BRITISH JOURNAL OF HOSPITAL MEDICINE

REVIEW

Imaging of the small bowel: a review of current practice

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Abstract

This article summarises radiological imaging of the small bowel, with an emphasis on Crohn's disease. Different imaging techniques are discussed, including the advantages and disadvantages of each modality, and radiological findings for common small bowel pathologies are described, supplemented with pictorial examples.

Key words: Computed tomography; Crohn's disease; Fluoroscopy; Imaging; Magnetic resonance imaging; Radiology; Small bowel; X-ray

Submitted: 13 May 2020; accepted after double-blind peer review: 15 May 2020

Introduction

The dynamic nature of the anatomy and pathophysiology of the small bowel, and the difficulty in accessing it via endoscopy, means that this is best investigated via a myriad of imaging modalities. Currently, magnetic resonance imaging is the workhorse of small bowel imaging, having in recent times superseded barium-based studies in many institutions. There remains a role for the latter, however, and it may still be used as an adjunct to help with diagnosis. Computed tomography and ultrasound also have their individual applications. This review provides the clinician with the indications for each modality, advantages, disadvantages, as well as giving a pictorial guide to common abnormalities, with an emphasis on inflammatory bowel disease (especially Crohn's disease).

Crohn's disease

Crohn's disease is a transmural chronic inflammatory bowel disorder that may affect any component of the gastrointestinal tract from the mouth to the anus. It typically has a relapsing-remitting course and predominantly affects patients in the second to third decade of life. A second peak in incidence between the fifth and eighth decade has also been observed in some studies (Sandler and Golden, 1986). Imaging plays a significant role in both diagnosis and in monitoring treatment response.

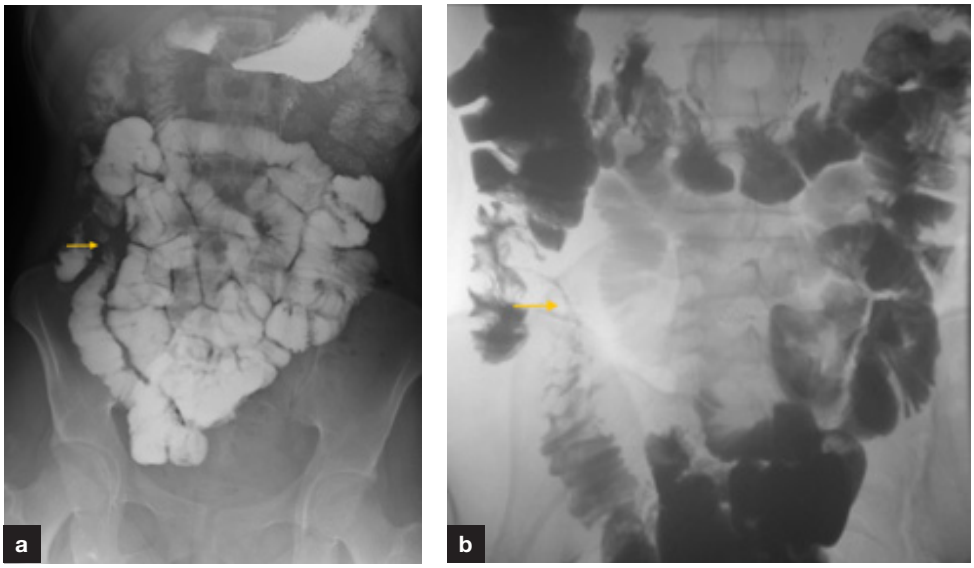
Barium-based studies

Although its use varies depending on the institution, barium-based studies remain a well-established, relatively low-cost imaging modality, with the small bowel follow-through being the main study of choice. It is readily available, non-invasive, achieves good mucosal detail and provides both static and dynamic information. Small bowel enteroclysis is also an option, although this involves the placement of a naso-enteric tube (which precludes assessment of the duodenum, incurs a higher radiation dose (Saibeni et al, 2007) and may be less well tolerated by patients).

Typical findings in patients with Crohn's disease include the 'cobblestone' appearance from ulceration, loop separation, mural irregularity, thickening and distorted valvulae conniventes (Gatta et al, 2012) (Figures 1a and b). Impaired peristalsis, strictures and fistulas may also be observed. Mesenteric adenopathy is not directly visible, but may be implied by its extrinsic effect upon bowel loops. Particular attention is paid to the terminal ileum during the procedure as it is the most commonly affected site in Crohn's disease.

