MR ENTEROGRAPHIC EVALUATION OF THE SMALL BOWEL CROHN'S SUBTYPES

MR ENTEROGRAFICKÉ HODNOTENIE PODTYPOV CROHNOVEJ CHOROBY TENKÉHO ČREVA

review

Zuzana Lišková[1]
Katarína Sláviková[1]
Peter Mikula[2]
Viera Lehotská[3]

[1]Radiológia s.r.o., CT and MR department, University Hospital Bratislava, Slovakia
[2]1st Department of Radiology, Faculty of Medicine of Comenius University in Bratislava, Slovak Medical University and University Hospital Bratislava, Slovakia
[3]2nd Department of Radiology, Faculty of Medicine of Comenius University in Bratislava and St. Elizabeth's Cancer Institute Bratislava, Slovakia

Accepted: 15. 6. 2018

Correspondence:
Zuzana Lišková, MD, MPH
CT and MR department,
Radiologia s.r.o.
University hospital Bratislava
Antolská 11, Bratislava, Slovakia
e-mail: bilickas@gmail.com

Disclosure: nothing to disclose.

Major statement
MR enterography has the potential to play an important role in the management of patients with Crohn's disease because it can help recognize the disease, monitor disease activity and effectiveness of treatment and objectify the clinical status.

SUMMARY

Lišková Z, Sláviková K, Mikula P, Lehotská V. MR enterographic evaluation of the small bowel Crohn's subtypes

Crohn's disease is a chronic inflammatory disease of the gastrointestinal tract that can affect any part of the gastrointestinal tract from the mouth to the anus. It typically involves multiple discontinuous sites, with a tendency toward remission and relapse. Abdominal symptoms may be nonspecific and can result from active inflammation or from fibrotic scarring and stricture formation. Activity assessment of the disease is important to optimize the therapy. MR enterography has a high soft-tissue contrast so it plays an important role in management of the patient with Crohn disease. It can differentiate active inflammation from chronic fibrosis and strictures and advance the patient to a more aggressive pharmacologic therapy or to surgical intervention if a significant stricture is found.

Key words: Crohn disease, enterography, inflammatory bowel disease, MRI.

Hlavní stanovisko práce
MR enterografia môže významným spôsobom ovplyvniť starostlivosť o pacienta s Crohnovou chorobou, nakoľko je nápomocná v stanovení diagnózy, v sledovaní priebehu ochorenia a v objektivizování klinického nálezu.

SOUHRN

Lišková Z, Sláviková K, Mikula P, Lehotská V. MR enterografické hodnotenie podtypov Crohnovej choroby tenkého čreva

Crohnova choroba je chronické zápalové ochorenie čreva, ktoré môže postihnúť hociktorú časť tráviacej trubice – od úst až po anus. Typicky postihuje viaceré diskontinuálne miesta a má tendenciu k remisii a relapsom. Abdominálne ťažkosti sú častokrát nešpecifické – môžu byť spôsobené aktívnym zápalom, ale aj fibrotickým jazvovitým procesom, s tvorbou striktúr. Posúdenie aktivity ochorenia je dôležité pre ďalšiu cielenú terapiu. MR enterografia má veľké tkanivové rozlíšenie, a preto dokáže detekovať aktívny zápal a komplikácie u pacientov so známou Crohnovou chorobou. Nález aktívneho zápalu môže zvýšiť agresivitu farmakologickej terapie, kým chronické zmeny často vyžadujú chirurgickú intervenciu.

Kľúčové slová: Crohnova choroba, enterografia, zápalové ochorenie čreva, MR.

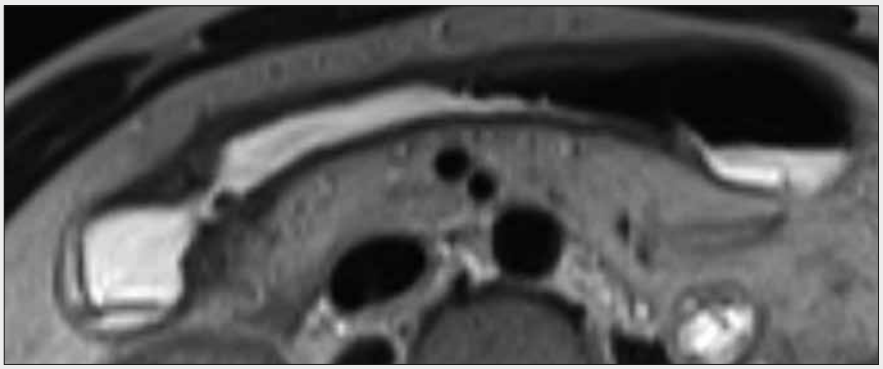
INTRODUCTION

Crohn's disease is an idiopathic chronic inflammatory disease of the gastrointestinal tract that has varying levels of severity, diverse manifestations, and an unpredictable course.

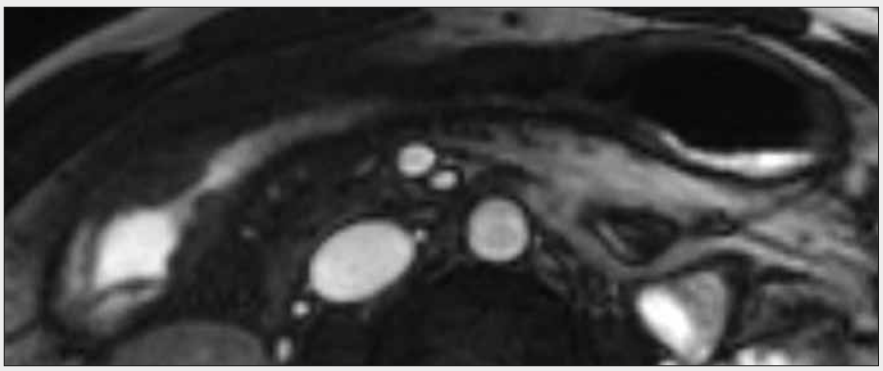
The small bowel is the most common site of Crohn disease and the least accessible with endoscopy. Often, the disease involves the terminal ileum by the time it is diagnosed. Although upper gastrointestinal involvement is rare, Crohn disease may affect any segment, or multiple non continuous segments, of the small bowel. Enteric involvement tends to be segmental, and inflammation often is transmural. The earliest change caused by the disease occurs as asuperficial mucosal (aphtoid) and deep linear ulcers, separated by segments of uninvolved mucosa ("skip lesions"). As the disease progresses, it extends to deeper layers of the bowel wall and aphtoid ulcers develop into coalescent linear (longitudinal and transverse) ulcers and fissures. Those yield an ulceronodular or "cobblestone" appearance (1). In more advanced active disease, the inflammation tends to penetrate the bowel wall with formation of fistulas and abscesses. Chronic disease is characterized by strictures that sometimes requires surgical intervention (2).

