Imaging the small bowel

Introduction

Imaging of the small bowel is one of the most difficult and interesting aspects of diagnostic radiology. Visualization of the small bowel is a big challenge because of its length, tortuosity and peristalsis as well as being relatively inaccessible to direct view with endoscopic techniques.

This article reviews current trends in the radiological investigation of small bowel disease. It discusses the spectrum of different radiological techniques, the positive and negative features of each technique and the clinical indications for these examinations. It provides practical help in choosing and requesting the optimal examination for each individual patient.

Anatomy

The small bowel represents the mid-part of the alimentary tract and extends from the ligament of Treitz (duodeno-jejunal flexure), usually situated in the epigastrium, to the ileocaecal valve in the right iliac fossa.

The adult small bowel measures approximately 6–7 m in length and contains multiple mucosal folds, called valvulae conniventes, which significantly increase its surface area, aiding the digestion and absorption process. Mucosal folds are more numerous and prominent proximally, producing a 'feathery' pattern of the jejunum. The ileum has a narrower lumen with fewer mucosal folds and higher number of mesenteric arcades. The lumen of the small bowel decreases along its length; the maximum diameter of the normal jejunum should not exceed 3.5 cm on a barium follow-through, or less than 4.5 cm with enteroclysis; corresponding figures for the normal ileum are 2.5 cm and 3.5 cm respectively.

The wall of the small bowel consists of mucosa, submucosa, muscularis propria and serosa, and should not measure more than 2–3 mm in thickness.

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Diseases of the small bowel not only involve the bowel wall, but may extend into its mesentery, blood vessels, lymph nodes and adjacent organs, making assessment of these structures a necessary part of the diagnostic process.

Imaging modalities used for the small bowel include plain film radiography, fluoroscopy, ultrasound, computed tomography and magnetic resonance imaging.

Plain radiography

Abdominal X-rays have a low specificity and sensitivity in diagnosis of small bowel disease, because of the similar density of loops of the bowel and surrounding soft tissue. The small bowel can be distinguishable from other visceral organs by abnormal accumulation of gas and fluid. Small irregular pockets of gas, which can be seen in the normal physiological condition, increase in size and number until the distended loop of bowel is completely outlined with clearly visible mucosal folds (*Figure 1*).

Therefore, abdominal X-rays may be performed on patients with acute abdominal pain when there is a suspicion of obstruction or perforation.

The distribution of gas and the particular mucosal pattern help to distinguish small from large bowel. Small bowel loops tends to lie centrally, the valvulae conniventes are thinner than colonic haustra and are visible through the whole diameter of the lumen. In distal obstruction, more loops of bowel may be distended and the level of intraluminal fluid usually increases with the duration of obstruction.

Figure 1. The abdominal X-ray shows a few dilated loops of the jejunum in the epigastrium (arrow), consistent with obstruction. Observe the difference in density between the upper and lower part of abdomen.

Technical factors which need to be considered to avoid misinterpretation of the abdominal X-ray include the patient's position during the X-ray. Free air under the diaphragm and dilated loops of bowel with fluid levels may only be seen on the erect or decubitus films. Even severe obstruction may be present as a 'gasless' grey abdomen on the supine projection, because of the intermediate density of fluid within the lumen.

Plain abdominal films remain the initial investigation in a suspected obstruction. However, most cases will require further imaging to identify the transition point and cause of obstruction.

Fluoroscopy or contrast studies

The first contrast study of the small bowel was performed around 1923, and consisted of a single abdominal X-ray taken after administration of oral contrast.

Contrast, which is clearly visible on the plain radiograph, opacifies the lumen of the bowel and allows the visualization of specific abnormalities within the wall, such as thickening or nodularity of the mucosa, ulcerations and filling defects.

Only abnormalities which change the contour of the opacified lumen or cause narrowing of the bowel loop can be demonstrated by the contrast technique. Pathological processes in the bowel wall which do not affect the shape of the mucosa or cause mesenteric abnormality very often remain undetected.

