CURRICULUM BASED CLINICAL REVIEWS

Curriculum based clinical review: small bowel imaging in Crohn's disease

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ABSTRACT

The multidisciplinary management of patients with small bowel Crohn's disease is complex with an increasing reliance on imaging to guide management. The use of barium fluoroscopy is in decline with a shift towards the cross-sectional modalities. This article provides an overview of the various techniques used to image the small bowel, and highlights the clinical scenarios where imaging tests are most useful.

INTRODUCTION

Crohn's disease is a chronic, transmural, relapsing granulomatous inflammatory disorder. Although various influences such as smoking, stress, diet, genetic and autoimmune abnormalities have been postulated as aetiological factors, there remains uncertainty as to the underlying cause.¹ Current estimates suggest a prevalence of 144.8/100 000,² which would equate to approximately 93 000 patients in the UK. The small bowel is predominantly affected (especially the terminal ileum, in up to 80% of cases)³ and involvement is commonly segmental with diseased areas interspersed with healthy bowel (so called 'skip lesions'). The earliest visible mucosal change is aphthoid ulceration, which progresses to superficial and then deep transmural ulceration. Subsequent sinus, fistula and abscess formation are relatively common. Later in the disease process mural fibrosis can lead to stricture formation with the risk of bowel obstruction.

Imaging now plays a crucial role in the multidisciplinary management of patients with Crohn's disease, particularly for monitoring disease activity and helping to identify complications, but also as a useful adjunct to aid initial diagnosis. In past decades the only way to image the small bowel involved fluoroscopic barium

examinations. Due to technological advances and increased scanner availability the gastroenterologist now has a plethora of small bowel imaging techniques available, including CT, MRI, ultrasound and capsule endoscopy. This article gives an overview of the various small bowel imaging techniques as well as summarising the current role of imaging in small bowel Crohn's disease to cover the relevant core and advanced competencies of the 2010 gastroenterology curriculum (box 1).

WHAT IMAGES TECHNIQUES ARE AVAILABLE?

A variety of techniques are now available to image the small bowel. In many cases the decision will be based on departmental protocol, available imaging resources and radiological expertise. Direct comparison of techniques based on cost can be complex and misleading, with vastly different figures between departments depending on number of procedures performed, equipment and staff time.⁴ The following section provides a brief summary of the most commonly used imaging techniques with reference to the latest European Crohn's and Colitis Organisation & European Society of Gastrointestinal and Abdominal Radiology (ECCO-ESGAR) guidelines.

FLUOROSCOPIC BARIUM STUDIES

Small bowel barium follow through (BFT) and small bowel barium enteroclysis (SBE) still outperform the cross-sectional modalities in terms of spatial resolution and fine mucosal detail (figure 1).⁵ BFT involves the oral ingestion of a dilute barium mixture (commonly with a prokinetic such as metoclopramide), with a series of

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Box 1 Gastroenterology Curriculum 2010

Core competency 2C: Intestinal disorders: Inflammatory bowel disease

- ▶ To recognise and understand the differential diagnosis of inflammatory bowel disease, and the investigations required to investigate and diagnose it
- ▶ Uses appropriate investigations including blood tests, stool cultures and intestinal imaging modalities

Advanced specialist area 3B: advanced inflammatory bowel disease

- ▶ To be able to identify appropriate investigations to make a positive diagnosis of IBD or to exclude it
- ▶ To be able to interpret the results of the above investigations
- ▶ Understand the appropriate investigations for assessing disease activity and extent including: upper and low gastrointestinal (GI) endoscopy, CT and MRI scanning, capsule endoscopy, enteroscopy and barium imaging.
- ▶ To be able to liaise with inflammatory bowel disease (IBD) nurses, radiologists and other healthcare professionals to ensure timely investigations and appropriate management of IBD and its complications.

radiographs and fluoroscopic images taken as the barium passes through the small bowel. SBE is a more invasive and less well tolerated test that involves the placement of a nasal-jejunal tube and instillation of barium and methylcellulose via a pump. Little reliable

