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REVIEW

Magnetic resonance imaging of small bowel neoplasms

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Abstract

Magnetic resonance (MR) imaging is rapidly increasing clinical acceptance to evaluate the small bowel and can be the initial imaging method to investigate small bowel diseases. MR examinations may provide the first opportunity to detect and characterize tumours of the small bowel. Intra- and extraluminal MR findings, combined with contrast enhancement and functional information, help to make an accurate diagnosis and consequently characterize small bowel neoplasms. MR enteroclysis should be recommended for the initial investigation in patients suspected of having small bowel tumours. In this article, the MR findings of primary small bowel neoplasms are described and the MR findings for the differential diagnosis are discussed.

Keywords: *Small bowel neoplasms; MR imaging; MR staging; MR enterosclysis; MR enterography.*

Introduction

The diagnosis of tumours in the small intestine, especially early detection and differential diagnosis of tumours, is still difficult although many sensitive, direct and indirect techniques have been applied[1,2]. Although the small bowel accounts for more than 90% of the mucosal surface of the gastrointestinal tract, small bowel neoplasms account for 1–6% of all gastrointestinal tract malignancies[3]. Early diagnosis of small bowel tumours is a diagnostic challenge for both clinicians and radiologists for two main reasons. First, patients with these neoplasms may present acute abdominal symptoms (obstruction, acute bleeding, and perforation) or chronic non-specific signs (vague abdominal pain, anorexia, weight loss, anaemia from gastrointestinal bleeding, jaundice, etc.). Second, the mesenteric small bowel is traditionally the most difficult portion of the gastrointestinal tract to investigate. Therefore, the diagnosis of small bowel tumours is often delayed, and in some instances, the tumours are discovered late, when clinical symptoms due to the dissemination of the disease are present.

Although conventional enteroclysis and capsule endoscopy (CE) represent the most common procedures used to visualize mucosal abnormalities of the small bowel, their use may be limited by the clinical conditions (i.e. obstruction) and they cannot evaluate the mural and extramural extent of these neoplasms; complete staging of the tumour, which is necessary to establish a therapeutic strategy, is not possible. Computed tomography (CT) and magnetic resonance (MR) are frequently used when a tumour of the small bowel is suspected or has to be excluded[1–3]. MR imaging, with excellent soft tissue contrast resolution, multiplanar imaging capability, and a lack of ionizing radiation, is particularly well suited for evaluation of the small bowel[4–6]. Furthermore, data acquisition can be repeated over time for functional evaluation of small bowel mobility, which is helpful for diagnosing low-grade stenosis and determining the level of obstruction[5].

MR imaging protocol

Two MR imaging based techniques are currently used: MR enteroclysis and MR enterography. In enteroclysis, enteric contrast material is administered through a nasoenteral tube; in enterography, large volumes of enteric contrast material are administered orally. The pulse sequences used for both MR enteroclysis and MR enterography are essentially the same, the only difference being that breath-hold two-dimensional T2-weighted fast spin-echo images are acquired continuously during the infusion of intraluminal contrast agent for MR

Table 1 **MR imaging protocol**

Parameter	True FISP		T2-weighted half-Fourier RARE		T1-weighted three-dimensional VIBE coronal and axial	Two-dimensional true FISP coronal and axial
	Axial	Coronal	Axial and axial fat-saturated	Coronal		
Repetition time (ms)/echo time (ms)	4.3/2.2	4.3/2.2	1000/90	1000/90	4.1/1.1	500/75
Flip angle (degrees)	50	50	150	150	10	50
Field of view (mm)	320–400	320–400	320–400	320–400	320–400	400
Matrix	256 × 224	256 × 224	256 × 224	256 × 224	256 × 224	256 × 256
Parallel imaging factor	2	2	2	2	3	2
Section thickness (mm)	5	3	4	3	2.5	10
No. of signals acquired	1	1	1	1	1	6
Receiver bandwidth (Hz)	125	125	62.5	62.5	62.5	1930
Acquisition time (s)	19	21	15–20	15–20	15–18	25

FISP, fast imaging with steady state precession; RARE, rapid acquisition with relaxation enhancement; VIBE, volume interpolated breath-hold examination.

enteroclysis but only once for MR enterography. For the MR enterography protocol, an initial thick-slab T2-weighted MR cholangiopancreatography study helps to assess small bowel dissention. If there is inadequate dissention of the ileum, the patient can return to the waiting room to drink more oral contrast material. The MR technical protocol is shown in Table 1.

