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SPECIAL SECTION: ENDOMETRIOSIS

Imaging of gastrointestinal endometriosis: what the radiologist should know

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Abstract

Deep invasive gastrointestinal endometriosis (DIGIE) is a frequent and severe presentation of endometriosis. Although most cases invade the rectosigmoid colon, DIGIE can involve any portion of the gastrointestinal tract from the stomach to the rectum, and is commonly multifocal and multicentric. Although histopathologic confirmation with surgery remains the gold standard for diagnosis, ultrasound (US) and magnetic resonance imaging (MRI) are the key non-invasive imaging modalities for initial assessment. US may be preferred as a screening study because of its easy availability and low-cost. Pelvic MRI and magnetic resonance enterography (MRE) provide substantial advantages for disease mapping in the pre-operative period, particularly in extensive bowel endometriosis. Although medical management of DIGIE with hormonal therapy can help control symptoms, disease course can be relentless and require surgical intervention. Surgical options depend on, the location; length; depth; circumference; multicentric or multifocal disease. With procedures including simple excision, fulguration of superficial lesions, shaving, disc excision, and segmental resection. A successful treatment outcome is largely dependent on good communication between the treating surgeon and the radiologist, who can provide vital information for effective surgical planning by reporting the key elements that we elaborate upon in this paper.

Keywords Gastrointestinal · Endometriosis · Bowel · MRI · MRE · Ultrasound · Gynecologic surgery

Introduction

Endometriosis is a chronic condition that affects approximately 10% of women of childbearing age [1]. The hallmark of this disease is the presence of endometrial glands and stroma outside the inner uterine lining [2]. This ectopic tissue is cyclically stimulated by ovarian hormones and triggers a localized inflammatory response, giving rise to recurrent

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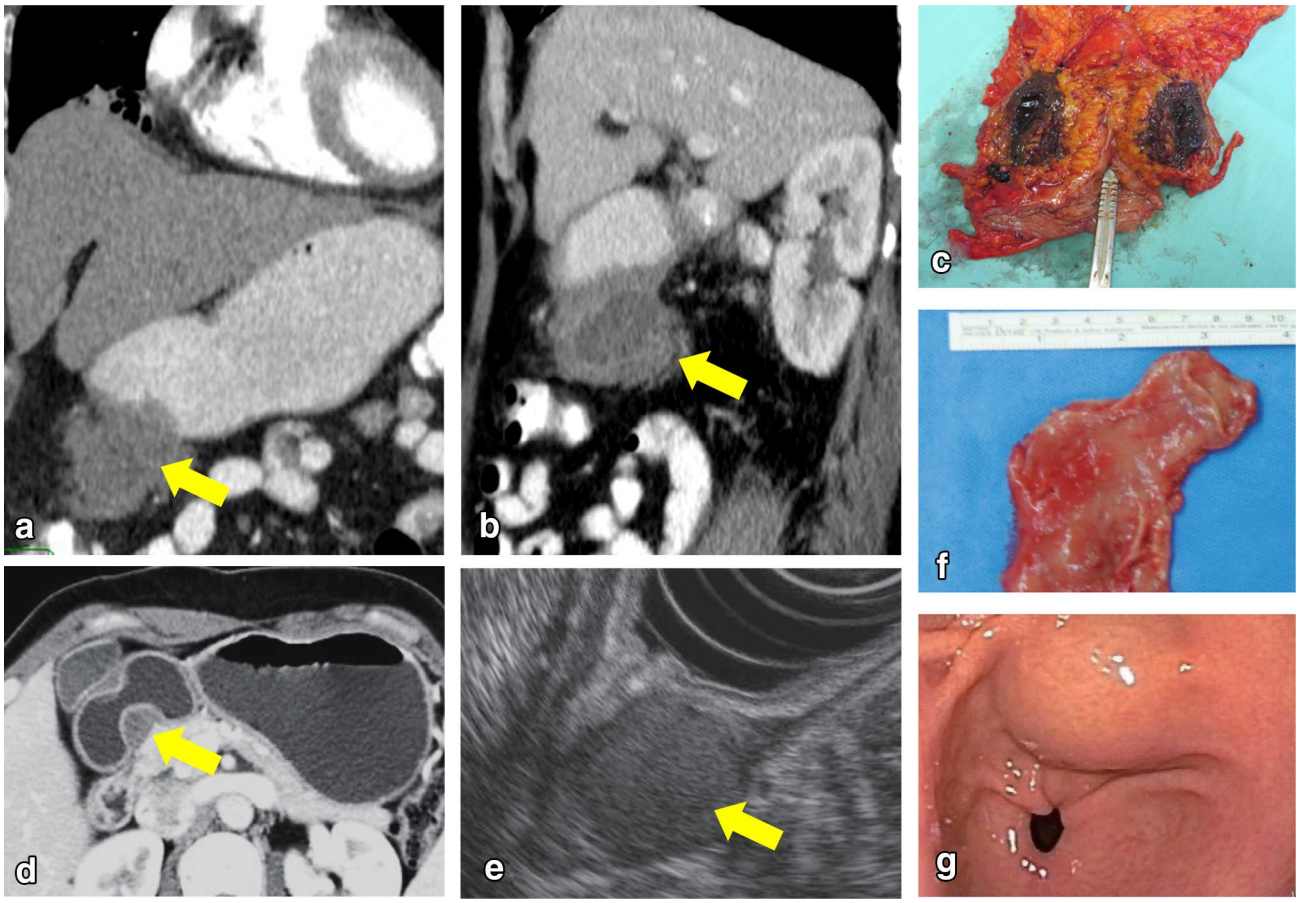