Figure 1 A 19-year-old woman with right iliac fossa pain and diarrhoea. Barium small bowel follow-through with pneumocolon. Spot image shows subtle mucosal ulceration within the terminal ileum (white arrows), plus further ulceration and distortion of the medial aspect of the caecal pole and appendix. The early changes in the terminal ileum would be difficult to appreciate on MR or CT. Findings were confirmed via ileocolonoscopy, with biopsies suggestive of Crohn's disease.

data is available to directly compare tests, a small randomised trial has shown BFT to be superior to SBE for identifying small bowel Crohn's disease.⁶ Both techniques can depict ulceration, strictures and fistulation.⁷ SBE results in a higher radiation dose than BFT, although for a competent operator this is less than that of CT.⁸ Fluoroscopy's main appeal is wide availability and relatively low cost, although given the increased availability of cross-sectional techniques and shift in knowledge base, the number of examinations performed is decreasing. It may retain a problem solving role where assessment of fine mucosal detail is required when MRI is equivocal and small bowel capsule endoscopy (SBCE) is contraindicated.

ECCO—ESGAR statement 3A: BFT and SBE have an acceptable accuracy for mucosal disease but are less accurate for mural disease and extramural complications.

CT ENTEROGRAPHY AND ENTEROCLYSIS

CT assessment of the small bowel using a modern multidetector scanner allows rapid image acquisition in a single breath hold, thus minimising motion and peristaltic artefacts. An injection of intravenous contrast is standard, and as with other diagnostic techniques achieving adequate small bowel distension is paramount. This can be achieved by gradual (over around 40 min) oral administration (enterography) or instillation via a nasojejunal tube (enteroclysis) of a high molecular weight compound (eg, mannitol) to minimise absorption. CT enterography provides good distension of the mid to distal ileum, although jejunal distension is usually limited. Findings in active disease include mucosal hyperenhancement, mural thickening and mesenteric hypervascularity (figure 2) and correlate well with endoscopic assessment of disease activity.⁹ The diagnostic accuracy of both tests for depicting active disease is similar, and comparable with that of US and MRI.¹⁰ CT enteroclysis is performed less frequently. It is more time-consuming requiring fluoroscopic nasojejunal intubation, pump infusion and is less well tolerated by patients. Extramural complications such as fistulas and abscesses are accurately depicted and CT can be used to guide percutaneous drainage. The main disadvantage is the large radiation dose in a typically young population, especially if repeated examinations are performed. Desmond *et al*¹¹ found that 15.5% of patients with Crohn's disease were receiving a mean cumulative effective dose exceeding 75 mSv, a level reported to increase cancer mortality by 7.3%. Modern CT scanners equipped with dose reduction techniques can reduce radiation exposure by 32–65%.¹²

ECCO—ESGAR statement 2C: Radiation dose is the major limitation of CT.

MR ENTEROGRAPHY AND ENTEROCLYSIS

MRI is increasingly used to evaluate small bowel Crohn's disease due to increased scanner availability

Figure 2 Coronal CT enteroclysis image shows markedly thickened segment of terminal ileum with mural oedema and mucosal hyperenhancement (solid white arrow) plus more subtly diseased segment of proximal ileum (dashed white arrow). Note excellent jejunal distension with enteroclysis.

and technological improvements. Fast T1 and T2 sequences, such as fast imaging with steady-state precession (FISP), HASTE and volume interpolated breathhold examination (VIBE) are used to minimise peristaltic artefacts. Postcontrast imaging with gadolinium is standard and diffusion weighted imaging can add useful information in detecting small bowel and large bowel Crohn's disease.¹³ Luminal distension is achieved either by oral ingestion or via a nasojejunal tube. Biphasic (negative effect on T1-weighted images and positive effect on T2-weighted images) non-absorbable oral contrast agents such as polyethylene glycol or mannitol are most commonly used. There remains debate as to whether the better luminal distension offered by MR enteroclysis significantly improves diagnostic performance. MR enterography is more frequently performed to avoid the discomfort of nasojejunal intubation. Findings in active disease include mural oedema, wall thickening, ulceration and increased mucosal enhancement as compared with adjacent loops (figure 3A, B).