Anti-peristaltic agents such as hosing butyl bromide (Buscopan; Boehringer Ingelheim, Ingelheim, Germany) or glucagon (Glucagen; Novo Nordisk, Bagsvaerd, Denmark) are used intravenously to eliminate peristalsis and reduce motion artefacts. Gadolinium-based contrast material is administered by injecting 0.2 mmol/kg body weight at a rate of 2 ml/s, followed by a bolus injection of 20 ml of isotonic saline. Coronal gradient-echo fat-saturated T1-weighted sequences are performed before and 30 and 70 s after the injection, followed by an axial sequence beginning 90 s after the injection that covers the entire abdomen. We administer an initial 10 mg of hosing butyl bromide or 0.2 mg of glucagon immediately before the examination starts to reduce intraluminal flow voids. The patient receives an additional dose of the same strength before injection of the gadolinium-based contrast material.

In the presence of luminal narrowing, multiphasic balanced gradient-echo sequences are needed to help determine if the narrowing is reversible (i.e. lymphoma) or fixed (i.e. adenocarcinoma). Visual assessment of diffusion-weighted images may provide greater accuracy in neoplastic detection but further studies are needed to define the practical clinical value of diffusion-weighted imaging[5].

MR imaging

MR enteroclysis is a validated technique for the detection of small bowel tumours and low-grade small bowel obstruction, whereas MR enterography has not yet demonstrated its potential for these indications[5–7]. MR enteroclysis provides optimal small bowel dissention and allows more accurate detection of strictures[8,9]. Moreover, small polypoid masses that do not cause obstruction may be difficult to detect using oral contrast material for dissention.

MR enteroclysis is known to provide better depiction of mucosal lesions in the small intestine than MR enterography performed with an oral contrast agent[8–11] and the evaluation of endoluminal abnormalities is particularly important in the detection of small bowel neoplasms at an early stage. MR enteroclysis allowed detection of small bowel neoplasms with an accuracy of 96.6% and can be an effective diagnostic technique in patients with a suspicion of small bowel neoplasm[12]. However, nasoenteral intubation for MR enteroclysis may cause patient discomfort, and it involves various technical and logistical difficulties, as well as exposure to radiation.

The appearance of intraluminal, mural and mesenteric neoplastic manifestations on the MR signal, can help in the differential diagnosis[13]. In addition, the characteristics on MR enteroclysis are useful to differentiate between benign and malignant neoplasms[6,14,15]. Small bowel tumours usually exhibit moderate signal intensity on true fast imaging with steady state precession (FISP) images, as opposed to the high signal intensity of the distended lumen and mesenteric fat. The imaging features associated with small bowel malignancy include the presence of longer solitary non-pedunculated lesions, mesenteric fat infiltration, and enlarged mesenteric lymph nodes[6,16].

In our institution, MR enteroclysis is used for the initial investigation in patients suspected of having Crohn disease or tumour in the small bowel, whereas MR enterography is used for follow-up of patients with established Crohn disease but without jejunal disease and for routine surveillance in patients with inherited polyposis syndromes.