There are several components of an adequate examination: patient preparation, the correct density and volume of barium suspension and careful spot filming combined with compression. Performed correctly, the technique allows good visualization of the villous pattern of the jejunum and ileum, dynamic evaluation of the bowel peristalsis and demonstration of pathology such as mucosal ulceration and fistulas or abscess formation.

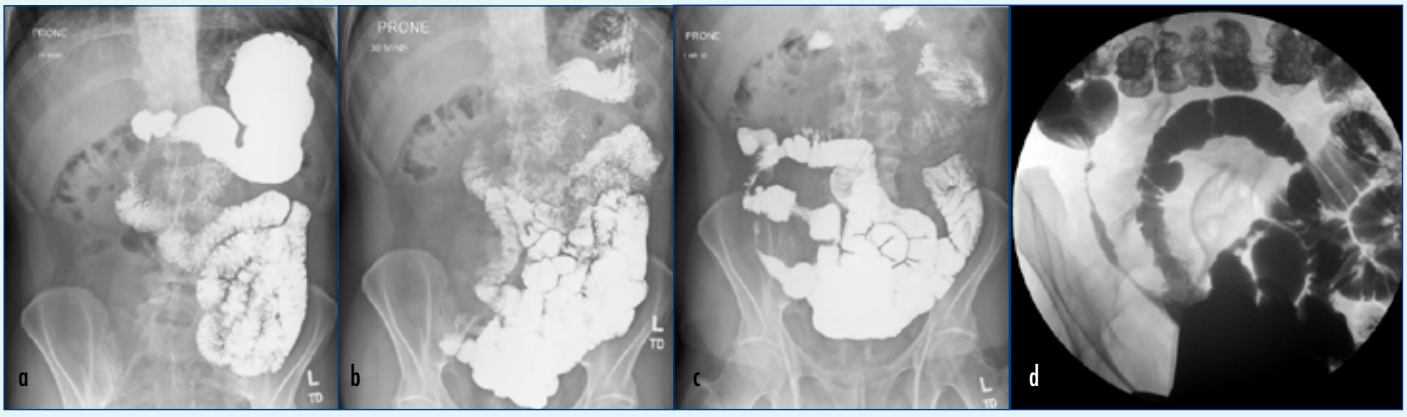


Figure 2. Follow-through examination of the small bowel. Films taken (a) 10 minutes, (b) 40 minutes and (c) 110 minutes after administration of oral contrast. d. Spot view with compression presents a narrowing and irregularity of the terminal ileum, consistent with Crohn's disease.

Small bowel follow-through

This examination consists of a series of abdominal X-rays taken at approximately 20-minute intervals (depending on the individual's peristalsis rate) following administration of oral barium contrast, until contrast passes through the entire length of the small bowel and reaches the caecum. Fluoroscopic screening is then performed with careful compression, which helps to separate overlapping bowel loops, assess mobility and define mucosal pathology. Multiple spot views of all abnormal segments are taken with a detailed visualization of the terminal ileum (*Figure 2*).

Multiple overlapping bowel loops, variable distension and sometimes suboptimal visualization of the mucosal pattern are the limiting factors of this technique.

Figure 3. Small bowel enteroclysis with duodenojejunal catheter visible in the upper part of the film. There is better distension and opacification of bowel loops than on follow through. There is a small diverticulum in the jejunum (arrow).

Small bowel enema

Small bowel enema or enteroclysis describes an intubation-based contrast study of the small bowel. The term 'small bowel enema' is mostly used in Europe and enteroclysis predominates in the United States.

The technique involves insertion of a catheter into the duodenum or proximal jejunum followed by infusion of oral contrast at a constant rate until it reaches the caecum. This technique allows better distension of bowel loops and a more detailed picture of the mucosal pattern than does a small bowel follow-through (*Figure 3*). Luminal distension and assessment of peristalsis can be controlled by the rate of contrast infusion.

