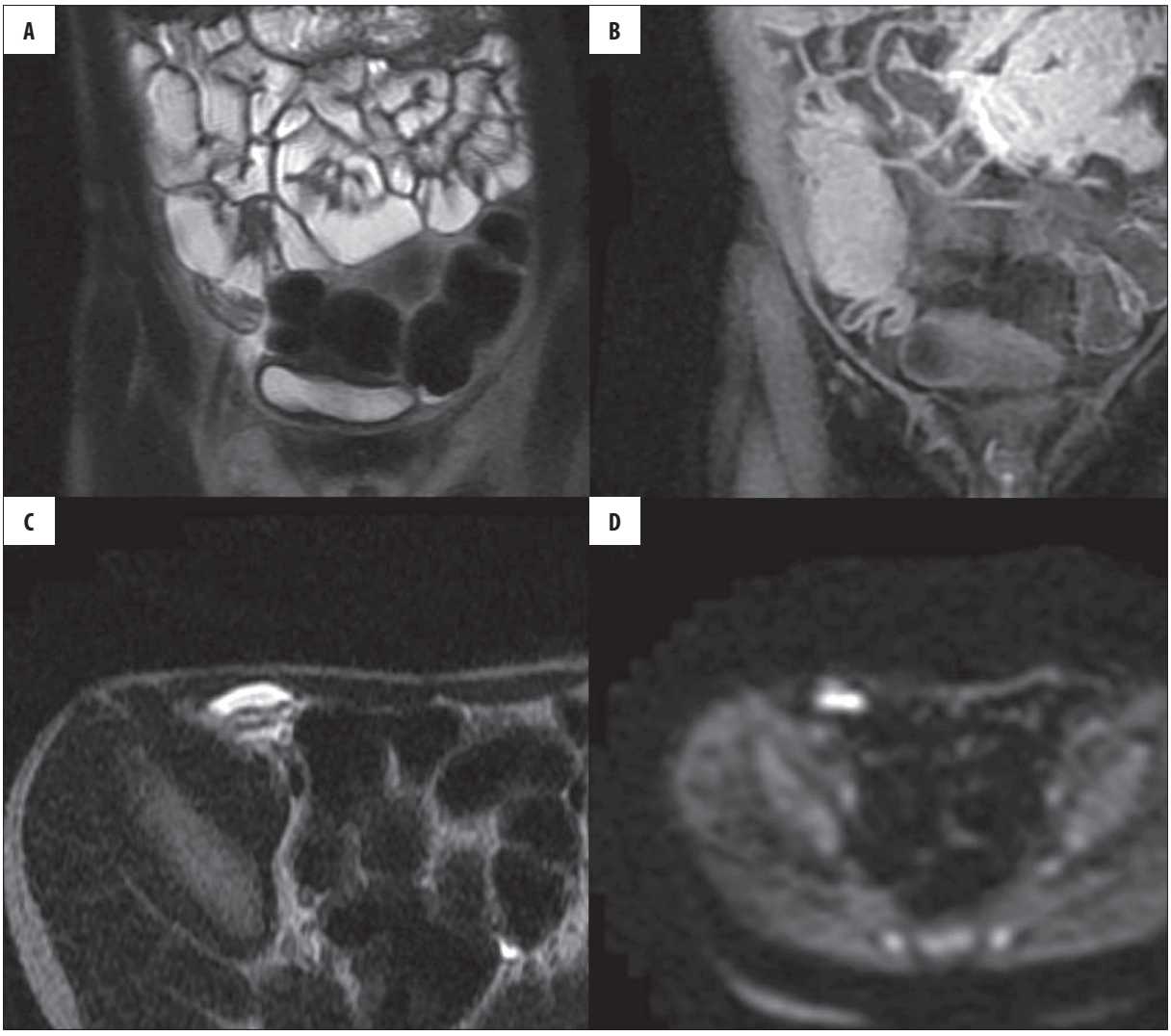

Figure 8. (**A**) Coronal SSFSE. (**B**) Coronal contrast-enhanced fat-suppressed T1-weighted gradient-echo (LAVA). (**C**) Axial SSFSE. (**D**) Axial diffusion-weighted image (b=1000 sec/mm^2). Images show signs of appendicitis in a patient with Crohn disease and no acute abdominal symptoms: thickened appendix wall, presenting with marked enhancement and restricted diffusion.

large bowel were found in 5 patients, including one patient who was not diagnosed with CD and was observed for IBD, and one patient in whom lesions in small bowel were also detected. On the other hand, in two patients no lesions in small bowel were found, despite the presence of symptoms suggestive of fistula. One patient had inflammatory changes within vermiform appendix, including wall thickening and lumen dilation with the presence of liquid in surrounding area (Figure 8). In the period preceding the examination, patient did not have any symptoms indicative of acute appendicitis. Therefore the changes must have been related to the location of CD within vermiform appendix.

Diffusion-weighted imaging

The role of DWI has not been yet established, but its diagnostic value in the detection of bowel segments involved with active inflammation has been highlighted. In our material diffusion restriction was also observed within affected bowel segments that showed other features of active process in other sequences.

Conclusions

1. Magnetic resonance (MR) enterography is a noninvasive diagnostic technique which enables detailed evaluation of CD extent, severity and comlications, as well as differentiation between active and chronic lesions.
2. A particular value in children, who are more susceptible to negative effects of exposure to ionizing radiation has to be underlined.
3. This technique should be regarded as a tool for baseline assessment of disease extent and severity, as well as for evaluation of treatment outcomes in children with CD.
4. The limitations of MR enterography incloude incapability of detecting early mucosal changes, which disqualifies this technique as a method for excluding CD.
5. Due to lack of capability of obtaining samples for histopathological examination this modality cannot replace endoscopic techniques.

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