Modern techniques such as diffusion weighted enterography (figure 4A, B) and MR quantification of small bowel motility have shown potential for assessing Crohn's disease activity.^{14 15} Extramural complications are well demonstrated and the study can be

combined with pelvic MRI for the evaluation of perianal disease. MR enterography has greater contrast resolution than CT, although overall diagnostic accuracy in small bowel Crohn's disease is comparable.¹⁰ The major advantage over CT is the lack of ionising radiation; disadvantages include a longer scan time, variable image quality with non-cooperative patients and inability to image patients with non-compatible implants or pacemakers.

ECCO-ESGAR statement 2D: MR enterography/enteroclysis has similar diagnostic accuracy and indications to CT, but with the major advantage of not imparting ionising radiation.

SMALL BOWEL ULTRASOUND

Transabdominal ultrasound of the small bowel is non-invasive, does not involve ionising radiation and is generally well tolerated by patients. The technique commonly involves a period of fasting and oral ingestion of a non-absorbable contrast. A systematic scanning approach using low frequency (5–7 MHz) and high frequency (13–18 MHz) probes is commonly performed. Sonographic findings in active Crohn's disease include wall thickening with loss of the normal five layer wall pattern, reduced or absent peristalsis and oedema in the adjacent fat blurring the interface between the bowel wall and mesentery (figure 5A–D). Addition of colour Doppler and contrast enhancement further improves sensitivity and specificity and may provide information regarding the contribution of fibrosis, oedema and inflammation to bowel wall thickening.¹⁶ In expert hands ultrasound is an excellent technique, especially for children and adolescents who are usually slim and tend to dislike a prolonged period within an MRI scanner. The proximal ileum and jejunum can be challenging to evaluate due to location and defining the distribution of disease can be difficult. Extramural complications are less well demonstrated than with the cross-sectional modalities. In addition, comparison between studies is difficult and clinicians can find acquired images challenging to interpret. Ultrasound has an important role providing real-time imaging guidance for drainage of Crohn's disease related abdominopelvic collections.⁸

ECCO-ESGAR statement 3B: US, CT and MRI have a high and comparable diagnostic accuracy for the initial presentation of terminal ileal Crohn's disease.

SMALL BOWEL CAPSULE ENDOSCOPY

SBCE involves the ingestion of a small video capsule, which passes through the intestinal tract by peristalsis. Imaging data are continually acquired and then analysed by a specialist. There is a risk of capsule impaction in stricturing disease; this can be avoided by a prior radiological examination or a trial run using a dissolvable device of similar dimensions known as a patency capsule. Patients with significant small bowel strictures on CT or MRI are not candidates for

Figure 3 (A, B) Coronal T2 fat saturated image of the right iliac fossa (A) shows a segment of thickened terminal ileum with mural oedema (solid white arrows). Coronal T1 VIBE postgadolinium image (B) shows marked mucosal hyperenhancement as compared with other bowel loops giving a layered appearance to the bowel wall with deep linear ulcers (dashed white arrows), findings seen in active disease.

assessment with capsule endoscopy. SBCE is more sensitive than MR/CT enterography for detecting early mucosal inflammation, particularly in the detection of lesions proximal to the terminal ileum.¹⁷ It may be used as the initial diagnostic modality in patients with negative ileocolonoscopy in the absence of obstructive symptoms.¹⁸ For patients with established Crohn's disease, cross-sectional imaging tests are preferable due to better demonstration of the anatomical distribution of disease, extramural complications and the increased risk of capsule impaction.

ECCO statement 11B: SBCE has a high negative predictive value for small bowel Crohn's disease (table 1).

WHEN TO IMAGE IN SMALL BOWEL CROHN'S DISEASE?

Imaging has a diverse role in the assessment of small bowel Crohn's disease, ranging from initial diagnosis

and disease staging to identifying complications in the emergency situation. The following sections describe the most common scenarios where small bowel imaging can be of benefit.

