Imaging of the small bowel: a pictorial review

Introduction

The small bowel is the longest part of the gastrointestinal tract (approximately 6–7 m in length) and extends from the duodeno-jejunal junction in the epigastrium to the ileo-caecal valve in the right iliac fossa.

Clinical symptoms of small bowel disease are non-specific and include abdominal pain or discomfort, diarrhoea, anorexia, weight loss and malabsorbtion. The clinical presentation is often similar, regardless of the underlying pathology, and therefore further investigations are necessary to establish a correct diagnosis.

Radiological examination is an important part of the diagnostic process because of the complex structure of the small bowel and its relative inaccessibility to direct visualization by endoscopic techniques.

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Small bowel obstruction

Approximately 20% of patients admitted to hospital with acute abdominal pain have intestinal obstruction, and small bowel obstruction is responsible for approximately 80% of these cases.

Mortality and morbidity rates depend on the aetiology and the patient's age at presentation. Infants with intussusception usually respond very well to pneumatic reduction, while the mortality rate can be high in elderly patients who may have associated bowel strangulation, ischaemia and multiple coexistent diseases.

Mechanical small bowel obstruction can be classified into three groups according to the site of obstruction: intraluminal, intramural and extraluminal (*Figures 1* and *2*).

Intraluminal causes are relatively rare and include:

Figure 1. Gallstone ileus – small bowel obstruction caused by multiple biliary calculi. a. Abdominal X-ray shows multiple dilated loops of small bowel in the upper abdomen with multiple calcifications in the right upper quadrant and in the pelvis. Computed tomography of the abdomen shows (b) dilated loops of bowel in the pelvis with intraluminal calculus, (c) calculi in the gallbladder and free air in the biliary system.

Figure 2. Small bowel obstruction in patient with multiple adhesions, post previous surgery. Multiple dilated loops of small bowel on (a) abdominal X-ray and (b) axial and (c) coronal computed tomography. Transition point is in the right iliac fossa and para-stomal hernia with loop of small bowel.

- Swallowed foreign bodies
- Gallstone ileus secondary to cholecystoenteric fistula (*Figure 1*)
- Parasites
- Undigested food or inspissated meconium.

Intramural causes are also infrequent and result from lesions in the bowel wall:

- Focal thickening with luminal compromise caused by inflammatory and infective disease
- Benign and malignant tumours
- Intussusception
- Intramural haematoma
- Congenital strictures and atresias.

Extramural pathology remains the most common cause of small bowel obstruction with adhesions (related to previous surgery or peritonitis) accounting for about half of mechanical obstructions (*Figure 2*). Small bowel hernias and congenital defects such as malrotation or congenital bands are found less frequently.

Patients with small bowel obstruction usually present with abdominal pain, vomiting, constipation and different degrees of distention. In general, the higher the level of obstruction, the less distention and more rapid onset of vomiting. Clinical signs of peritonitis suggest perforation or bowel ischaemia.

A variety of conditions can produce an adynamic or paralytic ileus, which can mimic an obstruction clinically and radiologically. In these patients there is no evidence of a focal obstructive lesion. Both the small and large bowel may be dilated. Common aetiologies include recent abdominal surgery, peritonitis, various medications and electrolyte imbalance. Reduced or absent peristalsis can also be seen in patients with myocardial infarction, neuromuscular disease, intracranial pathology and collagen vascular disorders.

Conventional plain radiography is usually the first-line imaging test to be performed (*Figures 1a* and *2a*). Unfortunately, the sensitivity of abdominal X-ray for diagnosing small bowel obstruction is only 50–66%, especially in cases with little or no gas in the proximal intestine and when the bowel lumen is filled with fluid.

Computed tomography of the abdomen is often extremely useful to evaluate the location and cause of obstruction and to detect its various complications, for example ischaemia, intra-abdominal collections and bowel perforation (*Figures 1b* and *2b*). It also provides additional staging information in patients with intra-abdominal malignancy.

Inflammatory disease

Inflammatory bowel disease, also known as small bowel enteritis, may have a variety of causes, of either infective or non-infective aetiologies (*Figure 3*).

