

Magnetic resonance enterography: a pictorial review of Crohn's disease

Use of magnetic resonance enterography has significantly increased and its role as an adjunct to ileocolonoscopy is best practice, particularly in the evaluation of Crohn's disease. This article reviews magnetic resonance enterography, and describes common findings related to Crohn's disease and unexpected extra-intestinal findings.

Small bowel magnetic resonance imaging is a form of cross-sectional imaging which, over the past decade, has become increasingly important in the diagnosis and assessment of Crohn's disease. Magnetic resonance enterography and magnetic resonance enteroclysis are both methods of small bowel magnetic resonance imaging. They differ by the route of contrast administration; magnetic resonance enterography is performed using oral contrast and magnetic resonance enteroclysis requires delivery via a nasojejunal tube. Magnetic resonance enterography is the preferred technique given patient preference and similar diagnostic accuracy.

Ileocolonoscopy is often seen as the reference standard in diagnosing and evaluating Crohn's disease and, for some time, there has been a standardized approach to assessing severity of Crohn's disease. Scores such as the Crohn's disease Endoscopic Index of Severity (CDEIS) (Mary and Modigliani, 1989) can be used to assess disease activity. However, the European Crohn's and Colitis Organisation and European Society of Gastrointestinal and Abdominal Radiology consensus guidelines highlight the importance of small bowel cross-sectional imaging as an adjunct to endoscopy in identifying intra- and extramural complications of Crohn's disease (Panes et al, 2013). Magnetic resonance enterography can be routinely used to diagnose and assess disease activity. In their meta-analysis, Horstius et al (2008) demonstrated a 93.0% sensitivity and 92.8% specificity of magnetic resonance enterography in the diagnosis of inflammatory bowel disease. Magnetic resonance enterography is also comparable to endoscopy at assessing mucosal healing and response to therapy in patients with Crohn's disease (Ordás et al, 2014). Locally, the average cost of a mag-

netic resonance enterography study is £350 compared to £500 for an ileocolonoscopy.

With the increasing use of magnetic resonance enterography comes a proportion of patients in whom unexpected findings are reported. Many of these are extra-intestinal and unrelated to inflammatory bowel disease. This has been documented frequently in other forms of cross-sectional imaging, but there are very few data in relation to magnetic resonance enterography. This pictorial review gives an outline of the intestinal and extra-intestinal findings in Crohn's disease as well as current experience of unexpected extra-intestinal findings observed in magnetic resonance enterography.

Magnetic resonance enterography protocol

Magnetic resonance enterography protocols vary slightly from centre to centre, but general principles apply. Oral contrast agents are given before the scan in order to distend the bowel. Commonly these are hyperosmolar, limiting water resorption across the small bowel and therefore maximizing distension. In the authors' centre mannitol is used, which is a biphasic agent showing low signal intensity on T1-weighted images and high-signal intensity on T2-weighted images. This improves the detection rate of subtle mucosal enhancement as well as fold thickness (Tolan et al, 2010).

Patients are given 1.5 litres of mannitol solution to drink during the 45 minutes before the scan. During the sequence, intravenous buscopan and gadolinium are administered, assuming there are no contraindications. Studies are performed using a 1.5-T scanner and last approximately 30–40 minutes. Routine scan imaging protocols are conducted as per current practice. A multi-planar combination of T1/T2 weighting and dynamic sequence and dynamic post-contrast methods is used. This is particularly useful in identifying peristalsis and therefore differentiating between transiently stenotic loops and true pathological segments. The highest quality images are obtained through a fast sequence and adequate luminal distension. Failure rates may result from a proportion of patients who are unable to tolerate the oral contrast load and those who cannot undergo the examination because they suffer from claustrophobia.

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Indications for magnetic resonance enterography

Indications for magnetic resonance enterography include initial diagnosis of inflammatory bowel disease, ongoing disease assessment and suspected intestinal complications of disease, e.g. strictures, abscesses and fistulae. It is particularly useful in evaluating response to therapy and there is now increasing use of magnetic resonance enterography in non-inflammatory bowel disease-related conditions. Authors have described its use in investigating suspected small bowel malignancy and coeliac disease, and for postoperative small bowel assessment (Tolan et al, 2010).

Magnetic resonance enterography and Crohn's disease

Crohn's disease is a relapsing, chronic inflammatory condition affecting the gastrointestinal tract. It has a predilection for the terminal ileum and can lead to chronic stricturing and fistulation of the small bowel.