Clinical scoring (such as the Crohn's disease activity index, biologic indexes) use medical history, laboratory data, and physical examination to assess disease activity and complications, but these tools are relatively nonspecific (3). Because the symptoms of active inflammation and those of complications may be indistinguishable, imaging often is needed. Assessment of activity is usually made using a combination of clinical symptoms, physical findings, laboratory investigations, endoscopy, and imaging tests. The challenge of the cross-sectional imaging technique is to be sensitive enough to allow differentiation of acute bowel inflammation and its complications that can be managed medically and of chronic changes that require surgery (4). In addition, the ideal imaging test would be reproducible, well tolerated by patients, and free of ionizing radiation.

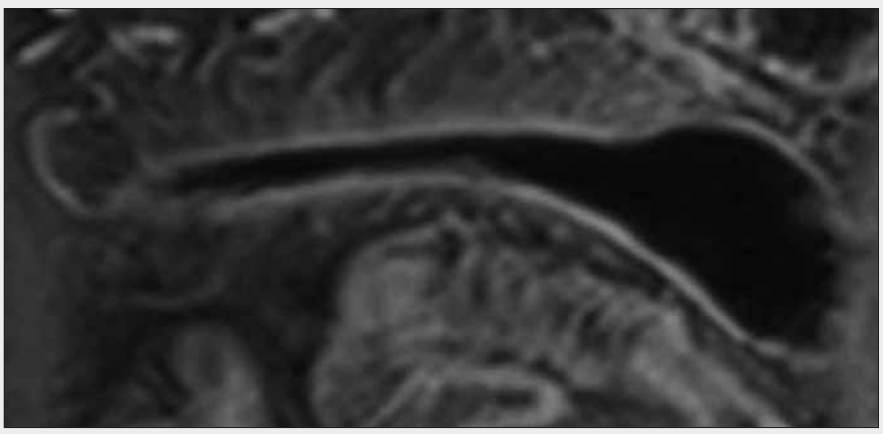
Advantages of magnetic resonance (MR) imaging include a lack of ionizing radiation, the ability to provide dynamic information regarding bowel distention and motility, improved soft-tissue contrast, and a relatively safe intravenous contrast



◀ Obr. 1A



◀ Obr. 1B



◀ Obr. 1C

Fig. 1. ***A typical appearance of Crohn's disease – chronic changes in combination with active inflammation.*** *Active inflammatory changes such as bowel wall thickening, with mild edema, mucosal hyperenhancement and mesenteric hyperemia are present, in a condition of chronic luminal narrowing and mild prestenotic dilatation. A – HASTE; B – true FISP with fat saturation; C – post gadolinium T1_VIBE with fat saturation*

Obr. 1. ***Typický vzhľad Crohnovej choroby – chronické zmeny v kombinácii s aktívnym zápalom.*** *V teréne chronického zúženia lumenu s miernou prestenotickou dilatáciou sú viditeľné aktívne zápalové zmeny ako zhrubnutie steny čreva s edémom, výrazné sýtenie mukózy a hyperemia mezentéria.*

agent profile. Limitations of MR imaging include cost, availability of examination, variability in examination quality, and lower spatial and temporal resolution compared with those of computed tomography (CT). MR imaging of the small bowel is indicated for patients with Crohn disease, those for whom exposure to radiation is a concern, those with contraindications to CT scanning, and those with low-grade small bowel obstruction (4–7). According to the American college of Radiology, indications for MRE include, but are not limited to, the following:

1. Diagnosis of IBD, including assessment of disease activity and extent.
2. Follow-up of known IBD, including assessment of disease activity and response to therapeutic intervention.
3. Evaluation of suspected IBD-related complications, such as stricture or penetrating disease (e.g., fistula or abscess).
4. Differentiation of Crohn disease from ulcerative colitis in children with "indeterminate colitis".
5. Nonemergent evaluation of suspected bowel disease with prior negative computed tomography (CT) examination and/or endoscopy, or in place of these other tests, and including a variety of processes, such as bowel obstruction or non-IBD enteritis (e.g., due to infection or vasculitis).
6. Evaluation of polyposis syndromes and small-bowel mass(es).

MR IMAGING FINDINGS IN CROHN DISEASE

In patients with proved or suspected Crohn disease, cross-sectional images of pathologically altered bowel segment should be analyzed for a) the presence of the disease, b) inflammatory lesion activity and c) the presence of extraintestinal complications (1). A characteristic feature of Crohn's disease of the small bowel is the wide variety of radiologic features and multiplicity of abnormalities that can be present in any individual patient (Fig. 1). It is common for a single bowel segment to exhibit characteristics of active inflammation, chronic changes, fibrosis or penetrating disease. An imaging-based classification system of Crohn's disease subtypes can help clinicians to plan appropriate therapy. The investigators classify the disease into subtypes that include a) active inflammatory, b) fibrostenosing, c) fistulizing/perforating characteristics and d) reparative or regenerative subtype. More than one subtype of the disease process may be noted in a segment or in multiple adjacent segments in the same patient and potentially they can't be distinguishable from each other (4, 8).

ENTEROGRAPHIC CHARACTERISTIC OF CROHN'S SUBTYPES

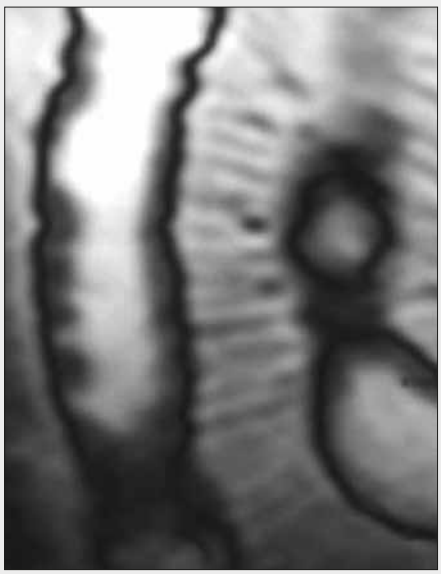
Active inflammatory subtype of Crohn's disease

Because of limited spatial resolution, it is not possible to see the earliest changes of Crohn disease (mucosal nodularity, erythema and superficial aphthous ulceration) at MR enterography, even with luminal distention at MR enterography (9).

Severe active inflammatory changes are visible as deeper longitudinal and transverse ulcers, with protrusion of edematous mucosa. Depiction of these changes is highly dependent on the quality of luminal distension. Moderate to deep ulcers appear as thin lines of high signal intensity on T2 weighted images, longitudinally or transversely oriented within thickened bowel wall, with a typical appearance of "cobblestone paving" (Fig. 2). Unlike mild inflammatory disease activity, the changes of severe inflammatory disease activity on MR enterography are easily appreciated. **Bowel wall thickening and mural hyperenhancement** are the most sensitive visual markers of active Crohn's disease (10, 11) (Fig. 3). Mural thickening is defined as a small-bowel wall thickness of