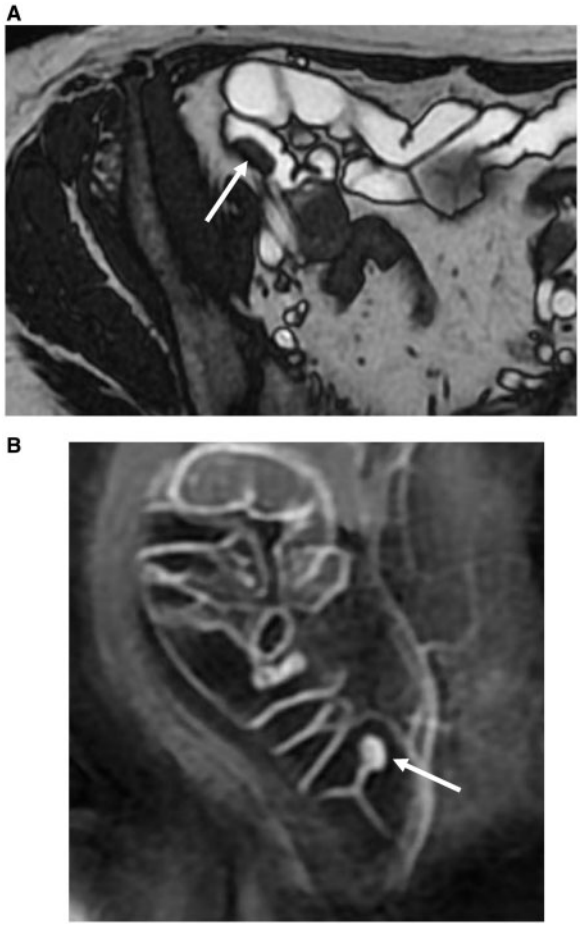

Figure 1 **MR images of two different patients with ileal polyps. (A) Transverse true FISP sequence shows a soft tissue flat polyp (arrow), which appears moderately low in signal intensity, with no sign of bowel wall infiltration. (B) Coronal contrast T1-weighted fat-suppressed image shows intense enhancement of a polyp (arrow) with a slender stalk.**

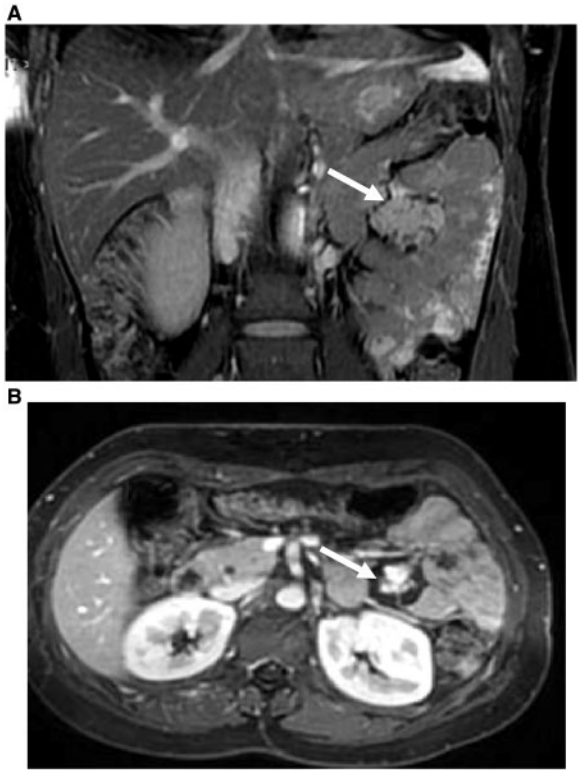

Figure 2 **MR images of a jejunal haemangioma. (A) Coronal true FISP images show a lobulated hyperintense mass (arrow) located in the jejunum, which is compressing the small bowel lumen. (B) Axial T1-weighted sequence shows central nodular enhancement within the tumour (arrow).**

MR enteroclysis and other imaging modalities in the assessment of small bowel neoplasms

The diagnostic accuracy of the small bowel enema in the diagnosis of small intestinal malignancies has been reported to be around 60%, whereas that of conventional enteroclysis has been reported to be as high as 95% if performed by experts[7]. Transabdominal ultrasonography is not accurate for detecting small bowel tumours; the reported sensitivity is low (26%)[1,15]. Contrast and water-enhanced multidetector CT enterography has a reported sensitivity and specificity of 85% and 97%, respectively, for the detection of malignant and benign small intestinal tumours[1].

MR enteroclysis has been shown to be more sensitive than CT enteroclysis for detecting mucosal lesions of the small bowel[5], and it appears to facilitate superior detection of segments with only superficial abnormalities. These findings may be due to the better soft tissue contrast that can be achieved with MR imaging, which may be important for tissue characterization and the detection of subtle areas of abnormality. Moreover, because of the exposure to ionizing radiation with CT, CT enteroclysis imaging can be performed at only a few time points. Repeated dynamic imaging, and hence assessment of small bowel peristaltic activity, are not possible. An intermittent spasm or peristaltic contraction during the CT examination can also be misdiagnosed as a small bowel neoplasms[1]. In addition, MR imaging provides a better degree of small bowel tumour characterization. The advantage of MR imaging by comparison with CT is that MR imaging can provide more information about the actual nature of the mesenteric small bowel tumour[5].