Crohn's disease can lead to a variety of macroscopic changes. Shallow ulcers develop which may extend into the submucosa to form deep ulcers. A 'cobblestoned' appearance can emerge when these ulcers are present around islands of normal mucosa. Inflammation and ulceration can be patchy, giving rise to 'skip lesions', with apparent normal segments of mucosa. Transmural involvement increases the risk of sinus tracts, fistulae and abscesses. Adjacent to the bowel wall, local structures can also be affected, the mesentery can be inflamed and eventually fibrosed and regional lymph nodes can become enlarged. Many of these changes can be appreciated through magnetic resonance enterography as described below.

Mucosal changes

Mucosal oedema and thickened folds are features consistently seen in patients with Crohn's disease. It is generally accepted that normal bowel wall thickness should not exceed 3 mm. In patients with Crohn's disease, bowel wall thickening may be asymmetrical and this process most commonly affects the terminal ileum (Tolan et al, 2010; Sinha et al, 2011; Griffin et al, 2012).

Mucosal ulceration is typically difficult to appreciate in its early stages and is dependent on adequate luminal distension. Transverse and longitudinal ulceration can be seen as linear protrusions with high signal intensity (enteric contrast can delineate deep ulcers). This can give the mucosa a cobblestoned appearance (Figure 1a). Post-contrast high signal intensity on T2-weighted and STIR (short T1 inversion recovery) images in the luminal wall is a marker of mucosal and submucosal oedema (Figure 1b). This is an independent predictor of the severity of Crohn's disease and active disease based on macroscopic and histological features (Punwani et al, 2009).

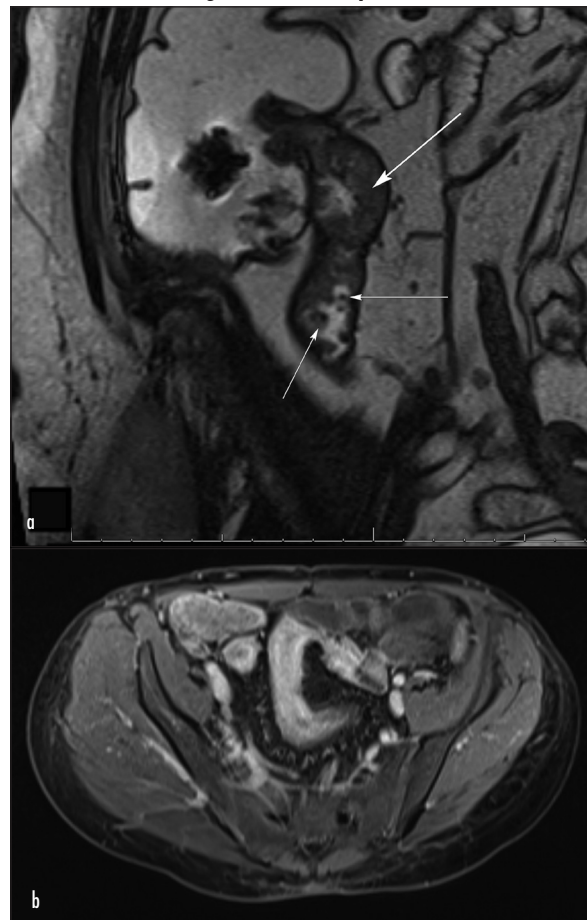
Mesenteric and local changes

The mesentery can give a clue to active disease. The 'comb sign' describes areas of marked vascularity within the mesentery and is therefore a surrogate marker for an active, inflamed section of small bowel (Figure 2). Fatty hypertrophy of the mesentery and local displacement of loops are often specific signs in Crohn's disease (Tolan et al, 2010). This can occur asymmetrically and is seen in well-established Crohn's disease, hinting at possible chronicity. Reactive mesenteric nodes are also a feature of active Crohn's disease. Enhancing and oedematous nodes are classically associated with Crohn's disease but one must be wary of other diagnoses in the context of large or non-enhancing mesenteric nodes.