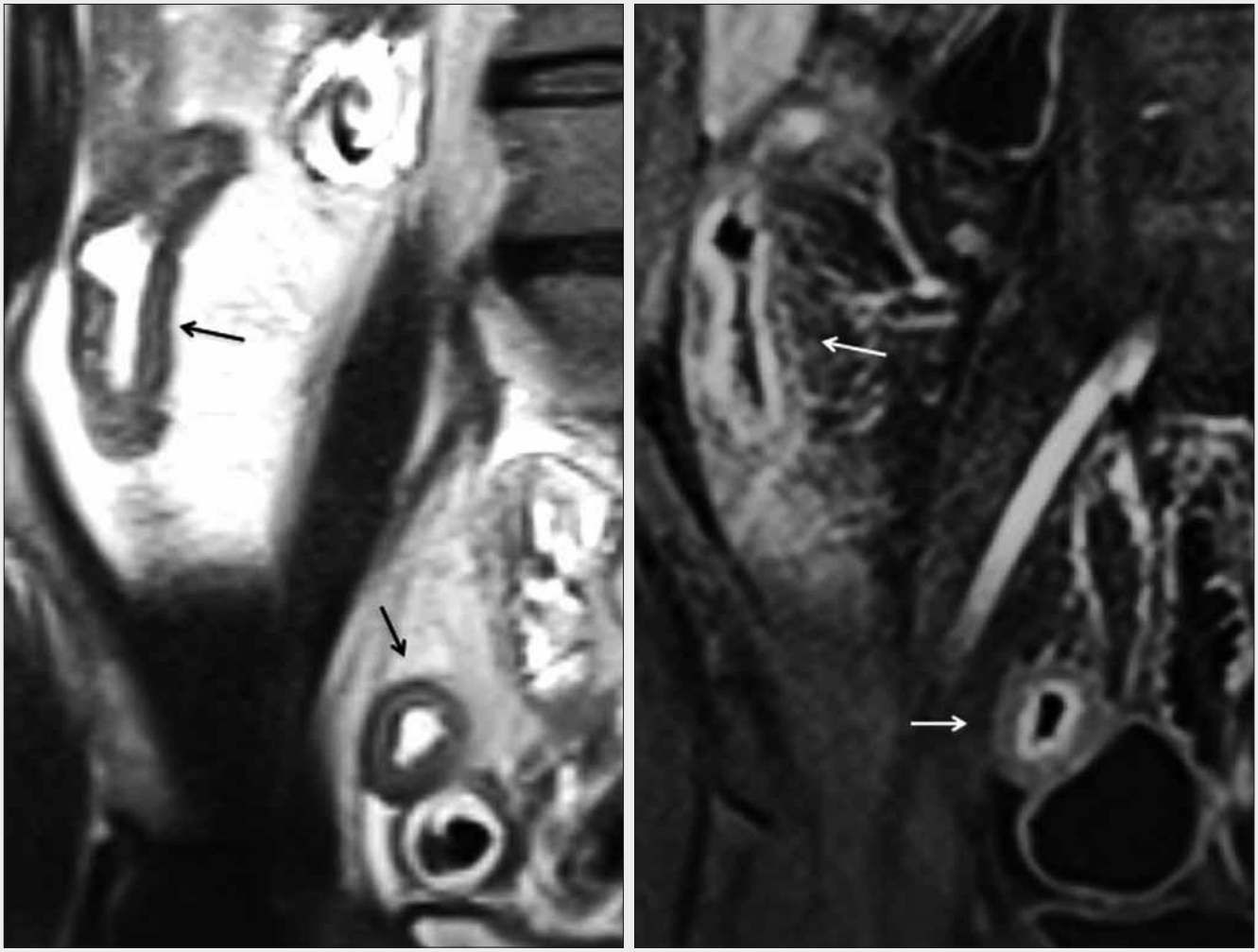
▲ *Obr. 2A*

▲ *Obr. 2B*



▲ *Obr. 2C*

Fig. 2. ***Severe active inflammatory changes of Crohn's disease. Deep ulcers in the affected bowel wall visible on HASTE sequence as small holes in the edematous mucosa (A, B).*** *Multiple ulcers resulting in a typical "cobblestone" appearance (C, HASTE sequence).*
Obr. 2. ***Výrazné aktívne zápalové zmeny pri Crohnovej chorobe. Hlboké ulkusy v postihnutom úseku čreva viditeľné v HASTE sekvencii ako male „diery" v edematóznej mukóze (A, B).*** *Početné ulkusy tvoria typický obraz „mačacích hláv" (C, HASTE sekvencia).*



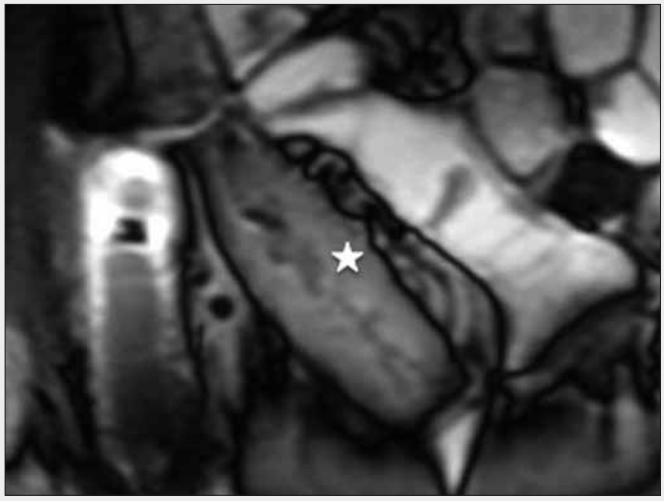
▲ Obr. 3A ▲ Obr. 3B

Fig. 3. ***Most typical appearance of severe active inflammatory changes of Crohn's disease. Bowel wall thickening with typical mural stratification ("target sign" or "halo sign") with submucosal edema is seen on multiple segment of small bowel (A – HASTE sequence). Mucosal hyperenhancement on post gadolinium T1WI with fat saturation (B).***
Obr. 3. ***Najtypickejší vzhľad aktívnych zápalových zmien Crohnovej choroby. Na viacerých segmentoch tenkého čreva je viditeľné zhrubnutie steny čreva s typickou stratifikáciou steny (vzhľad terča alebo „halo" znak) a so submukóznym edémom (A, HASTE sekvencia). Výrazné sýtenie mukózy na postkontrastných T1 vážených skenoch s potlačením tuku (B).***

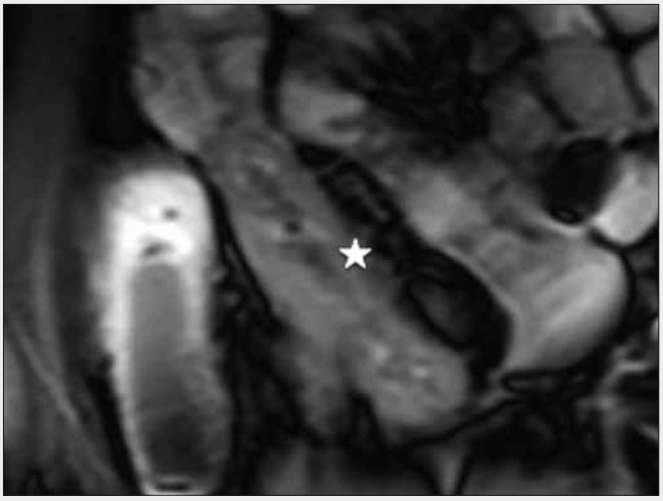
more than 3mm in a well distended bowel loop. It is often asymmetric and prominent along the mesenteric border (11). Mural hyperenhancement means segmental increases in the enhancement of the bowel wall (either transmurally or to the inner lining of the bowel wall) in comparison with enhancement of a normal surrounding loops with similar distension. The collapsed bowel loops have thicker bowel wall with pronounced enhancement and should not be taken in consideration. Segmental mural hyperenhancement is a nonspecific finding that is also associated with other inflammatory conditions; however, the presence of asymmetrical mural enhancement and thickening is virtually pathognomonic for Crohn's disease (11). If the transmural enhancement is mild and similar to the enhancement of the muscles, it is probably a chronic inflammatory process (12, 13).