A double-contrast effect can be achieved by subsequent infusion of methylcellulose solutions or with air insufflation.

Unfortunately, this examination is not well tolerated by patients because of the nasal intubation, it requires specialized equipment and is associated with a higher dose of ionizing radiation than small bowel follow-through.

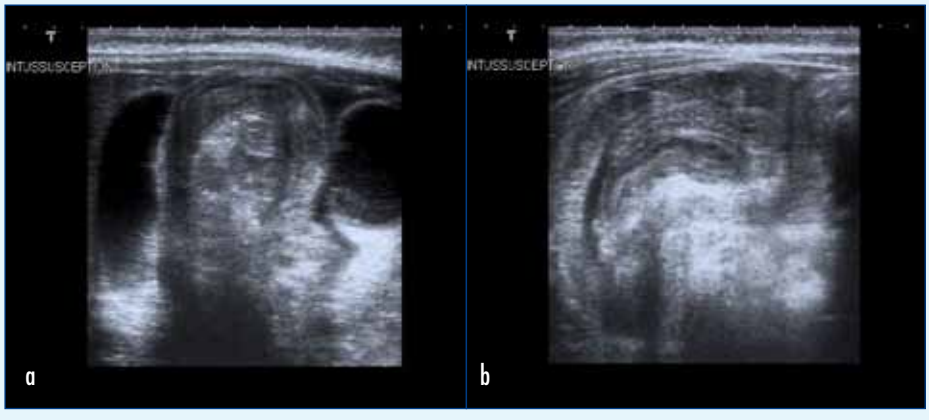
Ultrasound

Ultrasound is a well-established technique in abdominal imaging, most commonly used in the investigation of solid intra-abdominal organs such as liver, spleen or kidneys. Visualization of the small bowel is more difficult, but can be very rewarding, especially in the paediatric population.

Technical advances in grey-scale ultrasound, with increasing spatial resolution, as well as colour flow and Doppler sonography, have expanded the applications of ultrasound in small bowel disease.

Emergency conditions, such as intussusception or appendicitis, can often be diagnosed with no specific preparation or diet required before the test (*Figure 4*). Wall thickening of the terminal ileum can also be detected in patients with Crohn's dis-

Figure 4. Ultrasound examination of the abdomen showed a soft tissue mass with distended and fluid-filled loops of small bowel around. a. A target sign on the axial images and (b) characteristic appearance on coronal scan with visible mucosa is consistent with an intussusception.



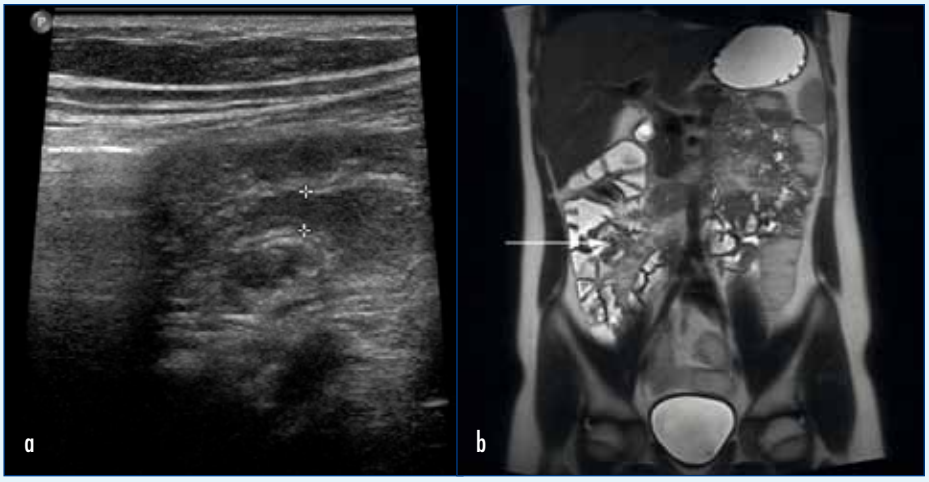


Figure 5. a. Ultrasound of the right iliac fossa demonstrated a diffuse wall thickening of the terminal ileum, which measured 8 mm. b. Subsequent magnetic resonance imaging showed terminal ileum thickening (arrow) and confirmed diagnosis of Crohn's disease.

ease, and information provided about peristalsis and blood flow in the affected bowel segment (*Figure 5*).