Complications of Crohn's disease

Severe, ongoing inflammation eventually leads to transmural involvement which increases the risk of fistula formation. Fistulae are connections between two epithelial surfaces and, in Crohn's disease, can exist internally or externally. Structures close to the small bowel are often

Figure 1. Mucosal changes in Crohn's disease. a. Coronal T2-weighted image of right iliac fossa. Thick-walled loop of terminal ileum in Crohn's disease. Note cobblestoning of mucosa with polypoidal thickening (arrows). b. Axial fat-saturated post-gadolinium image through the pelvis, showing a thick-walled, ulcerated and enhancing small bowel loop in Crohn's disease.



affected including other small bowel (enteroenteric), large bowel (enterocolic) and skin (enterocutaneous). Fistulae can be identified by enhancement of the fistulous tract on post-gadolinium T1-weighted sequences (*Figure 3a*) as well as linear tracks of high signal intensity from enteric contrast (Sinha et al, 2011; Liu et al, 2014). The 'star sign' is another appearance specific to fistulas described by Herrmann et al (2006). They describe a 'star-like arrangement' of bowel loops converging to a central fistula point, presumably from surrounding mesenteric oedema and fibrosis.

Patients with Crohn's disease can suffer from strictures throughout their disease course. Symptoms may include abdominal pain and nausea and there may be signs of subacute small bowel obstruction. Strictures can occur throughout the small bowel but are usually more common at sites of active or previously active disease, with the most frequent site being the terminal ileum. Symptoms may not necessarily reflect ongoing active disease and magnetic resonance enterography can be particularly useful in this setting. Chronic, non-active strictures have walls which appear hypointense on T1-

Figure 2. Mesenteric or local changes in Crohn's disease. a. Coronal T2 weighted image of right iliac fossa. Crohn's involvement of ileal loops (arrows) with wall thickening, fatty hypertrophy and loop separation. There is also a positive comb sign with linear inflammatory stranding of adjacent mesenteric fat. b. Coronal fat-saturated post gadolinium image. This patient has had a right hemicolectomy. There is evidence of recurrent Crohn's disease at the anastomosis: there is a thick-walled enhancing ileal loop, positive comb sign, connecting to the transverse colon.

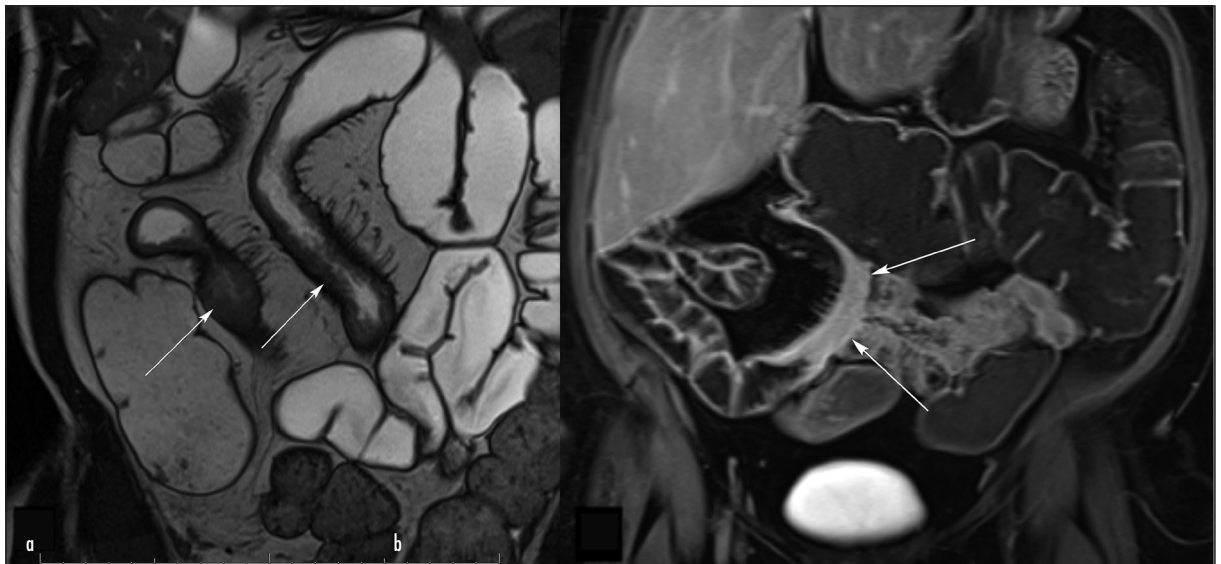
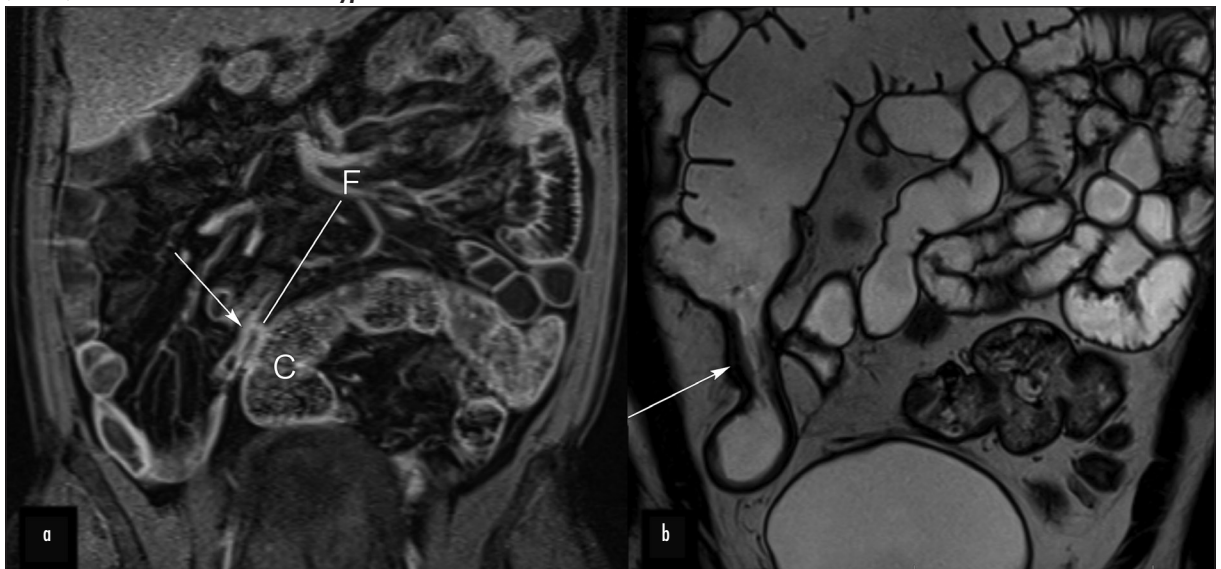