If the typical signs of active disease are not prominent, other signs have to be found: **mural stratification** ("target sign" or "halo sign"), **prominent vasa recta** ("comb sign") and **mesenteric edema**, reactive **lymphadenopathy** and associated complications (such as penetrating disease and bowel obstruction (5, 11, 13).

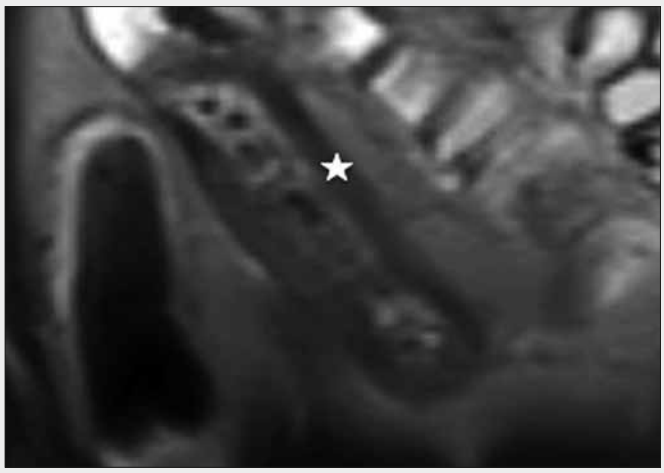
Mural stratification refers to the trilaminar or bilaminar appearance of the thickened bowel wall and reflects the submucosal edema. This mural stratification is composed of an inner ring of mucosal enhancement surrounded by an outer ring of muscular and serosal enhancement on post gadolinium T1W images, with an intermediate ring of submucosal edema with high signal intensity on T2W images and low signal on T1W images (8). The enhancing layers reflect underlying active inflammatory disease. The advantage of MR examination is in the possibility to recognize mural edema without administration of contrast media – on T2 like weighted images (HASTE – Half-Fourier Acquired Single-Shot Fast Spin-Echo Sequence, True FISP sequence – True Fast Imaging with a Steady Precession), without and with fat suppression. The "target sign" can be seen as inner and outer hypointense ring with hyperintense signal ring in between them. The "target" or "halo" sign from active inflammatory disease subtype



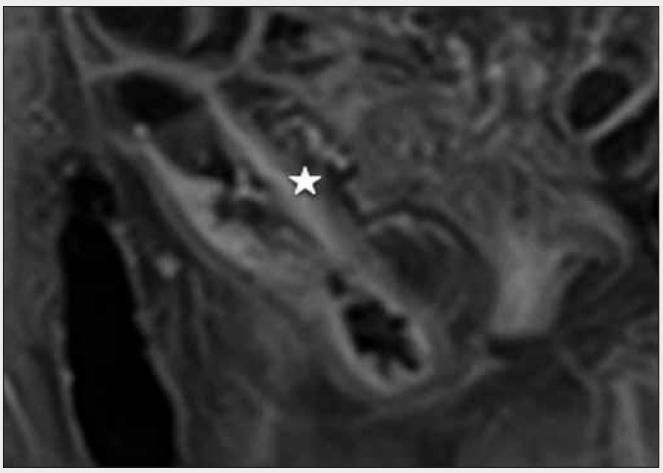
▲ Obr. 4A



▲ Obr. 4B



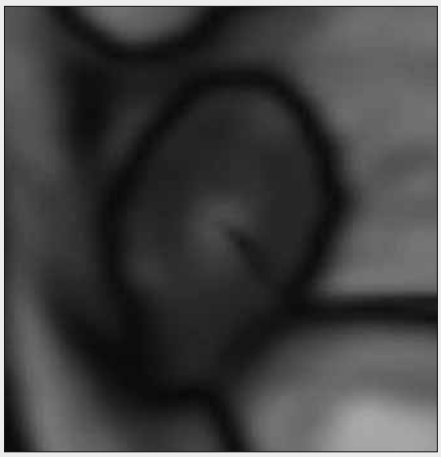
▲ Obr. 4C



▲ Obr. 4D

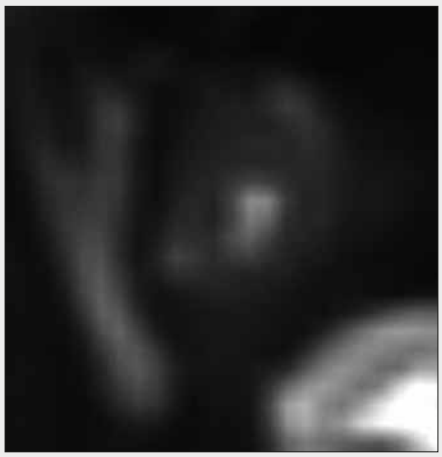
Fig. 4. ***Detection of submucosal edema on native MR enterographic images. High signal intensity changes in the middle layer of bowel wall on True FISP sequence (A) and HASTE (C), which are persistent on True FISP with fat suppression (B). Post gadolinium T1W images with mucosal hyperenhancement (D).***

Obr. 4. ***Detekcia submukózneho edému na natívnych MR enterografických skenoch. Hyperintenzívne zmeny v strednej časti steny tenkého čreva viditeľné na True FISP sekvencii (A) a HASTE (C), ktoré pretrvávajú aj na True FISP s potlačením tuku (B). Postkontrastné T1 vážené obrazy s výrazným sýtení mukózy (D).***