Fig. 1 Coronal (**a**) and Sagittal (**b**) CECT of the abdomen shows antral wall mass lesion with inhomogeneous enhancement. **c** Gross specimen of resected gastric endometriosis. Imaging of a similar lesion in a different patient (**d**–**g**). Axial CECT (**d**) shows a well-demarcated, non-enhancing homogenous gastric subepithelial tumor within the antrum. Endoscopic Ultrasound (**e**) shows a homogenous hypoechoic lesion within the proper muscle layer. Its echogenicity appears to be more hypoechoic than that of the muscle layer. **f** Gross specimen of resected gastric endometriosis. **g** Endoscopy showing a 2 cm-sized subepithelial tumor on the lesser curvature of the antrum with an intact mucosa. Images modified and reproduced with permission from the authors; **a**–**c** [25], **d**–**g** [26]

hemorrhage causing reactive smooth muscle proliferation, fibrosis and adhesions that ultimately result in debilitating symptoms. Chronic pelvic pain and infertility can be severe in patients with endometriosis and decrease quality of life for these women [3, 4]. Under-recognition or delayed recognition of endometriosis is a significant concern even in its classical adnexal presentation, with six in every 10 cases being missed. Underdiagnosis of endometriosis negatively impacts outcomes for patients due to increased symptom chronicity and delays in treatment. The latter is especially true for those with symptomatic deep infiltrating endometriosis (DIE, defined as > 5 mm subserosal organ or subperitoneal invasion) because delayed diagnosis precludes the possible benefits from early treatment [3, 5].

Rare anatomical locations of endometriosis pose an additional challenge for radiologists and surgeons because of the lower suspicion for involvement of these organs. Although it is generally considered an uncommon presentation, gastrointestinal endometriosis (GIE) has been found in up to 37% of women with DIE, manifesting as the leading cause of extra-genital endometriosis [6]. Colorectal involvement represents approximately 90% of GIE cases, nevertheless 56.6% of these lesions are misdiagnosed pre-operatively as malignancy [7, 8]. The estimated prevalence of GIE, its known diagnostic pitfalls, and frequent need for complex surgical interventions, all call for a multidisciplinary approach in management. As part of a multidisciplinary team, radiologists face the particular task of optimizing imaging for accurate assessment of the extent of GI involvement by endometriosis.