Disadvantages of this modality include the inability to evaluate extraluminal disease, and the exposure to ionising radiation, which is of particular importance in young patients who may need several repeat investigations during their lifetime (Masselli, 2013).

How to cite this article:
Peiris D, Wills M. Imaging of the small bowel: a review of current practice. Br J Hosp Med. 2020. https://doi.org/10.12968/hmed.2020.0242



Figures 1a and b. Barium follow-through images demonstrating terminal ileitis secondary to Crohn's disease (arrowed). The terminal ileum demonstrates a persistently narrowed lumen with mucosal irregularity and ulceration.

Ultrasound

Bowel ultrasound is free of ionising radiation, is readily available, and can be particularly useful in follow up and post-surgical assessment. In particular, contrast-enhanced ultrasound is useful for assessing recurrence following ileocolic resection with a sensitivity of 92.5% and accuracy of 87.5%, based on a series with endoscopic correlation (Calabrese et al, 2012).

Evaluation of the small bowel is performed using both low and high frequency probes. The low frequency curvilinear probe offers an overview of the abdomen and pelvis, detects gross abnormality and identifies areas to be focused on with the high frequency linear probe. The study is typically performed after a period of fasting (for example in the morning), to decrease artefact from bowel peristalsis and intraluminal air.

Findings in patients with Crohn's disease include bowel dilatation, mural thickening (normal mural thickness for small bowel is 3–4 mm; Andrzejewska and Grzymisławski (2018)), and absence of normal mural stratification, motility and compressibility. Doppler examination reveals increased vascularity (Figure 2). Extraluminal manifestations may also be seen, such as increased echogenicity (indicating inflammation) of the peri-enteric mesenteric fat, lymphadenopathy, free fluid, abscesses, fistulation and perforation. Contrast-enhanced ultrasound can help in differentiating an abscess from inflammation (Calabrese et al, 2012).

Accuracy of findings is very much operator dependent, with variability based on experience. The location of disease may also impact on accurate assessment, with better accuracy in accessible areas such as the terminal ileum.

Computed tomography

Computed tomography imaging helps in identifying extraluminal manifestations of inflammatory bowel disease. It is particularly useful in the context of an acute flare. Computed tomography with intravenous contrast (without oral contrast), computed tomography enterography and computed tomography enteroclysis are used, but the latter two modalities cannot be performed in an acutely unwell patient, especially if there are concerns regarding bowel obstruction.

Computed tomography enterography involves ingestion of an oral contrast agent at varying quantities and intervals, followed by administration of intravenous contrast. It affords good luminal distension without the need for specialist training and equipment as in computed tomography enteroclysis (Elsayes et al, 2010).