Crohn's disease

Crohn's disease is an idiopathic inflammatory disease, which can affect any part of the gastrointestinal tract from the mouth to the anal canal. It can be a devastating disease of the alimentary system with multiple unpredictable episodes of exacerbations, complex treatment, serious complications and chronic progression.

Crohn's disease is the most common primary small bowel disease in developed countries. The prevalence of the disease has been increasing with a peak incidence in teenagers and young adults between 15 and 25 years of age (British Society of Paediatric Gastroenterology Hepatology and Nutrition, 2008).

Clinical presentation includes non-specific abdominal pain, mild diarrhoea, weight loss and pyrexia. A survey based on a large population of children in the UK showed that 'classical symptoms' were present in less than 25% of patients (British Society of Paediatric Gastroenterology Hepatology and Nutrition, 2008). Most of the children presented with vague complaints such as lethargy, anorexia, abdominal discomfort or isolated growth failure. The difficult clinical picture often causes a significant delay between the initial presentation and diagnosis of Crohn's disease, and delays of 3–4 years are widely reported.

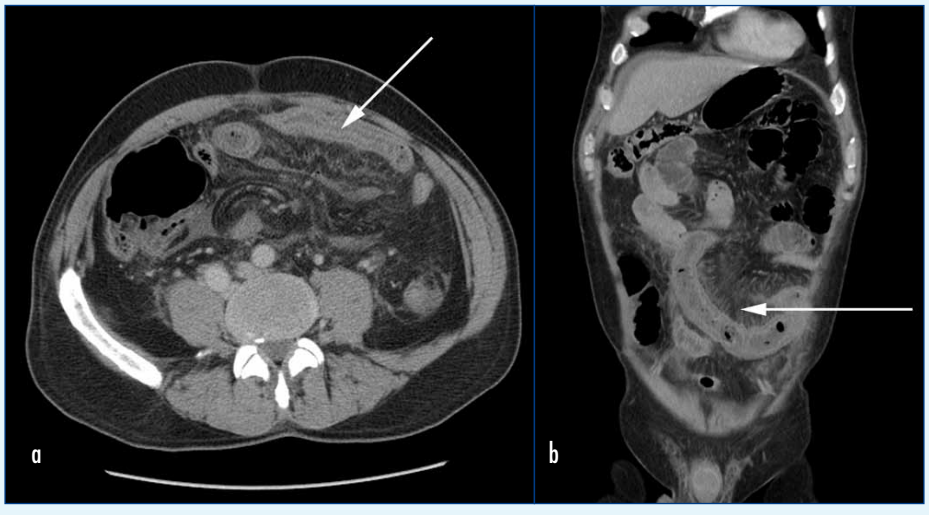
The small bowel is involved in Crohn's disease in 80% of patients, with the terminal ileum most commonly affected (55%). Disease is confined to the small bowel in 30% of patients, while isolated colitis occurs in 20% of patients, most often involving the right colon.

A hallmark of Crohn's disease is the presence of skip lesions, consisting of abnormal bowel interposed between normal segments of gut (*Figures 4a* and *5a*). Inflammatory changes extend through all layers of the bowel wall and can affect the surrounding mesentery and lymphatic system.

The radiographic appearance depends on the stage of inflammation, and can be divided into early, intermediate or advanced.

In the early stages, hyperplasia of lymphoid tissue and obstructive lymphoedema cause thickening and irregularity of the mucosal folds with shallow circular ulcerations, known typically as aphthoid. As the inflammatory changes progress, ulcerations become more linear and deeper, producing stellate or 'rose thorn' shapes. Areas of mucosal oedema between the ulcers create an appearance of 'cobble-stoning' with islands of mucosal hyperplasia, known as inflammatory pseudo-polyps. Formation of deep fissures and narrowing of the bowel lumen are characteristic features of advanced disease (*Figure 4*).

Figure 3. Non-specific enteritis – focal inflammatory changes in small bowel. Computed tomography demonstrates a diffuse bowel wall thickening with extensive inflammatory changes in the surrounding mesentery on (a) axial and (b) coronal images.