Sonography can be useful in further characterization of bowel loop abnormalities seen on barium studies. The modality is especially important in children and young adults as it does not involve ionizing radiation and can readily be repeated, for example in monitoring the course of medical therapy or detecting complications.

Unfortunately, several technical factors limit assessment of the small bowel. Increased intraluminal gas often creates significant artefacts, making assessment of the bowel wall and underlying structures problematic. Focal abnormalities, including strictures, can be easily missed between multiple distended loops. Patients with a high body mass index represent a further technical challenge.

In everyday practice, ultrasound is commonly performed in children and young adults, and can provide good visualization of the bowel wall, degree of peristalsis and the surrounding mesentery.

Computed tomography

Computed tomography is now a mainstay of abdominal imaging. For many years, visualization of the small bowel on computed tomography remained suboptimal – very often as a result of multiple collapsed loops, with very limited views of the mucosa and bowel lumen.

More recently, reduction in slice thickness and increased scanner rotation speeds have improved small bowel visualization. In addition, abdominal computed tomography examinations are usually performed with a reasonable volume of a positive or negative oral contrast agent to improve distension and conspicuity of the bowel. Administration of intravenous contrast can further improve diagnostic accuracy in defining bowel pathology as well as in evaluating other solid organs (*Figure 6*).

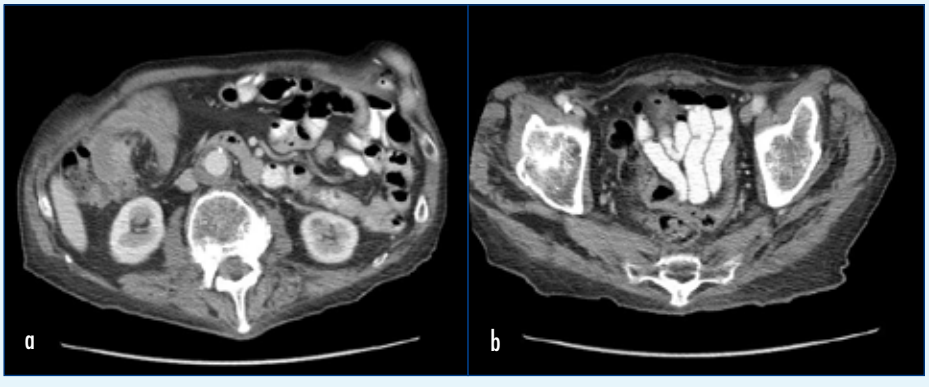
In specific clinical situations, computed tomography enteroclysis can be performed. Similar to contrast enteroclysis, a duodenojejunal catheter is inserted, a continuous infusion of positive contrast is introduced and the patient is scanned in both the supine and prone position.

Volumetric and multiplanar reconstructions of data obtained with modern multidetector computed tomography scanners help not only to evaluate the bowel wall and intraluminal contents, but also examine in detail the mesentery, other organs and associated vasculature.

Computed tomography provides an important information of mucosal, serosal and mesenteric extent of the neoplastic, vascular, inflammatory and obstructive diseases (*Figure 7*). It can be particularly useful in localizing the site and cause of small bowel obstruction, the source of bleeding lesions, and for assessing traumatic injury, congenital malformations and inflammatory disease, including fistulas, sinus tracts, abscesses and perforation.