▲ Obr. 5A

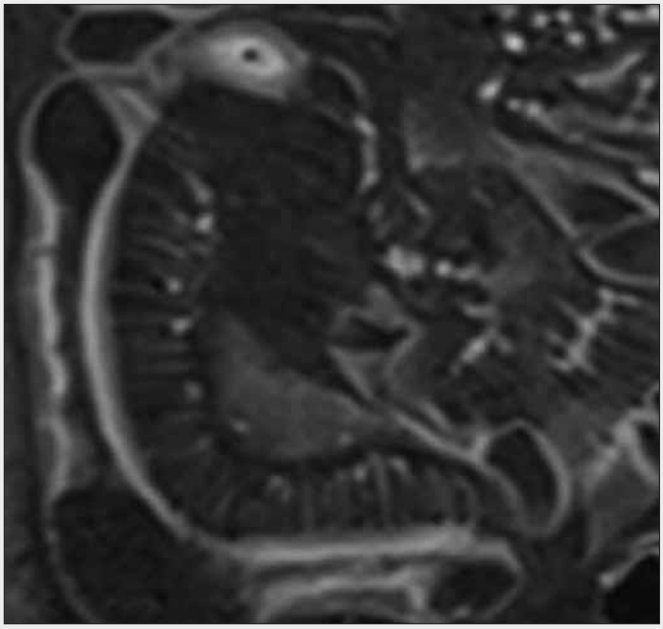
▲ Obr. 5B



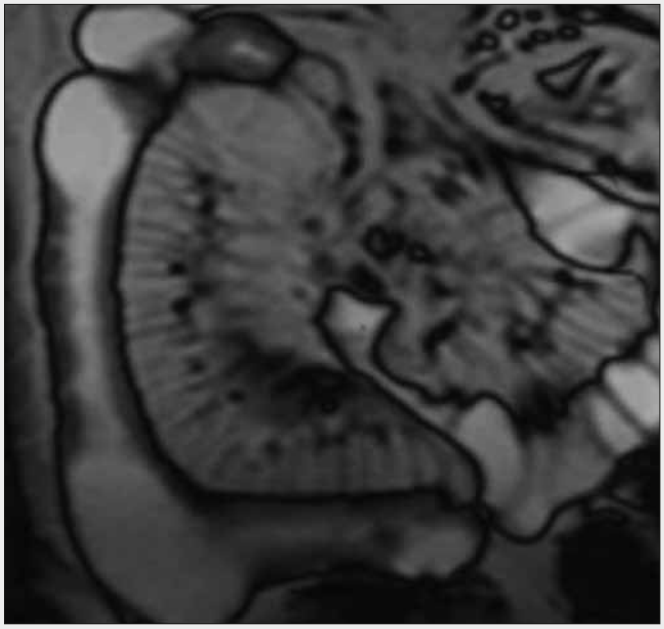
▲ Obr. 5C

Fig. 5. ***Detection of submucosal edema on native MR enterographic images with using HASTE sequence and HASTE with fat saturation. High signal intensity changes in the submucosa on True FISP sequence (A) and HASTE (B), with persistent hypersignal intensity on HASTE with fat suppression (C), which is consistent with submucosal edema.***

Obr. 5. ***Detekcia submukózneho edému na natívnych MR enterografických obrazoch s využitím HASTE stekvencie a HASTE sekvencie s potlačením tuku. Hyperintenzívne zmeny v submukóznej vrstve steny čreva viditeľné v True FISP sekvencii (A) a HASTE (B), ktoré pretrvávajú aj v HASTE sekvencii s potlačením tuku (C). Nález zodpovedá submukóznemu edému.***

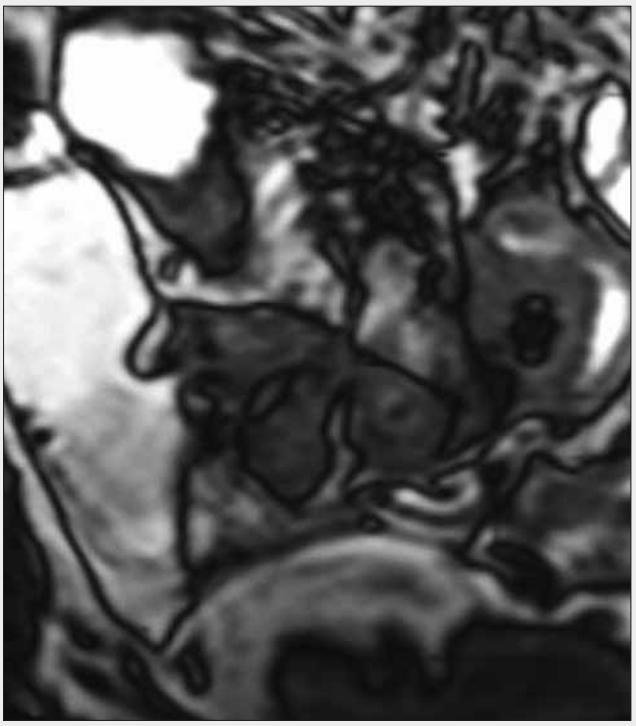


▲ Obr. 6A



▲ Obr. 6B

Fig. 6. ***Mesenteric hyperemia or "comb sign". The detection of mesenteric hyperemia is best on post gadolinium T1W images with fat suppression (A) and True FISP sequence (B).*** *The engorged vasa recta are crossing the mesenteric fat adjacent to the inflamed bowel loop.*
Obr. 6. ***Mezenteriálna hyperemia alebo „znak hrebeňa". Mezenteriálna hyperémia je najlepšie viditeľná na postkontrastných T1 vážených obrazoch s potlačením tuku (A) a na True FISP sekvencii (B).*** *Rozšírené vasa recta prebiehajú cez mezenteriálny tuk v blízkosti zapálenej črevnej kľučky.*



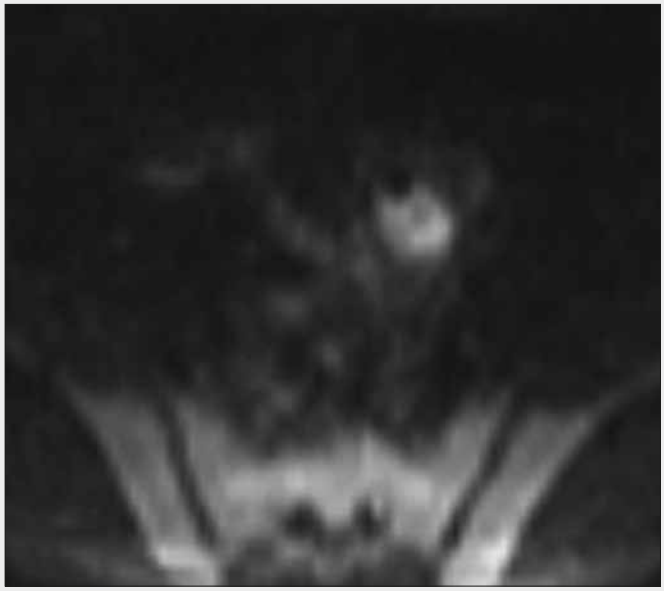
▲ Obr. 7

Fig. 7. ***Complex internal bowel fistula. Coronal True FISP MR image shows a stellate pattern of bowel loop retraction to a central point, a finding associated with a complex internal fistula.***
Obr. 7. ***Komplexná vnútorná fistula čreva. Na koronárnych True FISP skenoch je viditeľný hviezdicovitý útvar priťahujúci črevnú kľučku k centrálnemu bodu – nález zodpovedajúci komplexnej vnútornej fistule.***