In severely affected bowel and mesentery, scarring may develop which causes a focal bulging of the contralateral bowel wall and creates a characteristic pseudodiverticular appearance. Proliferation of mesenteric fat causes separation of affected bowel loops and displacement of normal bowel.

Multiple complications have been reported in the advanced stage of disease; these include obstruction, perforation or formation of fistulas, intramural tracts and abscesses. Late complications include strictures and malignant transformation (*Figures 5* and *6*).

Extra-intestinal manifestations of Crohn's disease are also common and include malabsorbtion, biliary calculi, fatty infiltration of liver, sclerosing cholangitis and cholangiocarcinoma.

Although the barium contrast study remains the first line of examination to demonstrate detailed mucosal findings and assessment of endoluminal disease, cross-sectional modalities (computed tomography and magnetic resonance imaging) are more suitable for diagnosing extraluminal disease and associated complications.

Computed tomography of the abdomen with intravenous contrast is the preferred technique in sick patients who cannot tolerate a longer magnetic resonance imaging examination. Computed tomography provides very good visualization of abdominal and pelvic organs, complications such as intra-abdominal collections and other related pathologies, including gallstones, pancreatitis, nephrolithiasis and arthritis.

Magnetic resonance imaging remains the examination of choice in young patients because of the high contrast resolution and the absence of ionizing radiation, with superior demonstration of bowel wall detail and surrounding structures, including delineation of fistulous tracts and assessment of peri-anal disease (*Figures 5* and *6*).

Bowel obstruction is the most severe and common complication in Crohn's disease and is reported in around 20% of patients (*Figure 5d*). It can develop in the active phase as a result of severe bowel wall thickening by inflammatory infiltrate, or in the chronic phase as a result of collagen deposition and formation of fibrotic strictures. Differentiation between active and chronic obstruction is extremely important with regard to the patient's treatment; obstruction with an active inflammatory process is treated medically while chronic fibrotic strictures require surgical intervention (*Figure 5c*).

Advances in radiological imaging, especially computed tomography enteroclysis and magnetic resonance imaging examination, make it possible to differentiate between luminal narrowing as a result of spasm, fibrotic stricture and active inflammation.

Infective enteritis

Small bowel infection is extremely common, with an estimated 20% of the British population suffering at least one episode of enteritis each year. Acute infections caused by a variety of organisms (Salmonella, Campylobacter or Staphylococcus) are usually self-limiting and do not require radiological investigation.

Chronic intestinal infections are less common in the developed world, but are still an endemic problem in developing countries and include parasitic infestations (ascariasis, giardiasis, strongyloidiasis) and bacterial, fungal and viral infections (tuber-

Figure 4. Crohn's disease. Small bowel contrast examination reveals the spectrum of changes seen in Crohn's disease: (a) thickened mucosal folds, nodularity and ulcerations in terminal ileum, (b) long segmental stricture and deep ulcerations more proximally, (c) stricture with fistula formation, (d) multifocal strictures with intervening areas of dilatations.