Most of the current radiological literature describing gastrointestinal endometriosis focuses on the more commonly involved segments such as the rectum and the sigmoid colon in the posterior pelvic compartment [9–14]. Fewer papers describe the varied appearances of involvement of the more proximal portions of the GI tract, including the stomach and

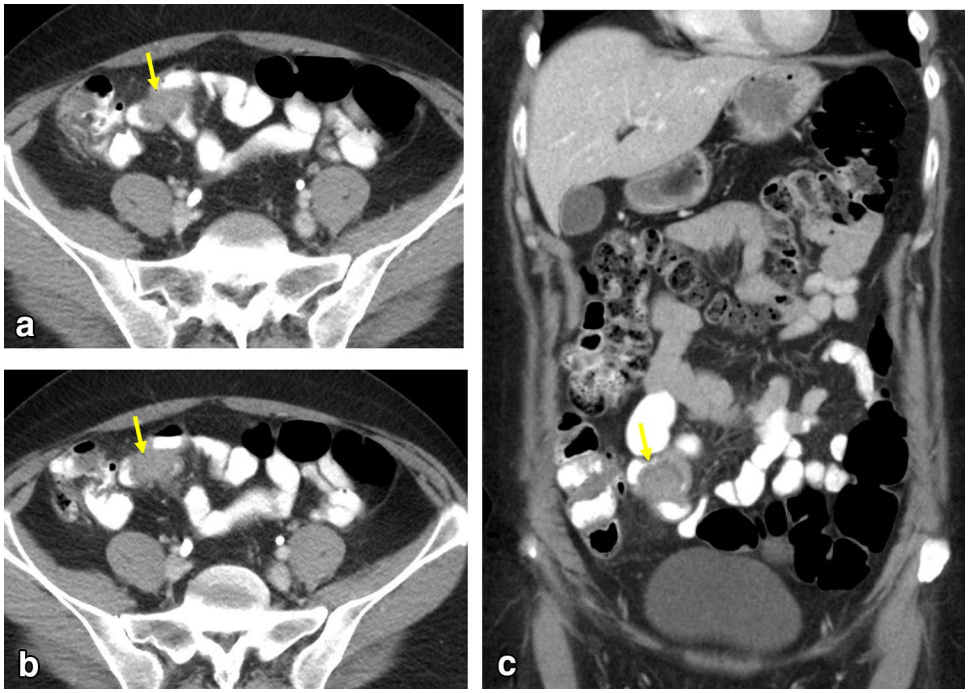

Fig. 2 Contrast-enhanced Axial (**a**, **b**) and Coronal (**c**) CT images show a soft tissue lesion within the distal ileal wall (arrows). Pathology review after excision reported foci of dark red areas and pin-point hemorrhages on the external surface with a stricture on the anti-mesenteric surface, confirming ileal endometriosis

small bowel [15]. The following pictorial review addresses the shortcomings described above, with reiteration of the spectrum of imaging findings of GIE in sequential order, from the stomach to the rectum.

Pathogenesis

To date, no single theory explains the exact etiology for endometriosis in its full spectrum. This polymorphic and multicentric disease is, therefore, likely to be multifactorial [16]. The most accepted theories include: the implantation theory, the Müllerian rest theory, and the coelomic metaplasia theory [2]. The implantation theory holds the most consensus and supports the transportation of endometrial tissue towards the peritoneal cavity from the uterus [6].

The implantation theory is also preferred by authors describing GIE because of the higher disease frequency in dependent organs closer to the uterus, matching the principle of retrograde menstruation [11, 17]. The peritoneal fluid is bloody in up to 90% of women during menstruation and this finding has also served to support the implantation theory [6]. Peritoneal fluid flows across the abdomen along the gastrointestinal organs in a clockwise fashion, with preference for stasis at the Pouch of Douglas, the right lower quadrant at the termination of the small bowel mesentery (ileocecal area), the superior aspect of the sigmoid mesocolon and the right paracolic gutter [9]. In the left pelvis, the proximity of the sigmoid colon and the adnexa forms a major barrier that impedes flow of the menstrual reflux from the ipsilateral fallopian tube. The anatomic distribution of GIE correlates with these sites and favors retrograde implantation of endometriotic tissue as the main culprit for the topography of endometriosis in the abdomen and pelvis, and its predilection for the rectosigmoid area [18, 19].