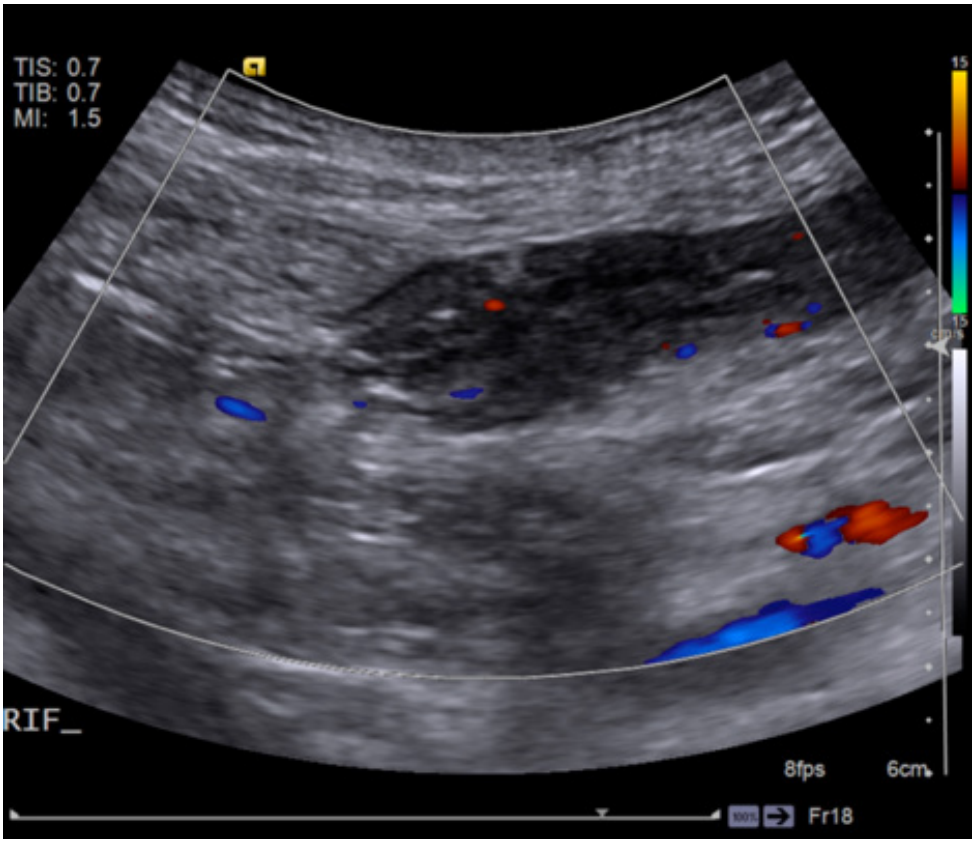


Figure 2. Curvilinear ultrasound of the right iliac fossa demonstrating thickening and oedema of the terminal ileum, with associated moderate hypervascularity on colour Doppler.

Computed tomography enteroclysis is performed with the administration of between 1.5 and 2 litres of an oral contrast agent through a nasojejunal tube. Neutral or positive oral contrast media may be used, but the former is preferred because it is less costly, less viscous, more rapidly injected and offers better identification of mural enhancement, thickening and mesenteric involvement (Gatta et al, 2012). Mannitol is an example of a neutral contrast agent. Hyoscine butylbromide (Buscopan) is also routinely administered to minimise artefact from peristalsis and encourage luminal distension. Before the patient's appointment, bowel preparation may also be administered to empty the small bowel, but this practice is becoming less common.

Several findings may be identified on computed tomography. Mural stratification with thickening in the form of a 'double halo' or 'target' appearance is observed in patients with Crohn's disease. Mesenteric oedema and engorgement of the vasculature of the small bowel and/or ileal mesentery ('comb' sign) is also noted (**Figures 3a** and **b**).

Other identifiable features include strictures, pre-stenotic dilatation, submucosal fibrofatty infiltration and mesenteric lymph node enlargement. The presence or absence of enhancement is very valuable in this setting to help distinguish an acute flare up (where enhancement is present) vs chronic fibro-stenotic disease (non-enhancement). A combination of these features may also be demonstrated in patients with acute on chronic Crohn's disease. Extraluminal manifestations may also be visualised, including abscess formation and fistulae.

Computed tomography also plays a role in post-surgical evaluation, in particular for abscesses, dehiscence of the anastomosis, fistulas, incisional hernias and adhesions.

Multiplanar reconstructions or reformats are invaluable in interpretation of images, particularly if equivocal findings are seen in the axial plane (Gatta et al, 2012).

While being a rapid imaging modality, with no need for sedation and relatively lower in cost than magnetic resonance imaging, disadvantages include exposure to significant ionising radiation, lack of mucosal detail and the need for the ingestion of large volumes of contrast in the case of computed tomography enteroclysis.