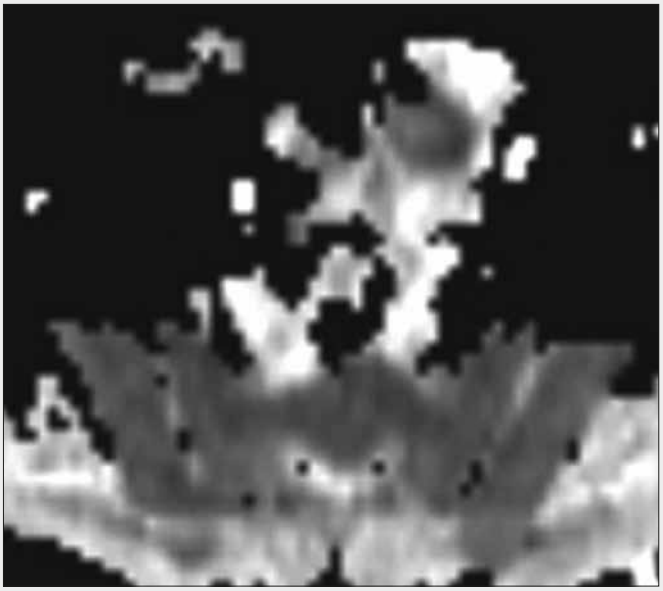
should be differentiated from the "halo" produced by submucosal fat deposition seen in chronic disease. Recognition of the fat attenuation in the submucosa will allow differentiation from edema. For those reasons, T2W images with fat suppression should be included in a standard enterographic protocol (Fig. 4, 5). However, one study has shown that this may be a normal variant and may not necessarily be associated with chronic bowel inflammation (5). Mesenteric hyperemia and edema are signs of transmural inflammatory process, which extend into the adjacent perienteric tissue (8, 11, 15–17). Increased mesenteric vascularity adjacent to the inflamed bowel loop is best identified on contrast-enhanced T1 – weighted fat-suppressed images or SSDP images and it can be seen as numerous linear structures in the perienteric fat reaching the pathologic bowel segment. These sequences also clearly demonstrate reactive regional mesenteric lymphadenopathy, which is another indicator of active inflammation (4, 15) (Fig. 6). Perienteric inflammation (e.g., edema, fluid, or enhancement) is indicative of more severe inflammation and is more conspicuous on T2-weighted fat-suppressed images.

Fistulizing/penetrating subtype of Crohn's disease

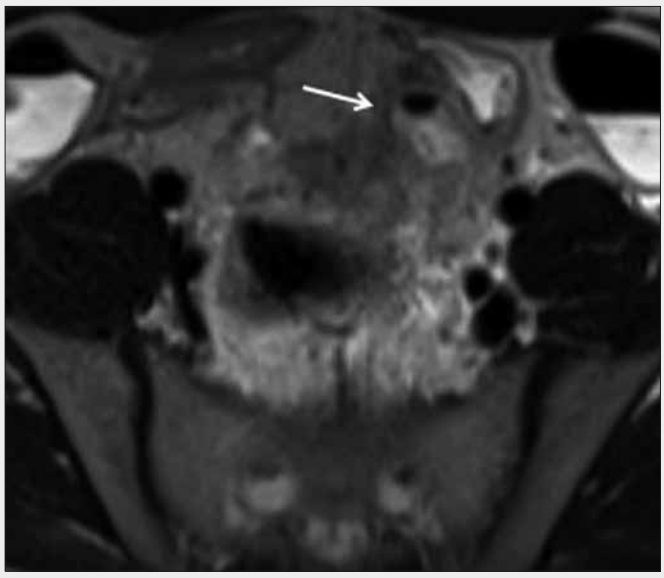
Deep ulcer formation may lead to transmural inflammation and sinus tract formation, which may progress to fistulation. Fistulas may bridge adjacent loops of small bowel or cross from small bowel to other surrounding structures (the colon, stomach, bladder, or skin). Penetrating disease may cause the formation of abscesses. Fistulas, sinus tracts, and abscesses are visible on contrast-enhanced T1-weighted fat-suppressed images because of their avidly enhancing walls. They may or may not contain fluid and air bubbles. Adhesions between ad-



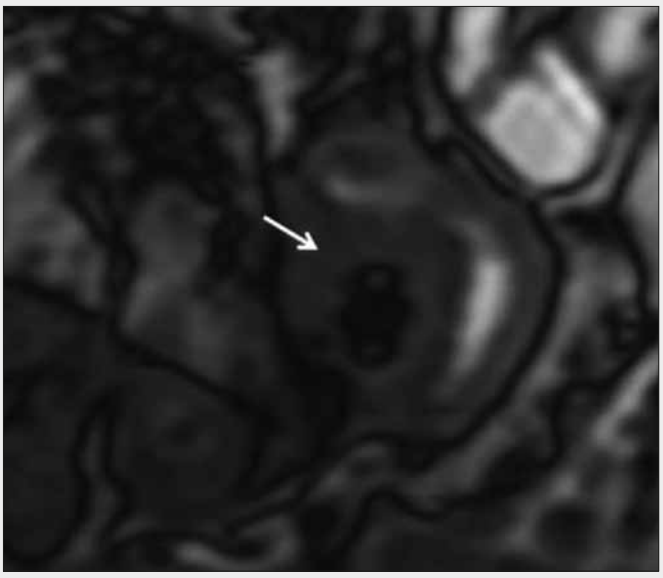
▲ Obr. 8A



▲ Obr. 8B



▲ Obr. 8C



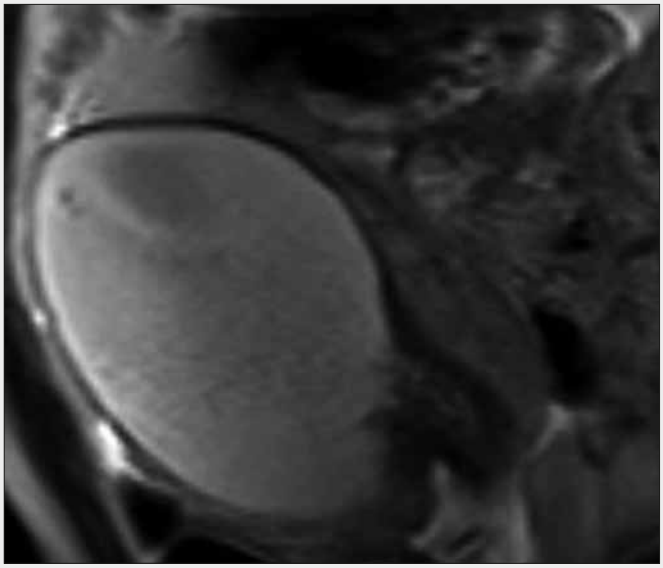
▲ Obr. 8D

Fig. 8. ***Interloop abscess. Diffusion weighted images b = 800 sec/mm² (A) shows restricted diffusion, with low signal intensity on ADC map (B), consistent with abscess. On native HASTE (C) and True FISP sequence (D) images it could be mistaken for an abnormal bowel loop.***
Obr. 8. ***Medzikľučkový abscess. Difúzne vážený obraz s hodnotami b = 800 sec/mm² (A) ukazujú výraznú reštrikciu difúzie s nízkymi ADC hodnotami (B), nález svedčiaci pre abscess. Na natívnych HASTE (C) a True FISP skenoch (D) by sa obraz mohol zameniť za abnormálnu črevnú kľučku.***