Figure 3. Complications of Crohn's disease. a. Coronal fat-saturated, post-gadolinium image of the abdomen showing a thickened and strictured, enhancing ileal loop (arrow). This is adherent to adjacent sigmoid colon (C) which has a thickened wall. There is a fistulous communication present (line F). b. Coronal T2-weighted image of right iliac fossa showing thick-walled and strictured terminal ileum (arrow) in Crohn's disease. Note the hypointense wall.



and T2-weighted sequences (*Figure 3b*) compared to active disease with the changes as described earlier. This distinction is important as chronic, fibrotic strictures are unresponsive to medical therapy and surgical options may be warranted.

Magnetic resonance enterography and Crohn's disease activity

The use of Crohn's disease activity scores are now being applied to magnetic resonance enterography. Rimola et al (2009) identified specific radiological predictors of severity comparable to endoscopic severity, as identified by CDEIS scores. This had led to development of a magnetic resonance index of activity (MaRIA) which has been validated using ileocolonoscopy as the standard (Rimola et al, 2011). Markers of active disease include small bowel mucosal thickening, deep ulceration, post-contrast wall signal intensity, mesenteric hypertrophy and mesenteric lymphadenopathy (Gourtsoyiannis et al, 2006; Rimola et al, 2009, 2011). This index has been used to reliably assess response to therapy and mucosal healing when directly compared to CDEIS and ileocolonoscopy (Ordás et al, 2014). This significant step highlights the value of magnetic resonance enterography as a non-invasive instrument in disease assessment.

Magnetic resonance enterography and colitis

Extra-small bowel manifestations of inflammatory bowel disease may also be identified through magnetic resonance enterography. A common finding is colitis, affecting various parts of the large bowel (*Figure 4*). Grand et al (2012) found that the sensitivity of detecting severe colitis in Crohn's patients with magnetic resonance enterography was 88% compared to colonoscopy and histology, which are the gold standard.

The notion that magnetic resonance can assess large bowel disease is not new. Initial reports assessing the feasibility of magnetic resonance colonography identified poor sensitivity when compared to colonoscopy (Schreyer et al, 2005). Further development of magnetic resonance imaging protocols has shown the use of magnetic resonance colonography in not only detecting colonic inflammation but also its severity, particularly with use of the 'dark lumen' technique (Rimola et al, 2009). Magnetic resonance colonography imaging protocols do not differ significantly from magnetic resonance enterography and so the possibility of whole bowel magnetic resonance imaging may not be too distant a prospect.