The high diagnostic accuracy and speed of image acquisition of computed tomography are its main advantages, and these need to be balanced against the relatively high dose of ionizing radiation as well as the inability to provide a real time evaluation of peristalsis.

Figure 6. Computed tomography of the abdomen with oral and intravenous contrast show (a, b) a difference in visualization of mucosal details in different loops of bowel within the same patient, depending on distention and opacification of the lumen. Acute intussusception was demonstrated on the right side of abdomen.



Magnetic resonance imaging

The first magnetic resonance imaging examination of the small bowel was performed in 1985. For many years the technique was limited to research centres as it was of limited clinical value because of the multiple artefacts associated with bowel peristalsis and respiratory movement.

Developments in magnetic resonance imaging technology have allowed the acquisition of good quality images of the small bowel with fast breath-hold sequences.

High soft tissue contrast resolution, excellent mural and extramural visualization and multiplanar imaging capabilities make magnetic resonance imaging a leading technique in imaging of the small bowel. The detailed structure of the

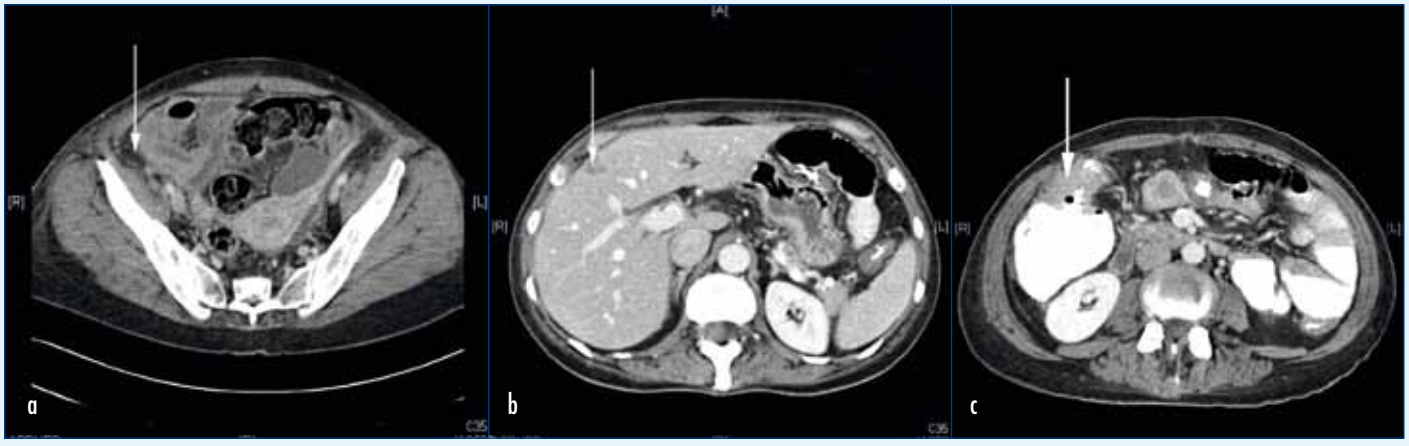


Figure 7. Patient with known Crohn's disease and acute exacerbation of abdominal pain. a. Computed tomography of the abdomen showed acute inflammatory changes in the ileum (arrow) on the right side of pelvis. Unexpected findings included: (b) irregular lesion in the liver (arrow) and (c) focal soft tissue lesion in the ascending colon (arrow).

bowel wall can be demonstrated with characteristic enhancement patterns for the different layers. Furthermore, a dynamic study can be performed to obtain functional information. The small bowel mesentery and vessels, omentum, peritoneum and large bowel are also included in the study.

The major advantage of magnetic resonance imaging is the absence of ionizing radiation, which is of particular benefit in inflammatory bowel disease; patients are often children or young adults and require frequently repeated investigations.

Magnetic resonance imaging of the small bowel is used in assessment of congenital abnormalities, characterization of benign and malignant lesions, and diagnosis and monitoring of other inflammatory, infectious and infiltrative disorders and their complications (*Figure 8*).