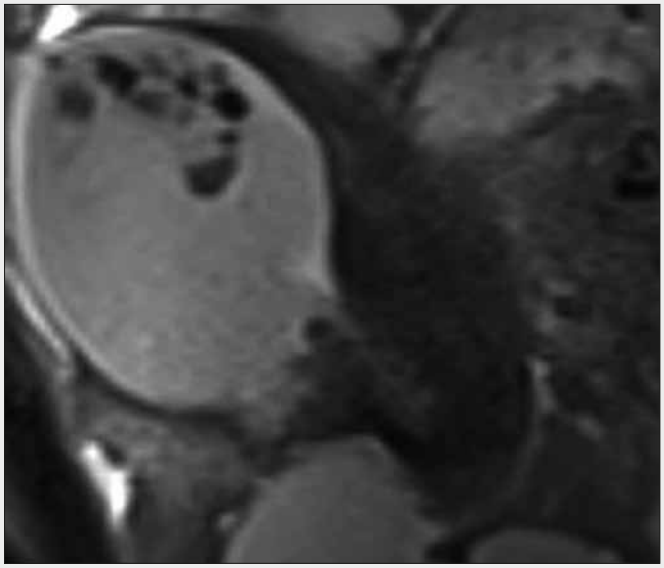
jacent bowel loops can be distinguished from fistulas because adhesions are fibrotic, contain no fluid and tend to be thinner and enhance later than fistulas, whereas fistulas are composed of more vascular inflammatory tissue. Complex enteroenteric fistulas often form a network between closely adherent small-bowel loops that may appear as a stellate configuration – with multiple tracts and bowel loops radiating from the central portion (4, 8) (Fig. 7). An abscess is a well-defined, encapsulated collection of pus. It appears as fluid collections with an enhancing wall, with or without associated air, with no connection to the bowel lumen. Interloop abscesses may be difficult to detect if there is retraction and matting of loops or the content of the abscess is heterogeneous and similar to that of the bowel loop. In these situation, use of diffusion weighted images (DWI) may be very helpful while it can increase the conspicuity of the inflamed colon and also the dense content of the abscess (4) (Fig. 8).

Fibrostenotic subtype of Crohn's disease

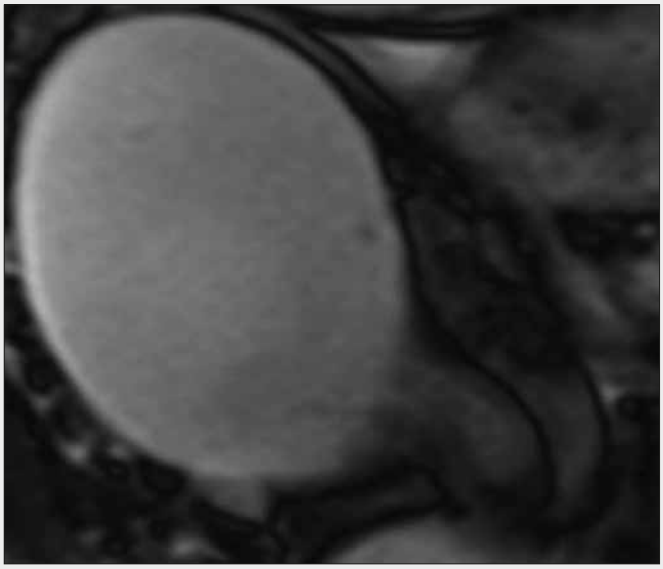
A long-going chronic inflammation within the bowel wall progresses to mural fibrosis (4). The thickened submucosa of a strictured fibrotic bowel segment has typically low signal intensity on both T1 and T2-weighted images in the absence of active disease because of the lack of mural inflammation and edema (4).



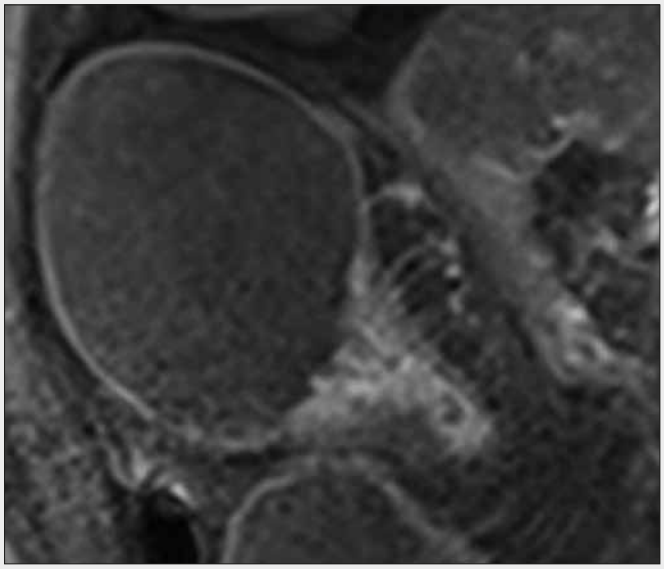
▲ Obr. 9A



▲ Obr. 9B



▲ Obr. 9C



▲ Obr. 9D

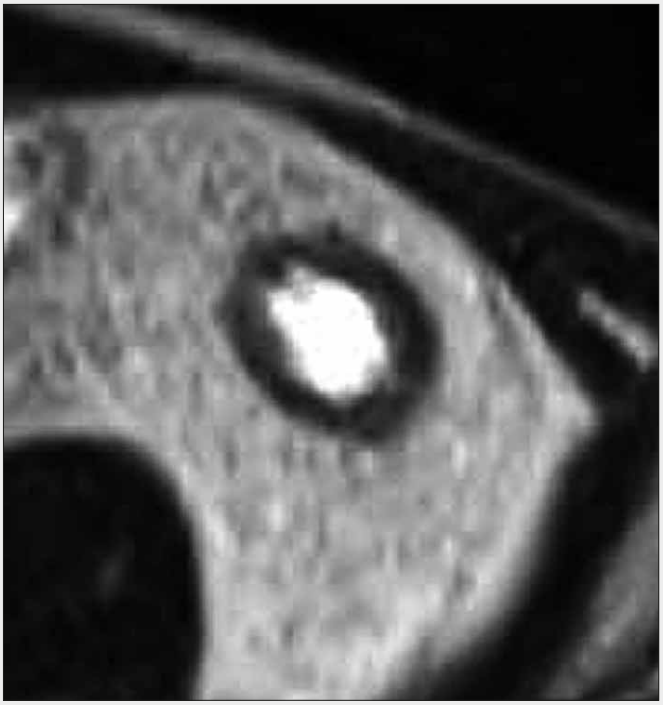
Fig. 9. ***Sever stenosis of the small bowel in chronic Crohn disease with coexistent active inflammation. A marked prestenotic dilatation is present. A mild hyperintense signal is visible within the stenotic wall on HASTE (A), persistent on HASTE with fat suppression (B), and also on True FISP (C). Post gadolinium T1 weighted image with fat suppression depict a mild but evident mucosal hyperenhancement and mesenteric hyperemia.***
Obr. 9. ***Ťažká stenóza kľučky tenkého čreva pri chronickej forme Crohnovej choroby so spolu prebiehajúcim aktívnym zápalom. Prítomná je aj výrazná prestenotická dilatácie. V stenotickej časti črevnej kľučky je v stene viditeľný mierny hyperintenzívny signal (A, HASTE sekvencia), ktorý pretrváva aj na skenoch s potlačením tuku (B, HASTE fat sat sekvencia) a taktiež na True FISP sekvencii (C). Postkontrastné T1 vážené obrazy s potlačením tuku taktiež ukazujú evidentné výraznejšie sýtenie mukózy a taktiež mezenteriálnu hyperémiu.***

When fibrosis is associated with stricture formation, bowel obstruction may develop (Fig. 9). It is the predominant clinical manifestation of this disease subtype and because it is unresponsive to pharmacologic therapy, it is important to identify a fibrotic stricture with certainty. The degree of stenosis is variable, ranging from mild to severe. If a symptomatic bowel obstruction is present, it typically requires a surgical intervention. On cine images, fibrotic strictures appear as aperistaltic bowel segments that often demonstrate fixed mural thickening and luminal narrowing. Bowel dilatation proximal to a fixed, narrowed segment implies obstruction. On static postgadolinium T1-weighted images it presents as a homogeneous soft tissue enhancement of the thickened wall with no evidence of edema (8). Fecalization of the small-bowel contents may be present but it is not specific to small-bowel obstruction (4).