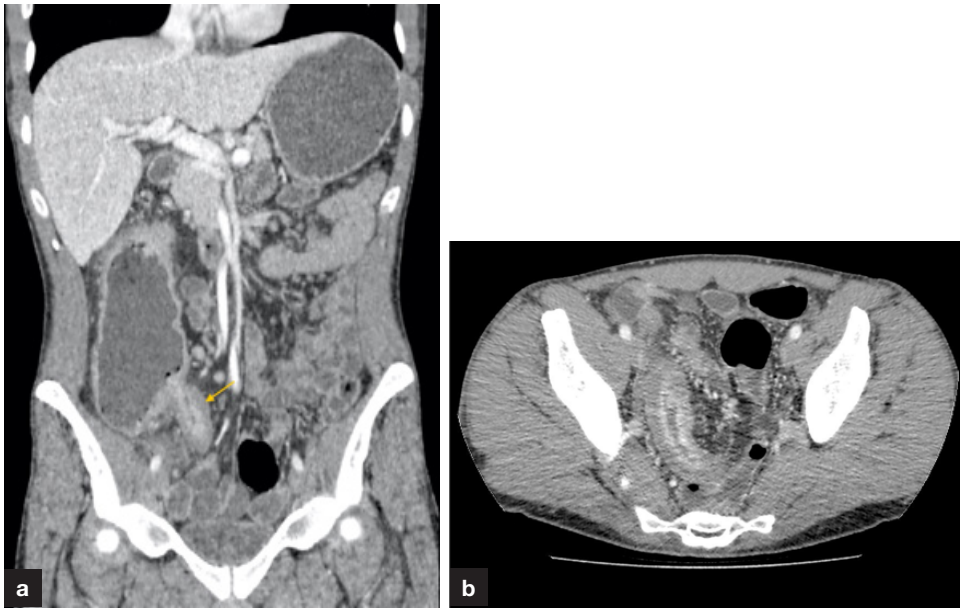


Figure 3. a. Coronal and (b) axial contrast-enhanced computed tomography abdomen and pelvis study performed during an acute 'flare' of Crohn's disease. The terminal ileum is thickened and oedematous, with mucosal hyperenhancement (arrow), in keeping with acute inflammatory Crohn's disease.

Magnetic resonance enterography or enteroclysis

Magnetic resonance imaging is often favoured because of its lack of ionising radiation and excellent soft tissue contrast resolution. Magnetic resonance imaging is a useful modality to evaluate disease activity and is particularly useful in young patients who require repeat studies, thus obviating the use of ionising radiation.

Two techniques are used at present. Magnetic resonance enteroclysis involves the insertion of a nasojejunal tube to administer contrast, while magnetic resonance enterography is non-invasive, involving oral administration of contrast. The latter is more commonly used.

Negative, positive or biphasic contrast agents may be used, with the latter most commonly used (Masselli, 2013). With biphasic agents, the lumen is hypointense on T1-weighted imaging and hyperintense on T2-weighted imaging. A wide selection of biphasic contrast agents may be used, ranging from simple water or mannitol, to more complex mixtures containing methylcellulose, water and sorbitol (Yoon et al, 2015).

Antiperistaltic agents such as intravenous buscopan are used to inhibit bowel peristalsis and reduce motion artefact, which particularly affects magnetic resonance imaging. Patients are scanned in either the prone or supine position with a torso or body coil for the purposes of a large field of view, using a 1.5 or 3T scanner.

The main sequences involved in magnetic resonance enterography are the single shot fast spin echo (SSFSE/HASTE) and balanced steady state free precision (SSFP/tru-FISP/FIESTA) sequences in the axial and coronal planes. With SSFSE, the required data are acquired in a single excitation. It is particularly valuable in identifying mesenteric oedema, intramural oedema and mural thickening. A HASTE sequence with fat saturation allows improved detection of wall or mesenteric oedema and will distinguish between mural oedema and focal mural fatty infiltration (Tolan et al, 2010) (Figures 4 and 5).

Some centres use cine imaging to observe intestinal motion in real time and in short time intervals. Post-contrast T1-weighted gradient echo sequences with fat suppression are used to identify mural hyperenhancement, local nodal enhancement and mesenteric hypervascularity.

Diffusion-weighted imaging is used in some centres to help with the assessment of inflammation, characterised by restricted diffusion. A review of 18 patients demonstrated that diffusion-weighted imaging was more sensitive in identifying active disease relative to dynamic contrast-enhanced sequences (Oto et al, 2011). A further study evaluating 25 patients suggests diffusion-weighted imaging may also have a role in detecting sinus tracts