Non-inflammatory bowel disease-related findings in magnetic resonance enterography

Cross-sectional abdominal imaging has undoubted benefits in the assessment of inflammatory bowel disease. However, with this comes the increased incidence of

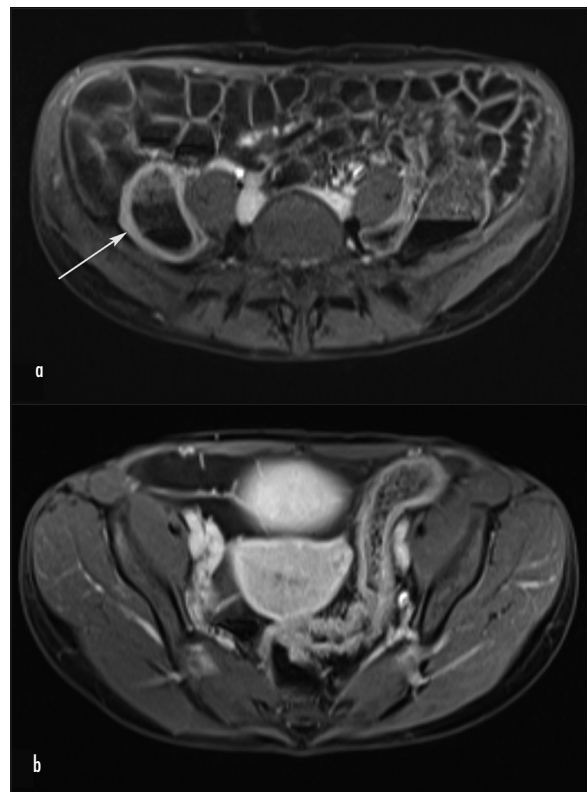
unexpected findings. Experience from this largely comes from the work done in computed tomography colonography. The incidence of these findings can be as high as 40% in symptomatic patients, with lower incidence in asymptomatic 'screening' populations (Xiong et al, 2005; Siddiki et al, 2008). However, the proportion of these findings that are clinically significant is relatively low. A few retrospective studies have investigated incidental findings in magnetic resonance enterography (Herfarth et al, 2009; Jensen et al, 2010; Shrot et al, 2011; Radhama et al, 2012). The incidence of these findings ranges from 3–25%, which highlights the varied interpretation and reporting of findings as well the paucity of data. Significant findings are those that require further investigation or management and within these series have a frequency as low as 2%.

Gastrointestinal tract

Small bowel manifestations of other diseases may be apparent on magnetic resonance enterography. For example, benign findings such as diverticula and mucosal changes in conditions such as coeliac disease are recognized (*Figure 5*).

There are a constellation of changes that can lead to radiological diagnosis of coeliac disease (*Figure 5b*); these include small bowel dilatation, increased wall

Figure 4. Magnetic resonance enterography and colitis. a. Axial T1-weighted, post-gadolinium image showing enhancement of the caecum (arrow) in active colitis. b. Axial T1-weighted, post-gadolinium image showing enhancement of the sigmoid in active colitis.



thickness, mesenteric lymphadenopathy and vascular changes. A 'reversed-fold pattern' describes an increase in ileal folds, or 'jejunization', with reduced jejunal folds and is a specific sign in coeliac disease (Paolantonio et al, 2007).

Cross-sectional imaging also increases the incidence of picking up lesions within the whole of the gastrointestinal tract. These can range from seemingly benign appearances to those that require urgent intervention (Figure 6).

Figure 5. Non-inflammatory bowel disease-related small bowel findings. a. Coronal T2-weighted image of abdomen. There is a large diverticulum seen in the third part of duodenum (arrow). b. Coronal T2-weighted image in a patient with coeliac disease. There is evidence of reduced jejunal folds (reduced fold pattern).