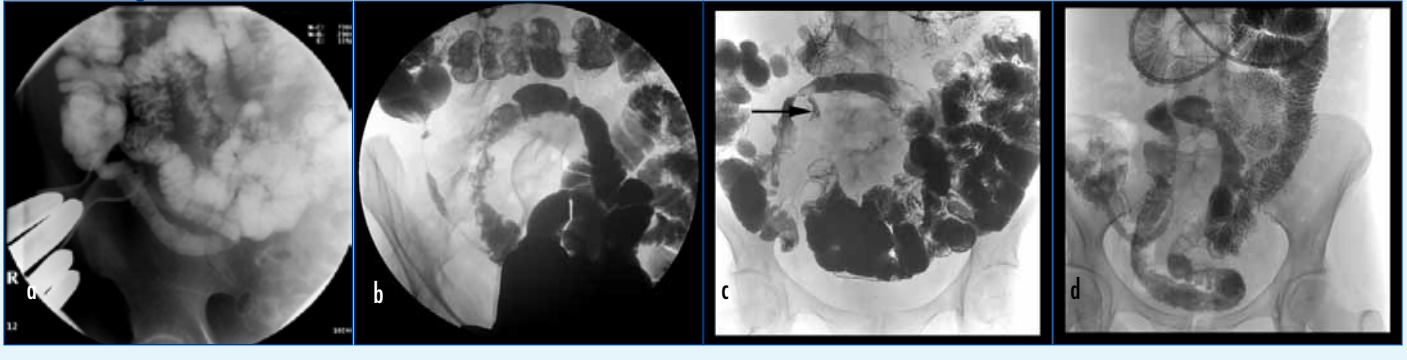
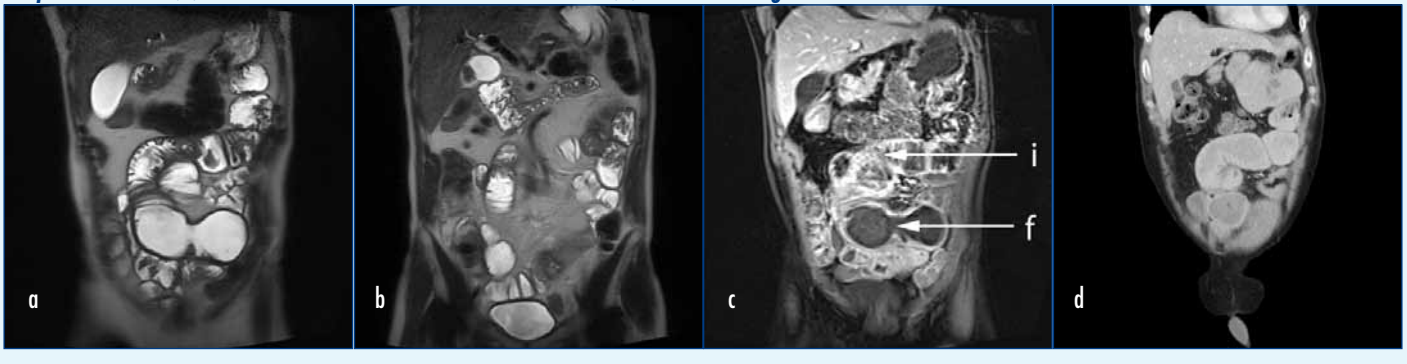


Figure 5. Advanced Crohn's disease. a, b. Magnetic resonance imaging shows multi-segmental involvement of small bowel with several skip lesions and strictures. c. Contrast-enhanced magnetic resonance imaging helped to differentiate between active inflammatory process (i) and fibrotic stricture (f). Subsequent complications were (d) obstruction as a result of fibrotic stricture and (b) calculus in the gallbladder.