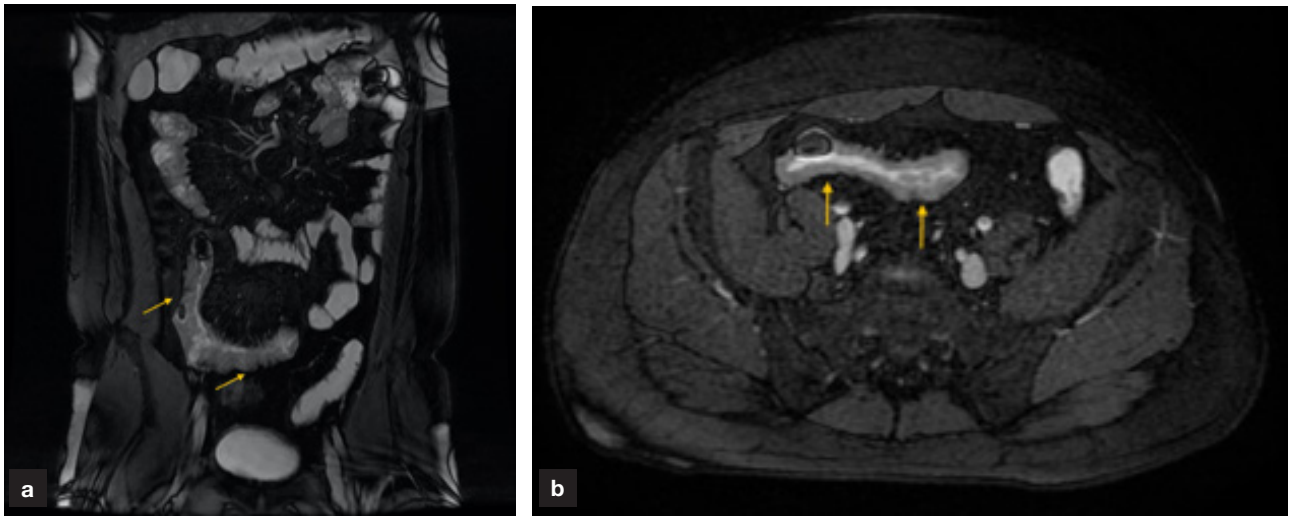


Figure 4. a. Coronal and (b) axial magnetic resonance images (FIESTA FAT-SAT) demonstrating high signal distal ileal wall thickening (oedema) and mesenteric hypervascularity ('comb sign') in a patient with inflammatory Crohn's disease (arrowed).

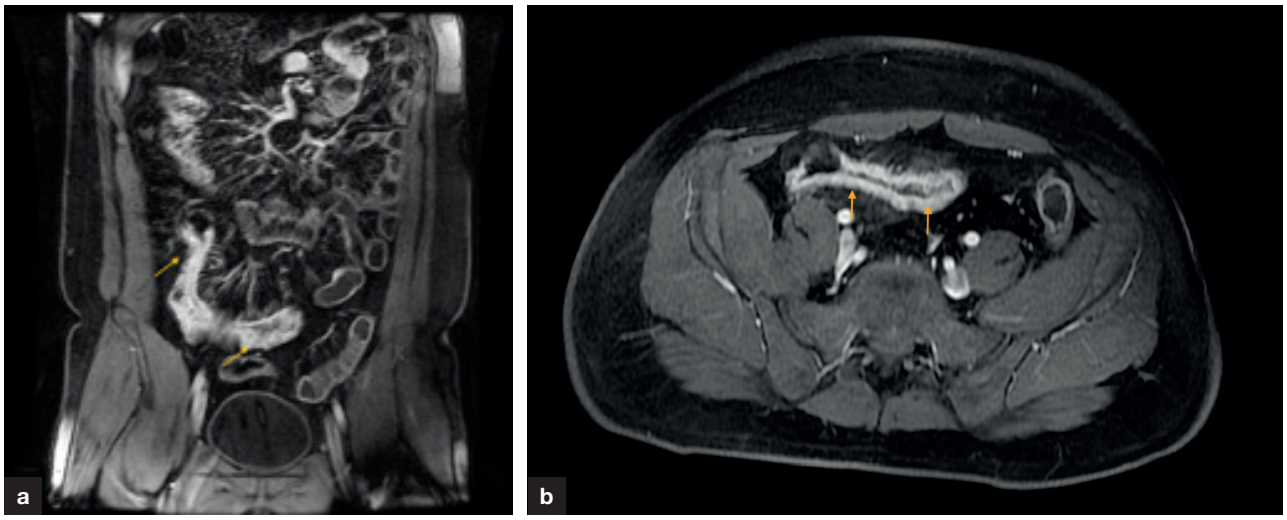


Figure 5. a. Coronal and (b) axial magnetic resonance images (post contrast) demonstrating marked mucosal hyperenhancement of the distal ileum and enhancing mesenteric hypervascularity ('comb sign') in a patient with inflammatory Crohn's disease (arrowed).

and internal fistulas (Schmid-Tannwald et al, 2012). Axial diffusion sequences are also included as one of the essential sequences on a magnetic resonance enterography study based on a multicentre prospective (METRIC) study (Taylor et al, 2014).

Disadvantages of magnetic resonance imaging include limited spatial resolution, cost, patients feeling claustrophobic and lengthy acquisition time. Magnetic resonance enteroclysis requires the fluoroscopic placement of a nasojejunal tube and instillation of large quantities of fluid to facilitate maximal bowel distention, although this can cause the patient considerable discomfort.