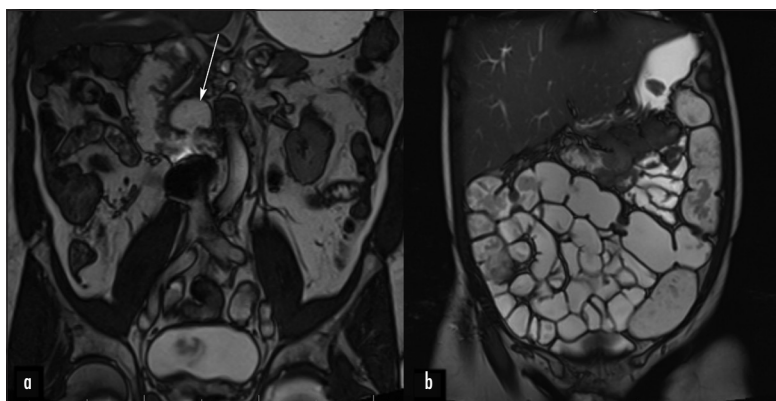
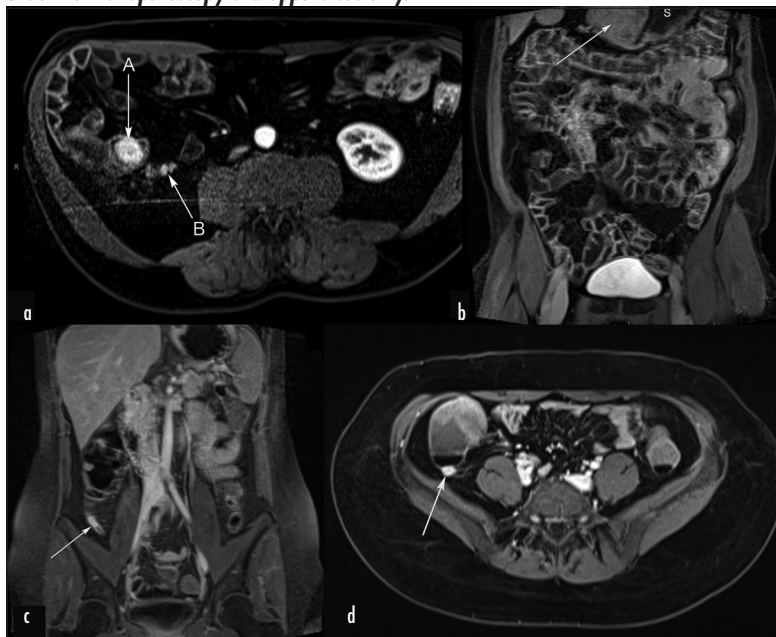


Figure 6. Unexpected gastrointestinal tract findings. a. This patient had evidence of an enhancing mass in the terminal ileum (arrow A; axial fat-saturated post-gadolinium). This was a proven malignant carcinoid tumour. Note the regional mesenteric metastatic lymph nodes (arrow B). b. Gastric tumour (arrow, S = stomach; coronal T1 post-gadolinium). This patient underwent a staging computed tomography, gastroscopy and finally a partial gastrectomy. The final diagnosis was a gastrointestinal stromal tumour. c and d. Thickened, enhancing appendix (arrow; coronal and axial T1 post-gadolinium). Coronal and axial both show an enhancing appendix. The patient subsequently underwent a laparoscopy and appendectomy.



Extra-enteric findings

A variety of extra-enteric findings are often found on magnetic resonance enterography (Figure 7). Gynaecological pathology is the most frequent of these, and accounts for 15–25% of patients with incidental findings (Herfarth et al, 2009; Jensen et al, 2010); the majority of these are ovarian cysts. Other findings include uterine fibroids, hydrosalpinx and dermoid cysts. Incidental gynaecological pathology is common to all abdominal cross-sectional imaging.

Renal cysts are another benign, common finding as well as congenital abnormalities such as duplex systems. However, these can be associated with increased risk of hydronephrosis and magnetic resonance is useful in their assessment (Adeb et al, 2013). Gallbladder stones are the next most frequent finding. These are often present in asymptomatic patients but, within this population, the annual risk of gallstone-related complications is 1% (Wang et al, 2009).

The sparse literature suggests that the majority of incidental findings are insignificant. However, a proportion of these findings do bear some clinical significance and may require further intervention. The costs and clinical burden of these findings are yet to be assessed.

Conclusions

Magnetic resonance enterography is a versatile, safe and effective tool in the assessment of patients with inflammatory bowel disease. Its increasing use over the past decade has changed the way clinicians approach a patient with Crohn's disease and a great deal of information can be gleaned non-invasively. Magnetic resonance has further potential applications in imaging other parts of the gastrointestinal tract, namely the colon. With increasing use incidental findings are likely to be reported more frequently. This is an area of research which needs to be expanded with potential impact on the costs and benefits of magnetic resonance enterography. **BJHM**

Conflict of interest: none.