Aiding initial diagnosis

The initial diagnosis of Crohn's disease relies on a combination of clinical history with endoscopic, radiological and histological findings, without a definitive gold standard.¹⁹ Ileocolonoscopy with biopsies remains the investigation of choice for patients with suspected Crohn's disease; the earliest mucosal changes of aphthoid ulceration and erythema are beyond the resolution of cross-sectional imaging techniques.⁸ In many cases, however, endoscopic assessment is limited by stricturing disease, and no endoscopic technique delineates extraenteric complications. Traditionally, small bowel barium

Figure 4 (A, B) A 35-year-old man with known Crohn's disease and left upper quadrant pain. Axial T2 HASTE image (A) shows a short segment of thickened jejunum in the left upper quadrant (solid white arrows). Axial diffusion weighted image (B) shows corresponding high signal diffusion restriction in this loop (dashed white arrows) ($b=750 \text{ s/mm}^2$). Jejunal disease can be difficult to evaluate, and in conjunction with other sequences findings were useful to help confirm active disease. HASTE, half-fourier acquired single-shot turbo spin echo.

Figure 5 (A–D) Longitudinal US image (A) shows thickened segment of terminal ileum with loss of the normal mural layer pattern (solid white arrows) and a fistulous tract (dashed white arrow). Transverse colour Doppler image (B) shows increased vascularity within the loop. Transverse image (C) shows a fistulous connection (dashed white arrows) between the terminal ileum and transverse colon, with marked oedema in the adjacent mesenteric fat (*). A coronal image from a CT performed several days later (D) confirmed active terminal ileal disease with colonic fistulation (dashed white arrow) and deep ulceration (solid white arrow).

examinations (which have high spatial resolution) have been used to delineate early small bowel involvement. A recent meta-analysis has shown CT, MRI and ultrasound to have comparable high accuracy for diagnosing inflammatory bowel disease (sensitivity 84.3–93.0%, specificity 84.5–95.6%).¹⁰ SBCE and MRI may have a role in diagnosing Crohn's disease in young patients with symptoms suggestive of the disease where ileocolonoscopy is negative.¹⁷ In equivocal cases cross-sectional imaging may offer valuable information regarding an alternative diagnosis.

Monitoring disease activity and therapeutic response

Assessment of disease activity and response to therapy is important as mucosal healing is associated with sustained clinical remission and reduced rates of

hospitalisation and surgery.⁸ Accurate assessment of disease extent and activity often requires a combination of clinical, biochemical, endoscopic and imaging techniques.¹⁰ Scoring systems such as the Crohn's Disease Activity Index incorporates clinical and biochemical parameters, but lack reproducibility and overlap with symptoms of irritable bowel syndrome. They cannot give information about specific disease sites. Barium studies provide limited information on disease activity and extramural complications such as abscess formation, vital information if aggressive immunosuppressive therapy is being considered. MR enterography is probably the most widely used technique and can eloquently identify the features of ongoing active disease while incurring no ionising radiation. Its specific role for assessment of treatment response is the subject of

Table 1 Comparison of the modalities used to image small bowel Crohn's disease

	Barium fluoroscopy	CT enteroclysis/enterography	MR enteroclysis/enterography	Small bowel ultrasound	Small bowel capsule endoscopy
Radiation dose	✓✓	✓✓✓	–	–	–
Intravenous contrast	–	✓	✓	–/✓	–
Fine mucosal detail	✓✓✓	✓✓	✓✓	✓✓	✓✓✓✓
Assess disease activity	✓	✓✓	✓✓	✓✓	✓
Extramural complications	✓	✓✓✓	✓✓✓	✓✓	–

ongoing research; a MR index of activity has been shown to correlate with ulcer healing as assessed via ileocolonoscopy.²⁰ After commencement of infliximab, resolution of small bowel lesions can be demonstrated on CT, although only fair correlation exists between CT features of response and clinical parameters.²¹ US can identify a significant reduction in bowel wall thickness after commencement of antitumor necrosis factor therapy,²² and resolution of hyperenhancement with contrast enhanced US shows correlation with the Crohn's Disease Activity Index;²³ more research is needed before this technique is adopted in a clinical setting.⁸

Identifying common complications (strictures and fistulation)

In many cases endoscopic assessment of stricturing disease is limited by an inability to pass proximally to assess the remainder of the small bowel. Traditional barium examinations have a relatively low correlation with surgical findings regarding number, location and severity of stricturing disease.¹⁹ CT and MR enterography have a high sensitivity (85% vs 92%) and specificity (100% vs 90%) for the detection of small bowel strictures and are the current imaging investigations of choice.⁸ In partially obstructing and early lesions CT/MRI enteroclysis may be more sensitive than enterography due to better luminal distension.²⁴ No validated criteria have yet been established to reliably determine the inflammatory versus fibrotic component of Crohn's strictures via imaging.⁸