CE is an excellent modality for visualizing the small bowel mucosa, but is limited in evaluating this proximal region because of rapid capsule transit, bile and/or bubble artefacts, and relatively poor luminal distension[1,2]. Adequate image capture of very large lesions located more distally can also be problematic during CE and, often, only fleeting views of the edge of the lesion may be recorded. It is difficult to identify the

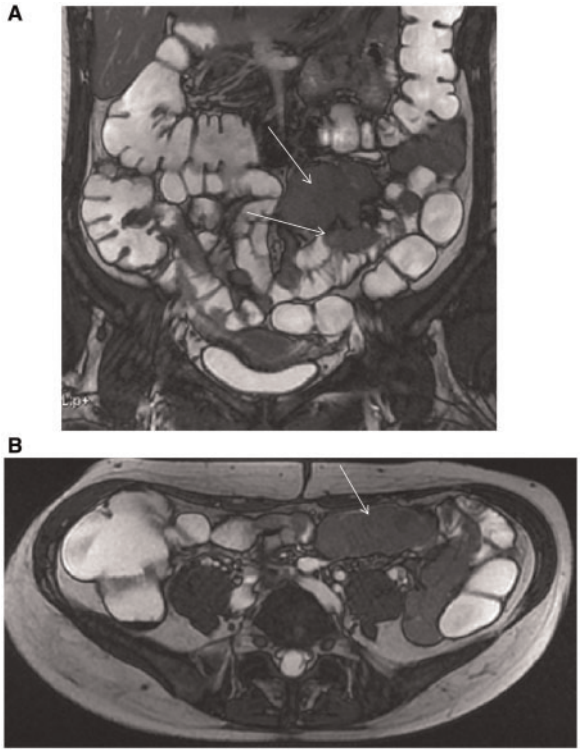

Figure 3 **MR images of a jejunal GIST. (A) Axial and (B) coronal true FISP images show a large lobulated mass (arrow) arising from a jejunal loop (small arrow) with exophytic growth. Areas of focal high signal intensity indicate a haemorrhage present within the mass The eccentric location is characteristic of GIST.**