Radiological manifestations in other small bowel conditions

While small bowel imaging is most commonly used in the assessment of inflammatory bowel disease, there are several other conditions that require imaging to guide management, for example, local staging in the context of small bowel malignancy. Other systemic conditions, in particular polyposis syndromes, connective tissue or autoimmune disorders (such as scleroderma, mastocytosis), have small bowel manifestations and also rely on radiology for diagnosis.

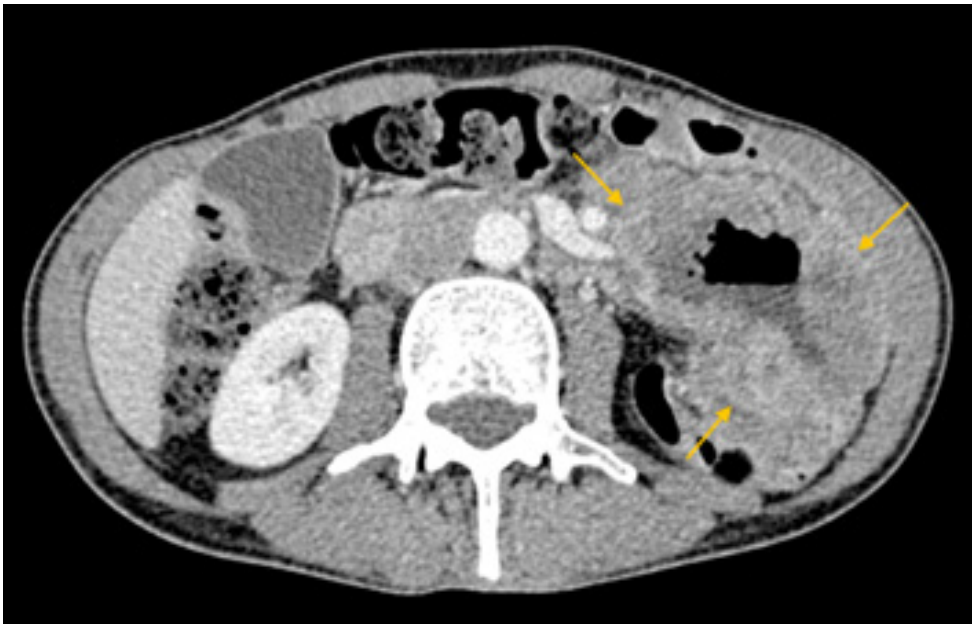


Figure 6. Axial contrast-enhanced computed tomography of the abdomen and pelvis demonstrating irregular, expansile bowel wall thickening secondary to a jejunal mass (adenocarcinoma) within the left upper quadrant of the abdomen (arrowed).

Small bowel cancer

Less than 5% of gastrointestinal malignancies relate to the small bowel (Fernandes et al, 2012). Of these, adenocarcinoma represents up to 30–50%. These are predominantly located in the duodenum, followed by the jejunum and ileum. Risk is increased in patients with familial adenomatous polyposis and Crohn's disease. Accuracy of detection on computed tomography has been estimated at approximately 47% (Hutchins et al, 2001). Computed tomography demonstrates a well-circumscribed mass (Figure 6), abrupt calibre change ('transition point'), and eccentric bowel wall thickening or circumferential stenosis (Fernandes et al, 2012). Added features include focal wall thickening (usually without aneurysmal dilatation), ulcerating lesion or intussusception (McLaughlin and Maher, 2013). These patients may present acutely with mechanical bowel obstruction (Minordi et al, 2018). In some cases, the tumour may result in acute haemorrhage into the gastrointestinal tract (Figure 7).

Barium studies show similar intraluminal findings as computed tomography but are not commonly used. Advantages of computed tomography over barium studies include assessment of extramural disease, lymph node enlargement and distal disease (metastases).

Scleroderma

Scleroderma is a systemic condition that manifests gastrointestinally in up to 90% of cases (Pickhardt, 1999). The small bowel is the second most common site of gastrointestinal involvement after the oesophagus. Barium studies are useful to identify the presence of small bowel involvement. The main finding is that of the 'hide-bound' appearance which describes the presence of narrowly separated valvulae conniventes of normal thickness in association with luminal dilatation (Pickhardt, 1999). Additional findings include the presence of flocculations (clumping together of contrast material) (McFarlane et al, 2018). These findings are also identifiable on appropriately performed computed tomography and magnetic resonance imaging studies (Figures 8a and b).

Coeliac disease

Coeliac disease is a chronic autoimmune condition induced by the ingestion of gluten. It primarily affects the small bowel. Features on barium contrast studies include duodenitis, dilatation, flocculations, slow transit, moulage sign, reversal of the ileal-jejunal fold pattern and transient intussusception (Scholz et al, 2011).