It has been suggested that magnetic resonance imaging is the imaging technique of choice for diagnosis and evaluation of Crohn's disease, including the monitoring of treatment and assessment of subsequent relapses. Different patterns of wall enhancement and changes in the surrounding mesentery help determine disease activity. Magnetic resonance imaging is also useful for assessing the site, length and chronicity of strictures (*Figure 9*).

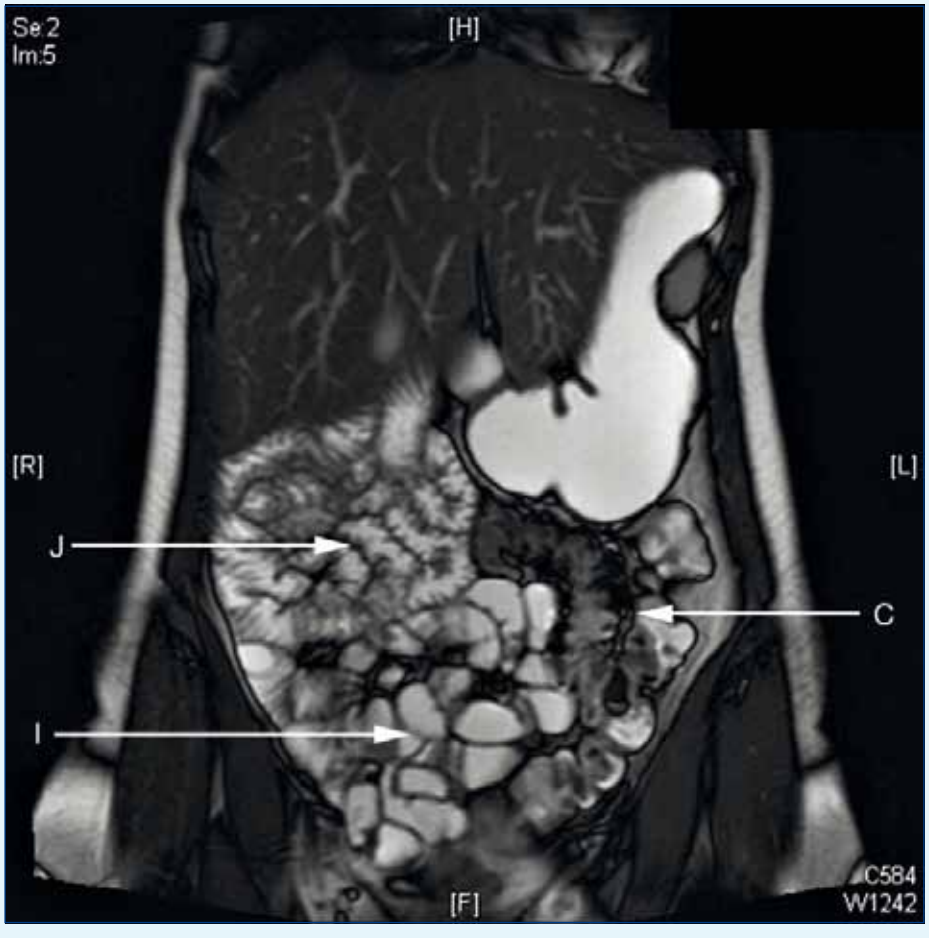
As with computed tomography, to achieve the best quality examination, the small bowel should be adequately distended with fluid, necessitating administration of a reasonable volume of oral contrast 1–1.5 hours before the scan.

Conclusions

Imaging of the small bowel remains an interesting and challenging task in diagnostic radiology. Familiarity with the different imaging techniques can help provide the best radiological investigation for each patient and thus aid diagnosis and guide treatment. BJHM

Conflict of interest: none.