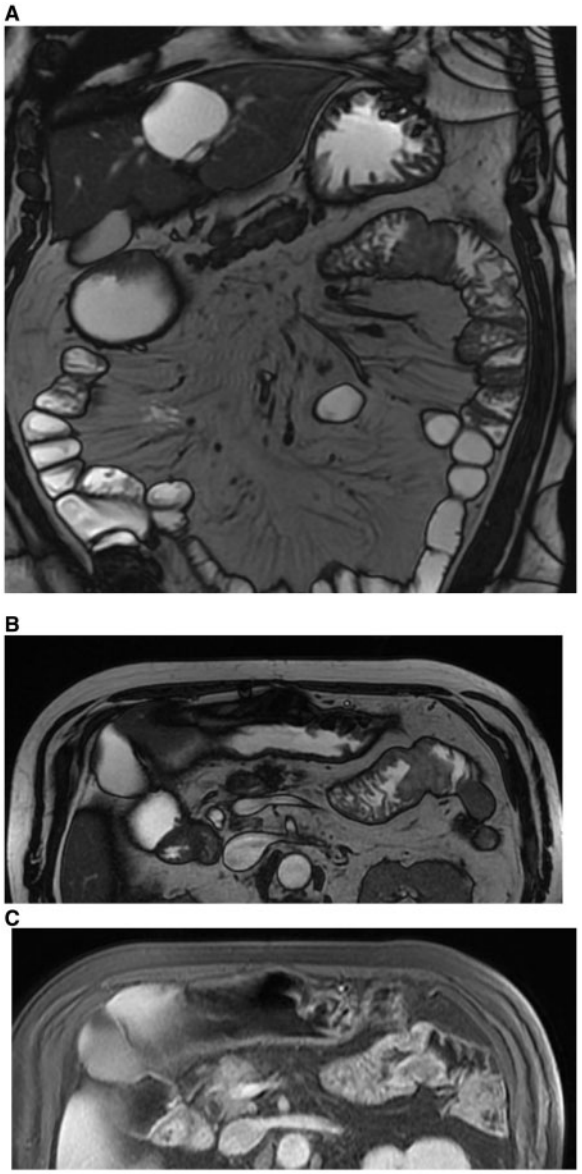

Figure 4 **MR images of infiltrative adenocarcinoma of the proximal ileum. (A) Coronal and (B) axial half-Fourier acquired single-shot turbo spin-echo (HASTE) sequence shows irregular wall thickening involving a short segment of the ileal small bowel loop. Axial T1-gradient recalled echo (GRE) sequence (C) shows heterogeneous enhancement of the lesion with evidence of extraluminal extension.**

pathology and tumour type based on the appearance of lesions on CE. The miss rate of CE for neoplastic disease can reach 18.9%. Several reasons contribute to that miss rate, but probably the crucial one in this particular subset of patients, is related to the fact that it is sometime difficult to discriminate masses from bulges based on the CE findings. A bulge is defined as a round smooth, large base protrusion in the lumen with an ill-defined edge on the surrounding mucosa; it can be a prominent normal fold or the luminal expression of intestinal loop angulation and stiffness, and sometimes it can be virtually indistinguishable from a small submucosal tumour[2].

Pasha et al.[16] described 51 patients with polypoid lesions revealed on CE that were not confirmed at further examinations (false-positive CE). This problem, highlighted also in other studies[17], can significantly influence the subsequent management; a positive CE requires further invasive examinations (double-balloon enteroscopy or surgical intervention). Moreover, CE is not reliable for accurate sizing of polyps[2,16,17].

Another important limitation of wireless CE is capsule retention in approximately 10–25% of cases of small bowel tumours[16,17], which may require surgery because of acute small bowel obstruction in a subset of patients. Consequently, a small bowel tumour is considered to be a risk factor for capsule retention[17] and this risk correlates with luminal protrusion of the tumour.

In patients with suspected small bowel tumours, MR enteroclysis might be used as the first modality of choice[18]. If the presence of a tumour is confirmed, double-balloon endoscopy is used to allow histologic determination. In addition, MR enteroclysis helps in the choice of the preferred route of insertion of the double-balloon endoscope.