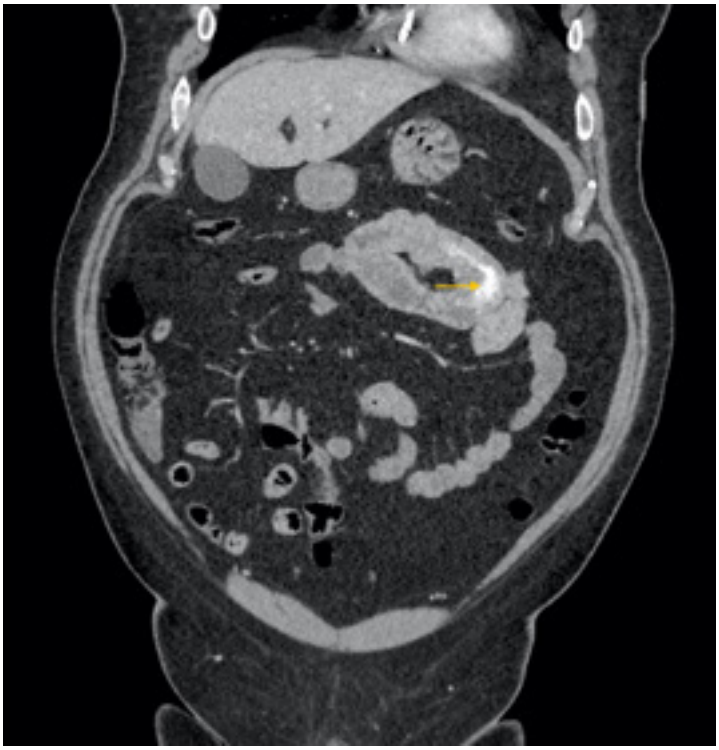


Figure 7. Coronal contrast-enhanced computed tomography of the abdomen and pelvis demonstrating extravasation of high density contrast into the lumen of the jejunum (arrowed), indicating acute haemorrhage. This haemorrhage is secondary to small bowel adenocarcinoma (evident as ill-defined thickening of the adjacent jejunal wall).

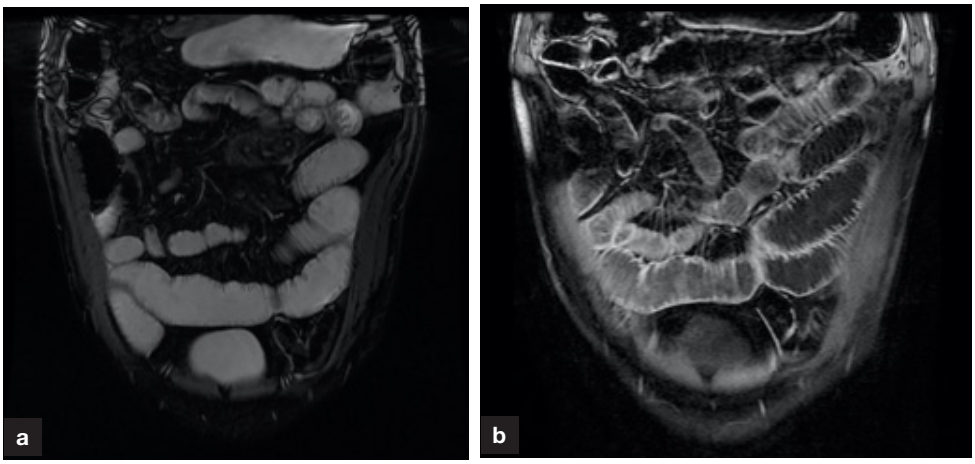


Figure 8. Magnetic resonance images ((a) coronal FIESTA FAT-SAT and (b) coronal post-contrast) demonstrating the typical 'hide-bound' appearance of the small bowel (narrowly separated valvulae conniventes) in scleroderma.

Additional features may be seen on computed tomography, particularly extraluminal manifestations such as mesenteric lymphadenopathy, and/or low attenuation/necrotic nodes, engorgement of mesenteric vascularity and splenic atrophy (Scholz et al, 2011). In addition, given the increased risk of lymphoma with coeliac disease, computed tomography is used for its detection and subsequent staging.