Approximately 16% of patients with Crohn's disease have penetrating lesions (fistula, phlegmon or abscess) at the time of diagnosis.²⁵ Although US (either alone or combined with barium small bowel studies) has a reasonable accuracy in identifying internal fistulas, cross-sectional imaging techniques such as MR and CT enterography are preferred.¹⁶ Both tests have moderate sensitivity (76% vs 70%) and high specificity (96% vs 97%).²⁶ Importantly, one study showed that penetrating complications of Crohn's disease identified on cross-sectional imaging were not suspected clinically in 50% of patients, and 79% went on to receive new medical therapy, surgical intervention or percutaneous intervention.²⁷

The emergency admission (high grade obstruction, perforation, abscess)

Imaging in the emergency situation is usually dictated by the need for timely and accurate diagnosis, and is commonly performed out of normal working hours by non-specialist radiologists. Plain film radiography and standard contrast enhanced CT (with or without oral contrast) are commonly performed due to their wide availability and speed of acquisition. Contrast enhanced CT has high accuracy for identifying free

Figure 6 A 27-year-old man with Crohn's disease admitted with severe abdominal pain, raised inflammatory markers and peritonism. Axial CT image of the pelvis shows segment of markedly thickened and distended ileum with local perforation and adjacent abscess formation (white arrow). The patient had extensive peritonitis at surgery, and required a significant small bowel resection.

intraperitoneal gas, mechanical bowel obstruction and abscess formation (figure 6),⁸ and CT and US can be used to perform percutaneous drainage of accessible abscesses and collections. Many young patients with Crohn's disease can accumulate a significant radiation dose if repeatedly imaged in this way, and careful consideration should be given as to whether emergency CT is indicated. MR enterography identifies collections with high accuracy in patients with small bowel Crohn's disease (sensitivity 86% and specificity 93%) as well as other extraluminal complications.²⁸ Depending on scanner availability and the clinical status of the patient MRI may be the preferred test; such cases should be discussed with the radiology team.

CONCLUSION

A variety of techniques are available to image the small bowel in Crohn's disease, including barium fluoroscopy, cross-sectional modalities such as MR and CT, ultrasound and capsule endoscopy. The correct choice of test depends on local departmental protocol, imaging resources and available radiological expertise as well as the specific clinical indication. The use of fluoroscopic barium techniques is diminishing with a greater shift towards cross-sectional modalities due to their reproducibility, ability to demonstrate the anatomical distribution of disease and accurate depiction of extramural findings. In this young patient cohort radiation sparing MR techniques have a distinct advantage although CT is likely to retain an important role for initial imaging in the emergency situation. Given the wide range of imaging techniques available for a disease with such a variable natural history, a multidisciplinary discussion (ideally involving a radiologist) is vital to review imaging and plan treatment.

MULTIPLE CHOICE QUESTIONS

1. A 27-year-old man presents with lethargy, cramping abdominal pain and intermittent bloody diarrhoea. You are suspicious for underlying Crohn's disease but ileocolonoscopy is negative. Which are the most suitable next-line investigations to image the small bowel?

- A. Barium small bowel follow-through
- B. CT enterography
- C. MR enterography
- D. Ultrasound
- E. Small bowel capsule endoscopy

Answer: A, C, E.

MR enterography and SBCE have a role in aiding the diagnosis of Crohn's disease where ileocolonoscopy is negative. It would be important to further evaluate the abdominal pain; if there are genuine obstructive symptoms then SBCE runs the risk of capsule impaction. Where access to other imaging tests is limited, barium small bowel fluoroscopy remains an acceptable technique. With a normal terminal ileum at colonoscopy most centres would not perform US as a first-line test. CT is less favoured in this scenario due to the large radiation dose.

2. A 45-year-old man describes a long history of diarrhoea and passing blood and mucous per rectum. He has avoided investigation until now, but has presented due to worsening right iliac fossa pain and weight loss. A barium small bowel follow-through has been performed (figure 7). What does it show?