Diagnosis of GI endometriosis

The presenting symptoms in women with DIGIE can vary widely and, in many instances, include organ-specific manifestations. For example, involvement of the stomach can present with symptoms of epigastric pain, upper GI bleeding or, rarely, perforation; small bowel deposits when severe may cause small bowel obstruction; terminal ileal and appendicular endometriosis may present with right lower quadrant pain; and rectosigmoid junction involvement can contribute to chronic deep pelvic pain; altered bowel habits including constipation or diarrhea, rectal bleeding, and painful bowel movements. It is by far easier to diagnose DIGIE in a patient who already carries a diagnosis of endometriosis, now presenting with the above symptoms. Alternatively, any woman in the childbearing age presenting with the above symptoms should prompt imaging directed towards detecting presence and extent of DIE involving pelvic and extra-pelvic organs.

The existing literature discussing GIE focuses predominantly on DIE rather than serosal lesions as defined by the American Society of Reproductive Medicine [20, 21], because the superficial serosal implants have long been regarded as asymptomatic. This assertion, however, has been challenged by the low association found between lesion type and symptom severity, meaning that many

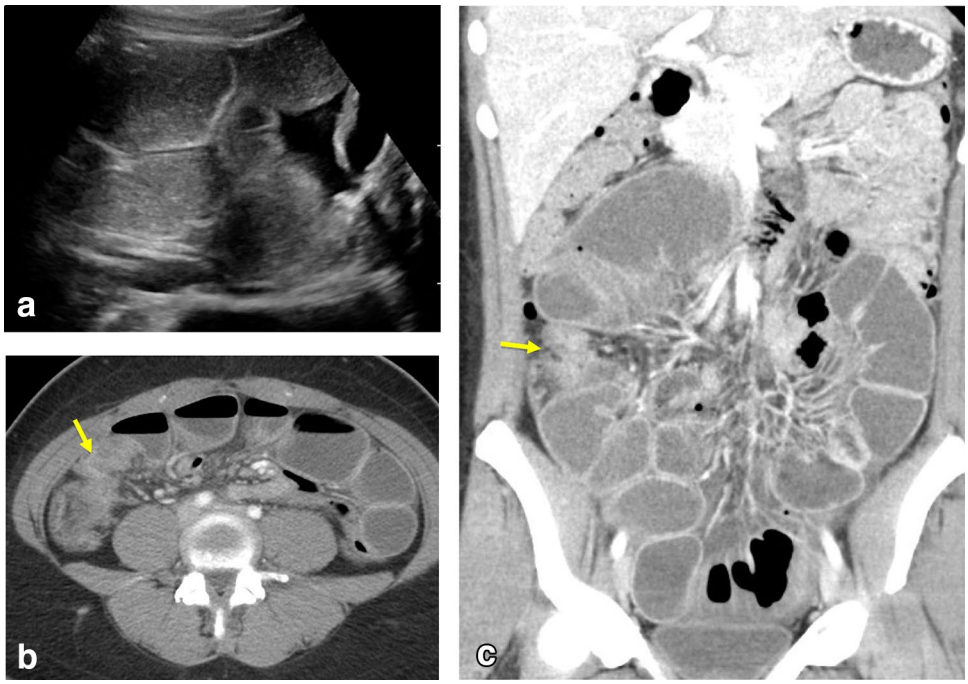

Fig. 3 Right lower quadrant transabdominal ultrasoud (**a**) shows multiple dilated loops of small bowel caused by a stricturing lesion at the terminal ileum, better noted on axial (**b**) and coronal (**c**) contrast-enhanced CT study—arrows. Ileocecectomy demonstrated mural deposits of endometriosis and associated fibrotic obstruction and segmental dilation proximal to these deposits