Chronic inflammation in the bowel wall can lead to various signs: fatty infiltration of the bowel wall, fibrofatty proliferation in adjacent mesenteric fat and pseudosacculations (9).

Submucosal fat deposition may occur in chronic inflammatory bowel disease and lead to a trilaminar appearance or target sign of the bowel wall. To differentiate fat from acute wall edema, fat-saturated and non-fat-saturated T2-weighted

▲ Obr. 10A



▲ Obr. 10B

Fig. 10. ***Chronic Crohn's disease with fibrofatty proliferation and formation of pseudodivertikulas. Fibrotic involvement of mesenteric border of the bowel wall (long arrow in A) and pseudosacculations formation on antimesenteric side (short arrow in A). Proliferation of the fatty tissue is also present (B).***
Obr. 10. ***Chronická forma Crohnovej choroby s fibroticko-tukovou proliferáciou a tvorbou pseudodivertiklov. Prítomné fibrotické postihnutie mezenteriálneho okraja čreva (dlhá šípka na A) a pseudosakulácie na antimezenteriálnej strane (krátka šípka na A). Viditeľné je aj zmnoženie okolitého tukového tkaniva (B).***

images are required. Edema will demonstrate persistent high signal intensity in both sequences, whereas fat saturation will reduce wall signal intensity if fat is present. Fatty deposition may occur also in healthy individuals, particularly in association with obesity (9) and therefore this sign has to be considered in a clinical context rather than assume it as a specific sign of chronic inflammation.

Fibrofatty proliferation refers to an increase deposition of fat in the perienteric region. Pseudosacculations or pseudodiverticulas are saccular dilatations of the antimesenteric border of the affected bowel loop. They are a consequence of relative sparing of the antimesenteric border from the ongoing fibrosis. Fibrosis and shortening predominantly affects the mesenteric site of the bowel wall (Fig. 10).

Reparative or regenerative disease subtype

This subtype reflects inactive Crohn's disease and may be associated with other phases of Crohn's disease located in different locations in the same small bowel. Mucosal atrophy and regenerative polyps characterize this phase (Fig. 11). There may be a decrease in lumen diameter, but there is no evidence of active inflammation (8).

CONCLUSION

This article has reviewed the imaging features that radiologists can use to classify the patients into clinical subtypes of Crohn's disease. Clinical scoring systems of Crohn's disease are imperfect, very subjective and rarely used in routine clinical practice. There is clearly a need for a more objective noninvasive measure of disease activity that can be repeatedly and reproducibly performed even in young patients. MR enterography has the potential to play an important role in management of small-bowel Crohn's disease. It is a useful tool to recognize the disease or to monitor disease activity, or to assess the effectiveness of interventions. Knowledge of the location, severity, and presence of complications assist in providing patients with appropriate treatment options.

▲ Obr. 11

Fig. 11. ***Regenerative subtype of Crohn's disease. Pseudopolyps of various size can be seen.***
Obr. 11. ***Regeneratívny podtyp Crohnovej choroby. Viditeľné pseudopolypy rôznych veľkostí.***

REFERENCES

1. **Fukurawa A, Saotome T, Yamasaki M, et al.** Cross-sectional imaging in Crohn disease. Radiographics 2004; 24(3): 689–702.
2. **Louis E, Collard A, Oger AF, et al.** Behaviour of Crohn's disease according to the Vienna classification: changing pattern over the course of the disease. Gut 2001; 49: 777–782.
3. **Freeman HJ.** Use of the Crohn's disease activity index in clinical trials of biological agents. World J Gastroenterol 2008; 14: 4127–4130.
4. **Leyendecker JR, Bloomfeld RS, DiSantis DJ, et al.** MR enterography in the management of patients with Crohn disease. RadioGraphics 2009; 29(6): 1827–1847.
5. **Fidler JL, Guimaraes L, Einstein DM.** MR imaging of the small bowel. Radiographics 2009; 29(6): 1811–1826.
6. **Lee SS, Kim AY, Yang SK, et al.** Crohn disease of the small bowel: comparison of CT enterography, MR enterography, and small-bowel follow-through as diagnostic techniques. Radiology 2009; 251(3): 751–761.
7. **Masselli G, Casciani E, Polettini E, et al.** Comparison of MR enteroclysis with MR enterography and conventional enteroclysis in patients with Crohn's disease. Eur Radiol 2008; 18: 438–447.
8. **Maglinte DD, Gourtsoyainnis N, Rex D, et al.** Classification of small bowel Crohn's subtypes base on multimodality imaging. Radiol Clin N Am 2003; 41: 285–303.
9. T**olan DJM, Greenhalgh R, Zealley IA, et al.** MR enterographic manifestations of small bowel Crohn disease. RadioGraphics 2010; 30(2): 367–384.
10. **Booya F, Fletcher J, Huprich J, et al.** Acive Crohn disease: CT findings and interobserver agreement for enteric phase CT entrography. Radiology 2006; 241(3): 787–795.
11. **Fletcher JG, Fidler JL, Bruining DH, Huprich JE.** New concepts in intestinal imaging for inflammatory bowel disease. Gastroenterology 2011; 140: 1795–1806.
12. **Gore RM, Balthazar EJ, Ghahremani GG, et al.** CT feature of ulcerative colitis and Crohn's disease. AJR Am J Roentgenol 1996; 167(1): 3–15.
13. **Macari M, Balthazar EJ.** CT of bowel wall thickening: significance and pitfalls of interpretation. AJR Am J Roentgenol 2001; 176: 1105–1116.
14. **American College of Radiology.** ACR appropriateness criteria. Reston, Va: American College of Radiology 2005.
15. **Elsayes KM, Al-Hawary MM, Jagdish J, et al.** CT enterography: Principles, trends and interpretation of findings. Radiographics 2010; 30(7): 1995–1971.
16. **Fukurawa A, Saotome T, Yamasaki M, et al.** Cross-sectional imaging in Crohn disease. Radiographics 2004; 24(3): 689–702.
17. **Koh DM, Miao Y, Chinn RJS, et al.** MR imaging evaluation of the activity of Crohn's disease. AJR Am J Roentgenol 2001; 177: 1325–1332.