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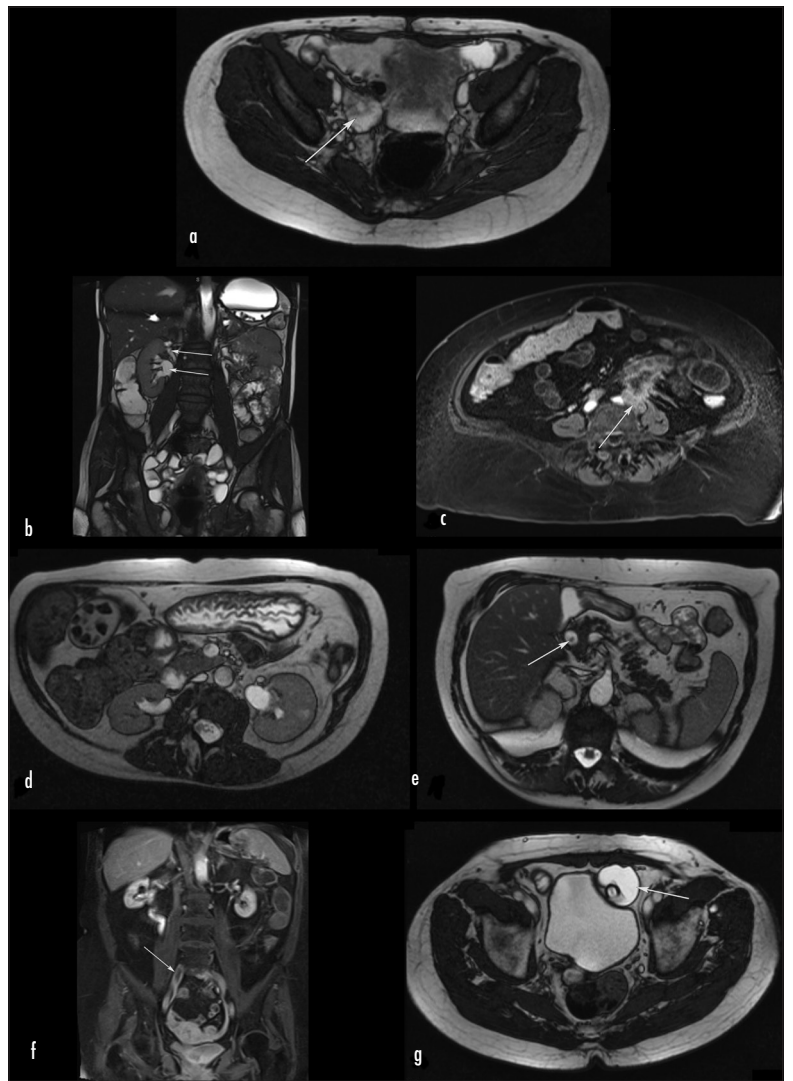


Figure 7. Extra-enteric findings. a. Right-sided adnexal complex fluid collection, likely hydrosalpinx (arrow; axial T2). b. Duplex kidney with upper and lower moieties identified (arrows; coronal T2). c. Locally invasive left ureteric tumour (arrow) with adherent jejunal loop (axial T1 post-gadolinium). An entero-ureteric fistula has been formed and there are necrotic mesenteric nodes. d. Gallstones in gallbladder (axial T2). e. Dilated common bile duct and gallstone visible in duct (arrow; axial T2). f. Right common iliac vein thrombus (arrow; coronal T1 post-gadolinium). g. Suprapubic catheter balloon (arrow) lying outside bladder (axial T2). This was replaced after review of the magnetic resonance enterography findings.

KEY POINTS

- Magnetic resonance enterography is proving increasingly useful in the diagnosis and assessment of Crohn's disease.
- Features of active small bowel Crohn's disease can include the 'comb sign', reactive mesenteric nodes and high signal intensity in the luminal wall.
- Complication of Crohn's disease include fistulas, often represented by the 'star sign', and strictures which appear hypointense when chronic.
- Magnetic resonance enterography can identify other small bowel disease including coeliac disease and large bowel disorders including colitis.
- There may be a proportion of findings that are unexpected and extra-enteric; the incidence varies with the most frequent being gynaecological in origin.