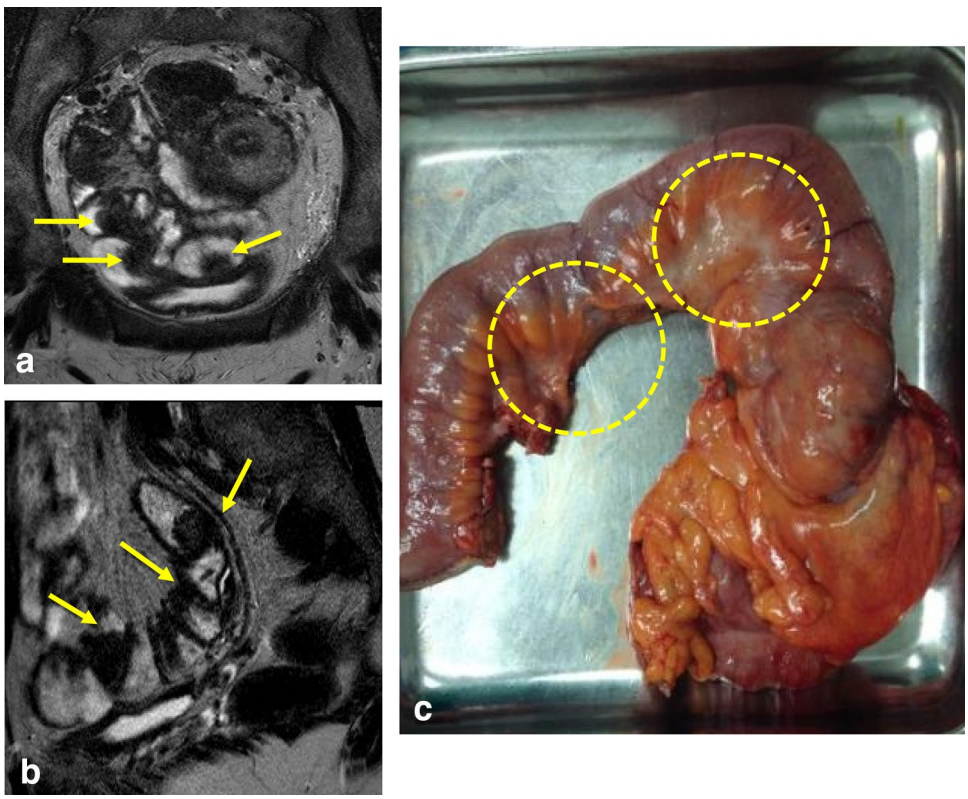

Fig. 4 Coronal (**a**) and Sagittal (**b**) T2-weighted MR images demonstrate three areas of small bowel DIE noted as focal T2-hyperintense thickening extending from the serosa inwards. Gross specimen (**c**) from small bowel resection showing two areas of serosal retraction with a "C-shaped" configuration in the areas of DIE (dashed circles)

patients with no obvious symptoms may have extensive endometriosis or vice versa [22]. As the understanding of the relationship between symptom severity and invasion evolves, the role of radiologists in identifying and diagnosing these patients may expand in the future, highlighting the importance of their awareness of the possible presentations of GIE on imaging.