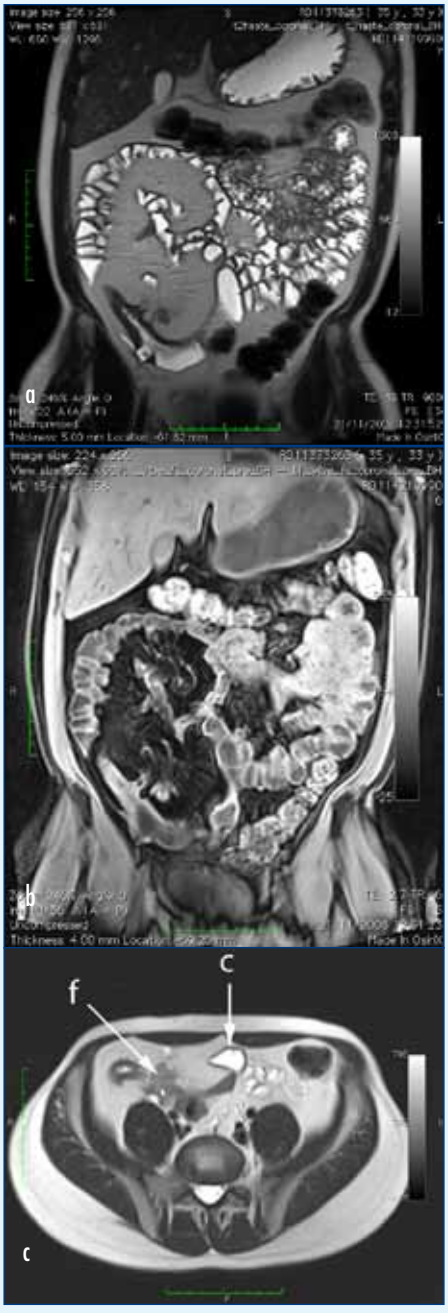


Figure 6. Advanced Crohn's disease. Magnetic resonance imaging shows wall thickening in the terminal ileum, proliferation of mesenteric fat, a focal collection in right iliac fossa (c) and small fistulous tract (f) to the sigmoid colon.

culosis, yersiniosis, histoplasmosis, cytomegalovirus infection).

Radiological features are often non-specific and include mucosal nodularity, irregular thickening and distortion of mucosal folds, ulcerations, luminal narrowing, stricture and occasional fistula formation (*Figure 3*). The terminal ileum and caecum are most commonly affected. Correct diagnosis requires correlation of the radiological findings with clinical presentation, laboratory and histopathological results.

Radiation enteritis

The frequency of radiation enteritis is increasing and occurs in more than 15% of patients who have received radiotherapy. The ileum and rectum are most often involved as a consequence of pelvic irradiation. Radiation with more than 50 Gy can damage the intestinal wall, causing acute or chronic changes. An abrupt transition between affected bowel and non-affected adjacent bowel which has been excluded from the radiation field is a characteristic radiological feature.

Radiation enteritis produces muscle fibre atrophy, ulcerative changes as a result of ischaemia and different degrees of obstruction as a result of fibrotic strictures.

Small bowel tumours

Small bowel tumours account for less than 5% of gastrointestinal neoplasms, with a slight predominance of benign lesions. These are usually found in patients between 50 and 80 years of age, with an equal frequency in both sexes. Benign lesions are usually asymptomatic, but may present with intermittent abdominal pain. When they become larger, clinical symptoms of obstruction, anaemia and occult bleeding may occur. Benign neoplasms include adenomas and tumours of mesenchymal origin (leiomyoma, lipoma, fibroma, neurofibroma, haemangioma and lymphangioma). Leiomyomas are the most common lesions and usually seen in the jejunum, while the second most common form, lipomas, are mostly seen in the ileum.

Lesions larger than 1.5–2 cm are usually visible on a barium contrast study, computed tomography or magnetic resonance imaging examination, whereas smaller tumours remain a diagnostic challenge (*Figure 7*).

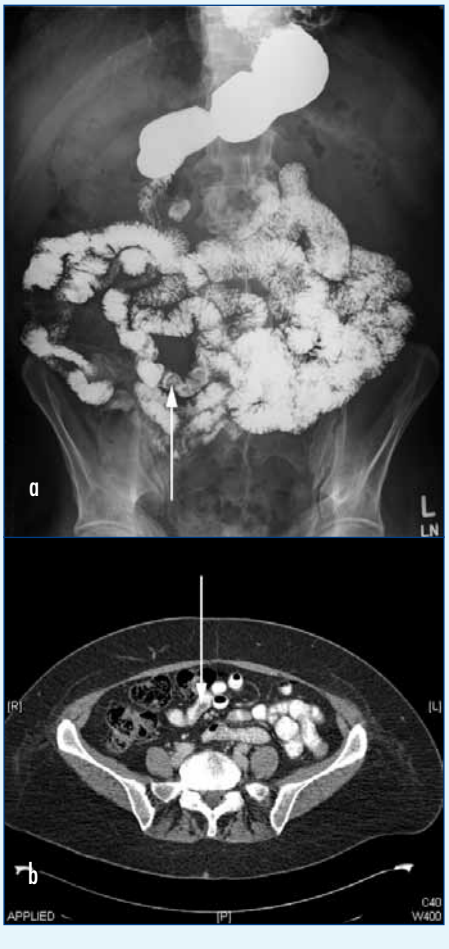
Benign neoplasms are usually single; the presence of multiple lesions in the small bowel suggests the possibility of one of several congenital syndromes: Peutz-Jeghers syndrome, Cowden disease, familial polyposis syndrome or Cronkhite-Canada syndrome. These are relatively rare, but early correct diagnosis allows screening of family members and allows treatment to reduce the risk of subsequent severe complications and malignant transformation (the potential for developing adenocarcinoma in patients with familial polyposis syndrome is 100%).