- A. Normal appearances of the terminal ileum and caecum
- B. Small bowel obstruction due to terminal ileal stricture

Figure 7 Multiple choice question 2.

- C. Complex fistulating terminal ileal Crohn's disease
- D. A terminal ileal stricture concerning for malignancy
- E. Early signs of terminal ileitis compatible with Crohn's disease

Answer: C.

The spot image from the barium small bowel follow-through shows complex terminal ileal Crohn's disease with several loops of narrowed, ulcerated and distorted terminal ileum. The loops are tethered with signs of interloop fistulation. On this single image no dilated small bowel loops are seen to suggest obstruction. Malignant strictures are typically short, unifocal and shouldered with signs of mucosal destruction. Subsequent caecal and terminal ileal biopsies were compatible with Crohn's disease.

3. Which of these radiological signs are suggestive of active small bowel Crohn's disease when performing MR enterography?

- A. Mural oedema and thickening
- B. Mural fibrosis
- C. Mucosal hyperenhancement giving a layered appearance to the bowel wall
- D. Submucosal fat deposition and adjacent mesenteric fat proliferation
- E. Diffusion restriction

Answer: A, C and E.

MRI findings in active Crohn's disease include mural thickening, mural oedema, mucosal hyperenhancement and ulceration. Diffusion restriction is seen in segments of active disease, but should be correlated with other sequences. Its specific role in assessing Crohn's disease activity is the subject of ongoing research. Mural fibrosis, submucosal fat deposition and mesenteric fat proliferation are not signs of active inflammation and are usually seen with long-standing chronic disease.

4. When performed by an experienced operator, which of the following imaging techniques involves the highest dose of ionising radiation?

- A. Supine abdominal radiograph
- B. Barium small bowel follow-through
- C. CT enterography
- D. CT enteroclysis
- E. MR enterography

Answer: D.

CT enteroclysis will usually incur a slightly higher radiation dose than CT enterography due to the additional fluoroscopic screening time required to insert the nasojejunal tube. The radiation dose from a barium small bowel follow-through is less than that of an abdominopelvic CT when performed by an experienced operator. As an approximate guide the effective dose of a chest radiograph is 0.02 mSv. Approximate doses for the above examinations are—abdominal radiograph (0.7 mSv), barium small bowel follow-through (5 mSv), abdominopelvic CT scan (14 mSv).

5. A 25-year-old man with a prior history of fistulating terminal ileal Crohn's disease has failed multimodality

medical treatment. He has not undergone any form of imaging for 18 months and is being worked up for surgical resection. Which are the most appropriate imaging tests to evaluate the small bowel?

- A. CT enterography
- B. Barium small bowel follow-through
- C. MR enterography
- D. Small bowel capsule endoscopy
- E. Ultrasound

Answer: C (and possibly A).

One of the main advantages of the cross-sectional modalities over ultrasound and SBCE is their ability to demonstrate the anatomical distribution of disease; vital if surgical resection is contemplated. Most surgeons (even in centres offering small bowel US) would want an up-to-date MRI prior to resection. If there is a contraindication to MRI, then CT enterography would be a reasonable alternative.

6. A 31-year-old woman with known multifocal small bowel Crohn's disease has had gradually increasing abdominal pain, diarrhoea and lethargy for a couple of weeks. She now presents to A&E with severe abdominal pain and high fever. Clinically she is peritonitic and blood tests reveal a C reactive protein of 275 mg/L. Which are the most appropriate initial imaging tests?

- A. Ultrasound abdomen
- B. MR enterography
- C. Erect chest radiograph
- D. Standard contrast-enhanced CT
- E. Supine abdominal radiograph

Answer: C and D.

In the emergency situation standard contrast-enhanced CT retains an important role for diagnosing the complications of acute Crohn's disease such as perforation or abscess formation as suggested by the history. Pregnancy must be excluded prior to the test. In the absence of obstructive symptoms an abdominal radiograph has a very low yield, and involves the equivalent radiation dose of approximately 35 chest radiographs. In a more stable patient MR enterography could be considered if the resources and expertise are available. Ultrasound is useful for image-guided drainage of collections, but is not suitable as the initial diagnostic test here.

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