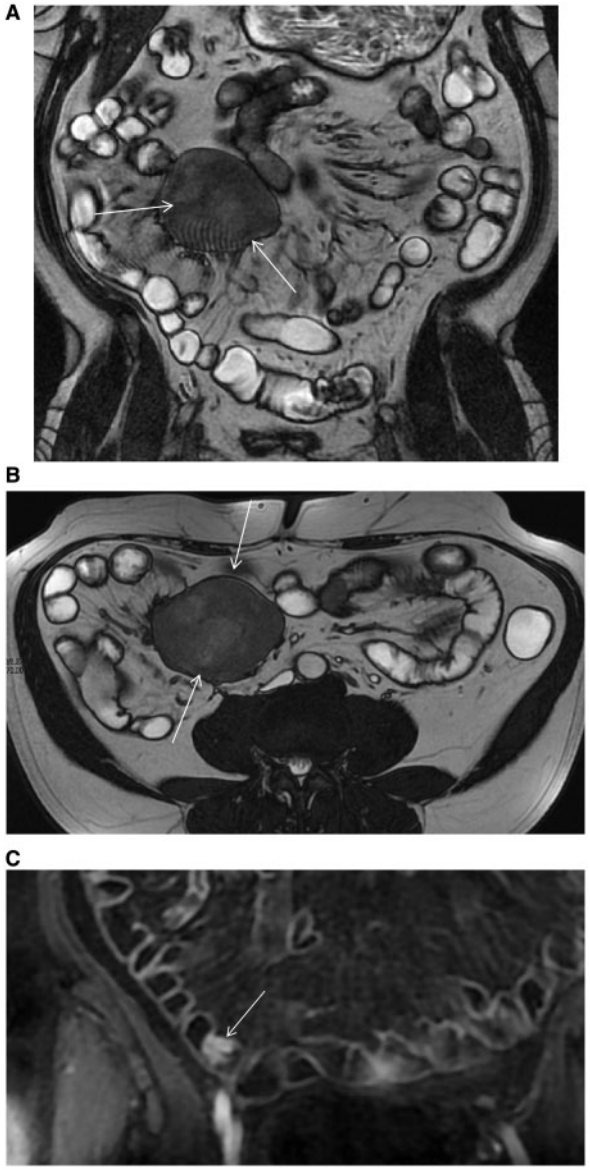

Figure 5 **MR images of an ileal carcinoid neoplasm. (A) Coronal and (B) axial true FISP images show a spiculated mesenteric mass (long arrow) with desmoplastic reaction. (C) Coronal contrast-enhanced T1-weighted GRE image shows a small hypervascular nodule in the wall of the small bowel, not seen on the true FISP sequences.**

In patients with obscure gastrointestinal bleeding, MR enteroclysis has a high accuracy for detecting inflammatory and neoplastic diseases, but can also detect other conditions that cause bleeding such as Meckel diverticulum[5]. Therefore, in the case of negative MR enteroclysis, an arteriovenous malformation is likely to be the cause of bleeding, and enteroscopy may be required for diagnosis and treatment of these vascular malformations. Thus, we believe that MR enteroclysis should precede enteroscopic modalities in the examination of patients with obscure gastrointestinal bleeding[5].

One study found no significant difference between MR enterography and wireless CE for the detection of large (i.e. more than 15 mm), clinically significant polyps in patients with inherited polyposis syndromes, and there was improved localization with MR imaging[19]; MR enterography may have a role in the routine surveillance in these patients because the detection of small polyps is not clinically relevant.

MR imaging features of small bowel neoplasms

Leiomyoma, adenoma and lipoma constitute the most common primary benign small intestinal tumours[1]. Depending on their location, leiomyomas may protrude into the lumen or produce a mass effect on adjacent bowel. A small bowel leiomyoma appears as a homogeneous focal round mass with intense uniform enhancement[20]. Leiomyoma shows uniform enhancement greater than that of adjacent bowel on post-gadolinium images, reflecting similar imaging findings[18,20]. On MR fluoroscopy, leiomyoma appears as a smooth, round, (or semilunar) mural defect that is demarcated by sharp angles to the intestinal wall. Adenomas appear as intraluminal masses of small size (<2 cm), as a well-defined soft tissue mass showing moderate enhancement after intravenous contrast administration, with clear planes around the tumour (Fig. 1). Lipomas arise in the submucosa, are high in signal on T1-weighted images and have signal intensity comparable with intra-abdominal fat on T2-weighted images. On T1- and T2-weighted fat-suppressed images, these lesions show a loss of signal intensity. Intestinal hemangiomas are usually submucosal tumours, and they are sessile or peduncolate. Haemangiomas show relatively low signal on T1-weighted images and rather higher signal intensity on T2-weighted images with central nodular enhancement in the mass[20] (Fig. 2).

On MR imaging, a gastrointestinal stromal tumour (GIST) typically appears as an exophytic, sometimes bulky mass, with moderate heterogeneous contrast enhancement, and tends to show central necrosis. GISTs can extend to several centimetres in size, displacing the adjacent bowel loops. Unlike adenocarcinoma and lymphoma, lymphatic spread does not usually occur in patients with a GIST. Mesenteric masses usually have a smooth surface and do not appear spiculated or show indrawing of the mesentery[21–24]. The predominant MR feature of a GIST is a heterogeneously enhancing exophytic mass, with regions of necrosis (Fig. 3).

The four main malignant histologic types of small bowel tumour are adenocarcinoma (40%), carcinoid (31%), lymphoma (20%) and sarcoma (9%)[1]. Small bowel adenocarcinomas appear as focal rounded masses with extraluminal growth or with circumferential constricting lesions that narrow the bowel lumen. Focal wall thickening involving a short segment that shows