Metastatic disease is the most common malignant process in the small bowel and metastases represent more than half of small bowel tumours. Haematogenous metastases include malignant melanoma, bronchogenic and breast carcinoma, whereas colonic, gastric and ovarian malignancies more often involve the small bowel through direct extension or lymphatic spread.

The frequency of primary small intestinal malignancies are carcinoid – 41%, adenocarcinoma – 24%, lymphoma – 22% and sarcoma – 11%.

Carcinoid tumours are multiple in half of cases and mostly found in the appendix (50%) and in the terminal ileum (35%). These are difficult to diagnose radiologically if they are less than 2 cm in size.

Figure 7. Small bowel polyp. a. Contrast study and (b) computed tomography with oral contrast demonstrate a well-defined filling defect in the distal small bowel.



At the time of presentation, 80% of ileal carcinoid tumours have metastatic disease with involvement of lymph nodes, small bowel mesentery or liver. Mesenteric involvement characteristically incites a desmoplastic reaction, creating a 'spoke-wheel' appearance on computed tomography or magnetic resonance imaging examination as a central soft tissue mass with radiating dense strands and changes in the surrounding soft tissue (*Figure 8*). Hepatic metastases with high levels of hormone secretions present clinically as 'carcinoid syndrome' and lead to multiple complications, include right-sided endocardial fibrosis.

Primary adenocarcinomas are found more commonly in the jejunum and can present as polypoid, ulcerating or an infiltrating abnormality.

Figure 8. Small bowel carcinoid. Computed tomography of the abdomen shows a lobulated soft tissue mass in the mesentry. a. Axial and (b) coronal images. 'Spoke-wheel' appearance represents a desmoplastic reaction, which is characteristic for carcinoid (c). Enlarged focal mesenteric lymph nodes can be seen (ln).

In contrast to other malignant neoplasms, lymphoma tends to originate at multiple sites and extends along the small bowel long axis (*Figure 9*). Small bowel lymphoma is non-Hodgkin in origin and may be associated with human immunodeficiency virus, acquired immunodeficiency syndrome, coeliac and Crohn's disease. It has different radiological presentations: multiple small nodules, a polypoid or infiltrative mass with lumen narrowing, and rarely aneurysmal dilatation of the bowel lumen secondary to distraction of nerve plexuses.

Figure 9. Small bowel lymphoma. a, b. Computed tomography and (c) magnetic resonance imaging revealed diffuse bowel wall thickening and multiple enlarged lymph node in the mesentery.

Congenital abnormalities

Congenital abnormalities of the small bowel are very rare and include atresia, stenosis, duplication anomalies, malrotation and diverticula.

Malrotation occurs from abnormal bowel rotation during fetal development and can cause a midgut volvulus, usually in paediatric patients (*Figure 10*). Incidentally diagnosed rotational anomalies in adults are usually of no clinical significance.

Meckel's diverticulum is present in approximately 2% of the population and typically is located within 1 m of the ileocaecal valve. In the majority of cases, it is asymptomatic, but may cause bleeding, obstruction or act as a leading point for intussusception.

Other small bowel diverticula are usually acquired and most commonly seen in the jejunum (*Figure 11*).

Figure 10. Malformation. a. Upper gastrointestinal contrast study confirmed an abnormal position of duodeno-jejunal junction on the right side of the midline. b. On magnetic resonance imaging examination jejunum and ileum is located on the right side of abdominal cavity with colon visible on the left.