Figure 8. Magnetic resonance imaging of the small bowel – coronal T2 weighted image of the patient with recurrent abdominal pain, shows a bowel malrotation. Duodeno-jejunal flexure, jejunum (J) and ileum (I) are located on the right side of the abdomen. Stomach and colon (C) are visible on the left side of the midline. Look at the difference in structure of mucosal folds in jejunum and ileum.



Further reading

Chapman S, Nakielny R, eds (2009) *Aids to Radiological Differential Diagnosis.* 5th edn. Saunders, Edinburgh

Dahnert W (2007) *Radiology Review Manual.* 6th edn. Lippincott, Williams & Wilkins, Baltimore

Davis M, Houston JD (2002) *Fundamentals of Gastrointestinal Radiology.* 1st edn. Saunders, Philadelphia

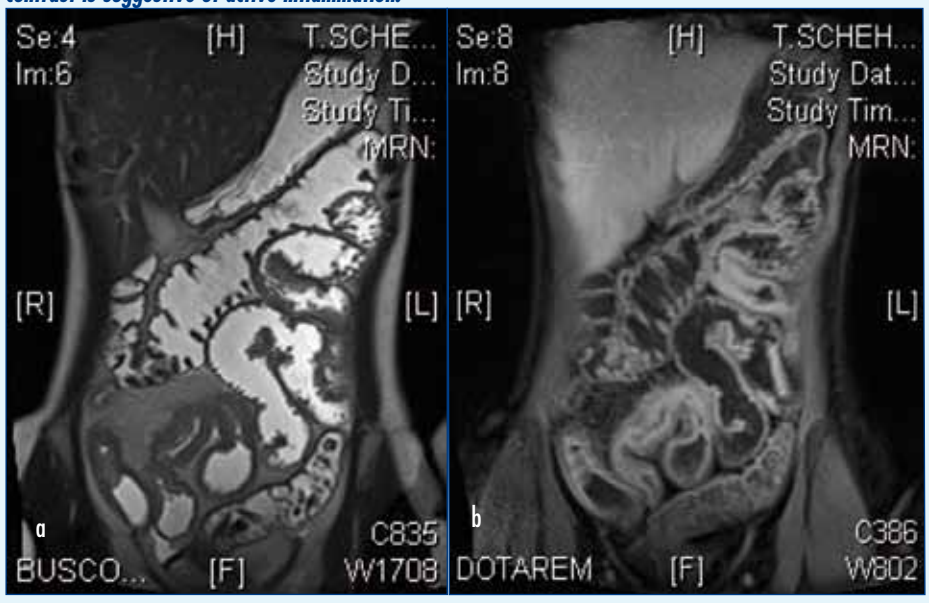
Gore RM, Levine MS, Laufer I (2007) *Textbook of Gastrointestinal Radiology.* 3rd edn. Saunders, Philadelphia

Grainger R, Allison D, eds (2007) *Diagnostic Radiology. A Textbook of Medical Imaging.* 5th edn. Churchill Livingstone, London

Semelka RC, Ascher SM, Reinhold C (1997) *MRI of the Abdomen and Pelvis.* Wiley-Liss, New York

Sutton D, ed. (2002) *A Textbook of Radiology and Imaging.* 7th edn. Churchill Livingstone, Edinburgh

Figure 9. a. Magnetic resonance imaging of the small bowel on patient with Crohn's disease – multiple abnormal loops of bowel with wall thickening and irregularity. b. An enhancement with intravenous contrast is suggestive of active inflammation.



KEY POINTS

- Imaging of small bowel includes plain X-ray, contrast study, ultrasonography, computed tomography and magnetic resonance imaging examination.
- Plain radiography remains the first examination on suspicion of perforation or obstruction. Contrast study is the best way to show the detailed pattern of the bowel mucosa and its subtle changes.
- Cross-sectional imaging (computed tomography and magnetic resonance imaging) is the most common examination in patients with abdominal symptoms and may demonstrate intraluminal and extraluminal bowel pathology with an assessment of other abdominal organs.