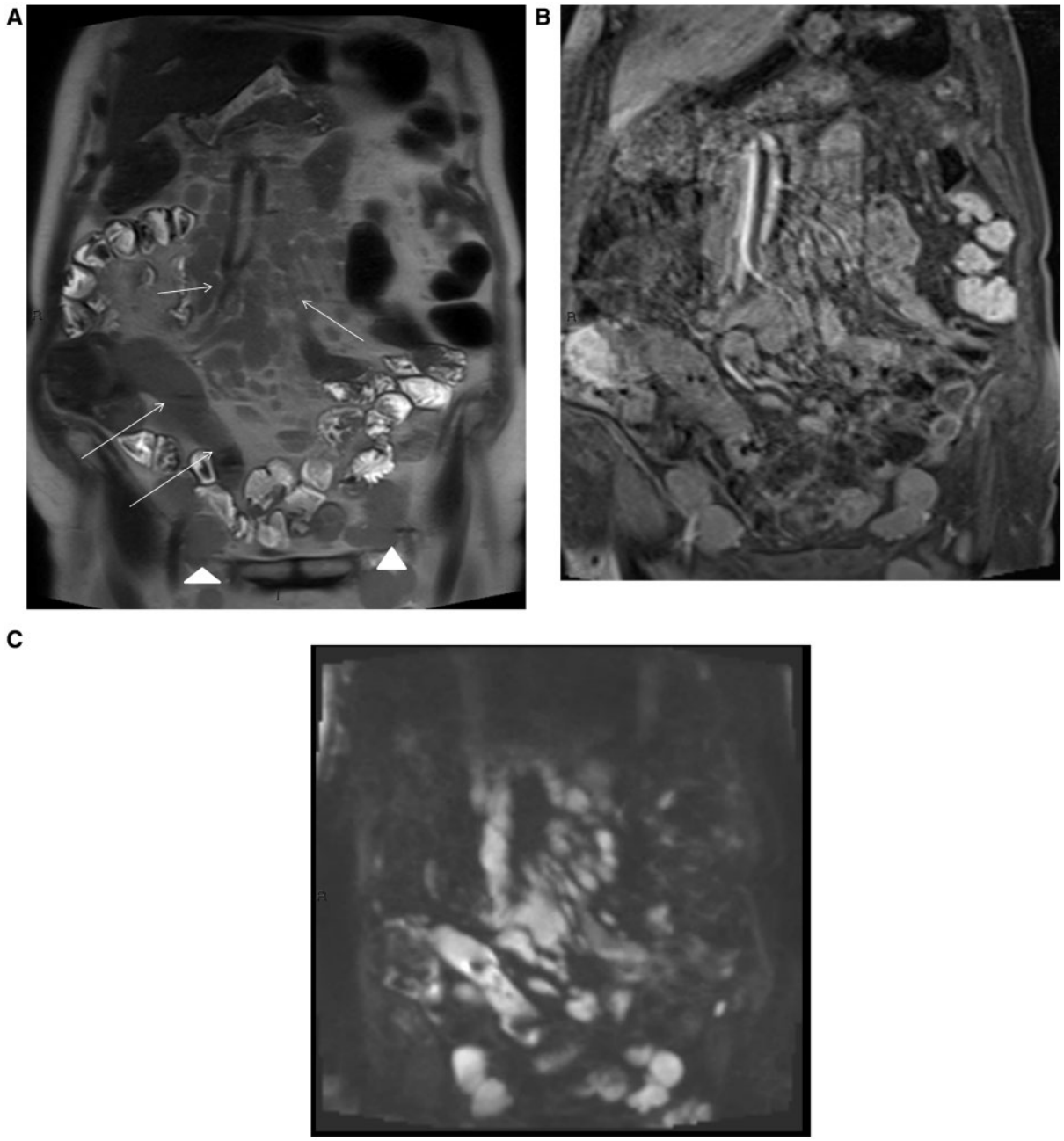

Figure 6 **MR images of an ileal lymphoma. (A) Coronal HASTE sequence shows a long segment of terminal ileum (arrow) with abnormal thickening, smooth margins, and luminal narrowing with loss of normal mucosal folds with mesenteric nodes (short arrows) encircling the vessels and pelvic nodes (arrow heads). (B) Coronal contrast-enhanced T1-weighted GRE image shows a mild enhancement of the terminal ileum walls and of the lymph nodes, characteristic of lymphoma. (C) Diffusion coronal image (*b* value = 1000) shows restricted diffusion of the terminal ileum walls and of the lymph nodes.**

hypointensity on T2-weighted images and a heterogeneous moderate enhancement on gadolinium images are frequently seen (Fig. 4)[24]. MR fluoroscopy shows luminal high-grade irregular stenosis with a fixed, unchanging appearance during the infusion of the intraluminal contrast.