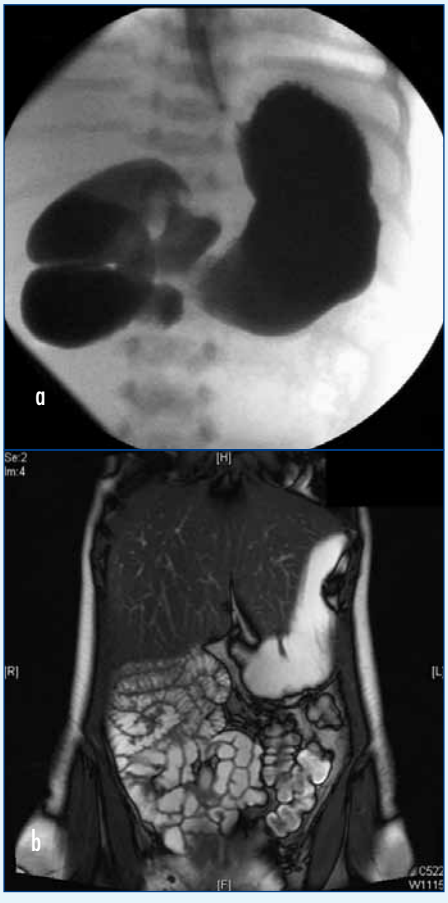
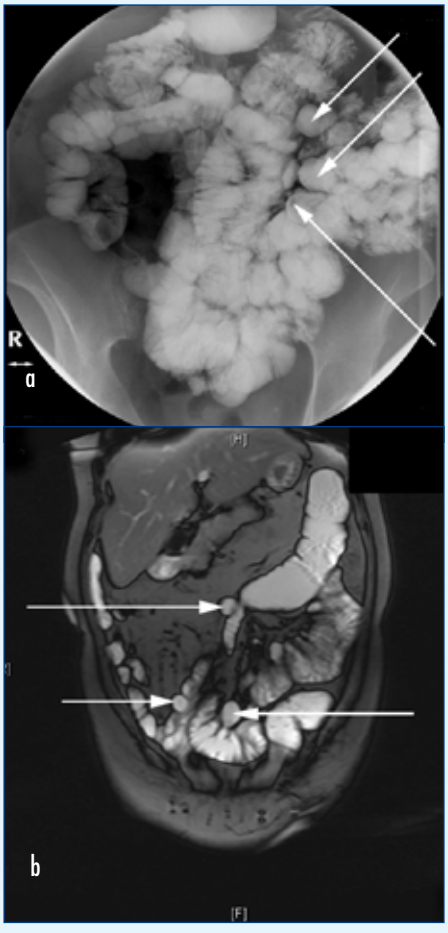


Figure 11. Jejunal diverticulosis. (a) Contrast study and (b) magnetic resonance imaging demonstrates multiple diverticula of varying sizes in jejunum.



Diffuse intestinal disease (hypoproteinaemia, mastocystosis, scleroderma, coeliac disease and other conditions) are outside the scope of this article. Diagnosis is usually based on clinical presentation, laboratory tests and histopathological results. Radiological features are non-specific and mainly include a distortion and abnormality of the mucosal folds.

Conclusions

The diagnosis of small bowel disease remains a challenging task, but has been improved by developments in magnetic resonance imaging and computed tomography imaging. Good visualization of the mucosal structure, acute and chronic changes in the intestinal wall and of the surrounding mesentery can guide early diagnosis and ensure optimal treatment. BJHM

Conflict of interest: none.

British Society of Paediatric Gastroenterology Hepatology and Nutrition (2008) *Guidelines for the Management of Inflammatory Bowel Disease (IBD) in Children in the United Kingdom.* British Society of Paediatric Gastroenterology Hepatology and Nutrition, Stourbridge

Further reading

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KEY POINTS

- Clinical symptoms of small bowel disease are very non-specific and radiological examination remains an important part of the diagnostic process.
- Cross-sectional imaging (computed tomography and magnetic resonance imaging) can show detailed abnormalities of the small bowel, any extension and location of the pathological process, and a variety of potential complications.
- New imaging techniques help to differentiate between the active inflammatory process and chronic changes to guide the correct treatment in patients with long-standing disease.