Findings on magnetic resonance imaging are also similar and have several advantages. It allows for the direct acquisition of coronal images and therefore improved distinction between jejunum and ileal loops, the use of non-ionising radiation and also improved soft tissue contrast resolution (Tomas et al, 2006). In addition, dynamic contrast-enhanced magnetic resonance imaging is useful in evaluating the extent of inflammation in affected patients (Masselli et al, 2010).

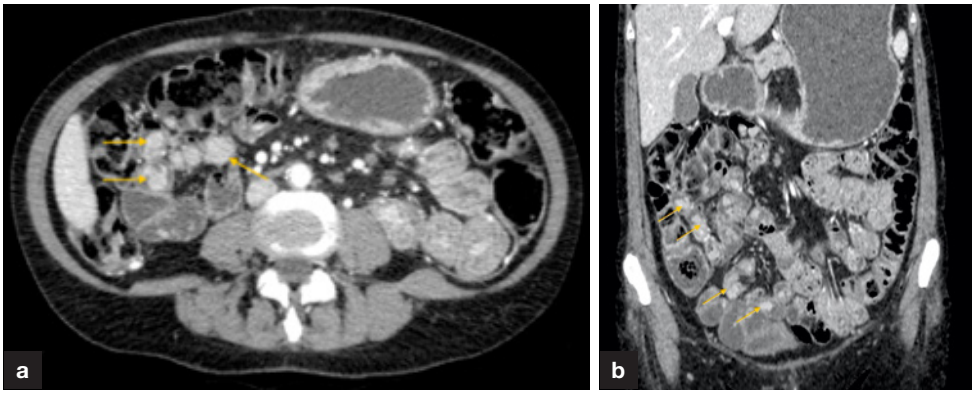


Figure 9. a. Axial and (b) coronal contrast-enhanced computed tomography enterography demonstrating innumerable enhancing polyps throughout the small bowel (arrowed) in a patient with Peutz–Jeghers syndrome.

Peutz–Jeghers syndrome

Peutz–Jeghers syndrome is an autosomal dominant condition characterised by gastrointestinal hamartomatous polyposis and mucocutaneous pigmentation. Polyps are most commonly visualised in the small bowel, in particular the jejunum and ileum, followed by the colon and stomach (Buck et al, 1992).

On barium studies, multiple polyps are typically seen as filling defects within the stomach and bowel. These polyps vary in size and shape. Some may be sessile, while others are larger and pedunculated. Typically, they are separated by areas of flat mucosa (Buck et al, 1992).

Computed tomography enteroclysis and computed tomography enterography are valuable in detection of small bowel tumours, with a sensitivity of 92.8% and specificity of 99.2% for computed tomography enteroclysis (Tomas et al, 2014). Findings mirror those of barium studies, where polyps vary in size, may be pedunculated and are widespread (**Figures 9a** and **b**). Standard computed tomography has a role to play in patients presenting with acute abdominal pain triggered by small bowel intussusception (Tomas et al, 2014), but is less sensitive in detecting smaller polyps because the luminal distension is more limited.

An alteration in protocol to include both prone and supine acquisitions in magnetic resonance imaging has been suggested to increase detection of visible polyps (Maccioni et al, 2012). The smallest polyp identified in the aforementioned study was 3 mm. There was also a 75% concordance with endoscopy, which increased to 93% on polyps over 15 mm in diameter.

Conclusions

Diagnosing abnormalities in the small bowel is heavily reliant on radiology and each imaging modality has a dedicated role to play in helping the clinician evaluate the small bowel. In some instances, obtaining a diagnosis, treatment outcome evaluation and follow up may require the use of multiple imaging modalities to answer specific clinical questions. While inflammatory bowel disease accounts for a large number of requests for small bowel imaging, other conditions also rely on imaging for aiding diagnosis. With the current trend in technological advancement, it is possible that small bowel imaging will become entirely non-invasive, thereby increasing throughput, streamlining services and improving patient experience.

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Conflicts of interest

The authors declare no conflicts of interest.

Key points

- The dynamic nature of the anatomy and pathophysiology of the small bowel, and the difficulty in accessing it via endoscopy, means that this is best investigated via a myriad of imaging modalities.
- Magnetic resonance imaging has superseded barium studies in most centres for the evaluation of inflammatory bowel disease (Crohn's disease).
- Small bowel imaging allows for assessment of features of acute active inflammation vs chronic fibrostenotic disease in Crohn's disease.
- Imaging is also performed to evaluate other inflammatory and autoimmune conditions of the small bowel, as well as small bowel malignancy and polyposis syndromes.

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