Carcinoid tumours cause focal, asymmetric bowel wall thickening and usually manifest as nodular wall thickening or a smooth submucosal mass. On unenhanced sequences, these lesions are isointense to muscle on T1-weighted images and isointense or mildly hyperintense to muscle on T2-weighted images. The primary lesions show contrast enhancement. Mesenteric masses range between 2 and 4 cm in size and are typically isointense to muscle on T1- and T2-weighted images. Previous reports on ileal carcinoid described a mesenteric

mass with radiating strands of tissue. This constellation of imaging findings is not uncommon for these tumours (Fig. 5)[1,18,24]. The characteristic desmoplastic changes in the mesentery and retroperitoneum that occur in response to the secretion of serotonin and tryptophan show low signal on both T1- and T2-weighted images and negligible enhancement after contrast[13]. Carcinoid neoplasms rarely cause annular narrowing, but kinking of the bowel wall occurs with narrowing of the lumen.

Gastrointestinal lymphomas comprise 1–2% of all gastrointestinal malignancies[1] and can have different gross appearance: (1) diffusely infiltrating lesions that often produce full-thickness mural thickening with effacement of overlying mucosal folds; (2) polypoid lesions that protrude into the lumen; (3) large, exophytic, fungating masses that are prone to ulceration and fistula formation[1]. The diverse appearance of small intestine lymphomas on MR studies reflects the gross morphology of the disease. In the setting of diffuse infiltrating lesions, the bowel wall appears dilatated, possibly because of interference with the normal innervation and regulation of smooth muscle bowel wall contraction. The presence of a bowel wall mass and dilatation without proximal bowel obstruction is suggestive of lymphoma. Aneurysmal dilatation of the small bowel, characteristic of lymphoma, due to loss of muscle tone of the intestinal wall is caused by lymphomatous invasion and destruction of the muscle layers and neural plexuses. The presence of diffuse splenomegaly and mesenteric and retroperitoneal lymphadenopathy supports the diagnosis (Fig. 6).

Smooth mural contour, diffuse segmental bowel loop aneurysmal dilatation, and absence of a distinct mesenteric or anti-mesenteric distribution are highly suggestive of the presence of lymphoma in patients with coeliac disease[25,26]. An association was also observed between certain mural characteristics and the presence of coeliac disease, most notably that of a smooth marginal component. In two patients with lymphomas complicating celiac disease, circumferential ileal loop thickening was found[27].

Metastases account for approximately 50% of all small bowel neoplasms. In a patient with a known neoplasm, a small bowel neoplasm is most likely a metastasis. Metastases develop through four major pathways: direct extension, intraperitoneal seeding, lymphatic and haematogenous spread[1]. Metastatic lesions often lodge on the anti-mesenteric border of the small bowel. On gadolinium-enhanced fat-suppressed spoiled gradient-echo images, metastases are moderately high in signal intensity in contrast to the low signal intensity of intra-abdominal fat[24]. Malignant peritoneal tissue enhances moderately to substantially on interstitial phase gadolinium-enhanced images and appears as nodular or irregular thickened peritoneal or serosal disease. Gadolinium-enhanced fat-suppressed imaging has been shown to be more sensitive than CT imaging for detecting small tumour nodules[28].

Low-grade small bowel obstruction may be due to numerous causes, although the most common are adhesions. Because MR enteroclysis provides improved dissention of the small bowel, it may demonstrate subtle transition points or an obstruction that might escape detection if more routine imaging methods are used, including enterography.

Conclusion

MR imaging can provide exquisite anatomic, functional and real-time information without the need for ionizing radiation in the evaluation of small bowel tumours. MR enteroclysis may be considered as the best radiologic modality for the examination of the small bowel and should be recommended for the initial investigation in patients suspected of having a small bowel tumour[5,29]. If the presence of disease is confirmed, enteroscopy is performed for biopsy and histologic evaluation. In addition, MR enteroclysis may be helpful for the selection of the most appropriate insertion route for the endoscope. The appearance of the lesions on MR imaging, combined with the contrast enhancement behaviour and the characteristics of stenosis, can help to differentiate neoplastic lesions from other non-neoplastic diseases of the small bowel.

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