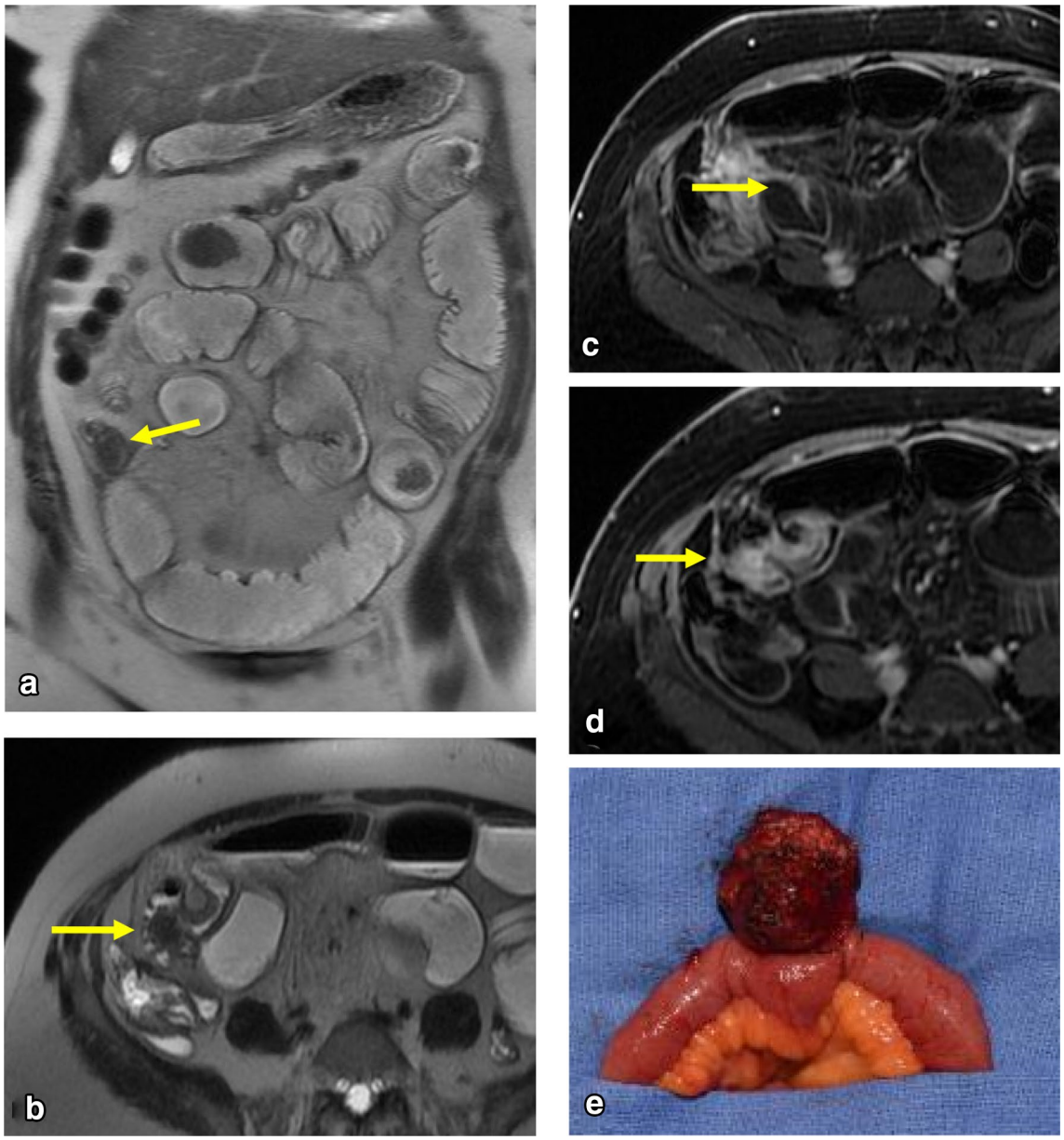

Fig. 5 Coronal (**a**) and Axial (**b**) T2-weighted images demonstrate T2-hypointense transmural nodules extending into the bowel lumen located on the terminal ileal wall (arrows). Post-contrast Axial T1-weighted fat suppressed images (**c**, **d**) demonstrate enhancing plaques on the terminal ileum corresponding to the finding in images **a** and **b**. Intraoperative findings (**e**) in the same patient showing a surface endometriotic deposit on the small bowel wall—this site does not correspond to the site described on the MR images in this figure

Imaging findings by gastrointestinal tract segment involved

Imaging of DIE of the stomach

Gastric involvement is one of the least common manifestations of endometriosis, which is why awareness of this entity's appearance is important for early diagnosis. Gastric endometriosis should be considered in the differential diagnosis in young females with chronic or cyclic epigastric pain matching the periodicity of their menstrual cycle. Routine transabdominal ultrasound has no role in diagnosing this entity due to its inherent limitations, lacking visualization of the gastric wall. Gastroenterology literature has described the endoscopic ultrasound appearance of gastric endometriosis in case reports [23–26]. These lesions can be seen as submucosal hypoechoic nodules with irregular hyperechoic margins and scattered echogenic foci spanning the serosa and muscularis in an

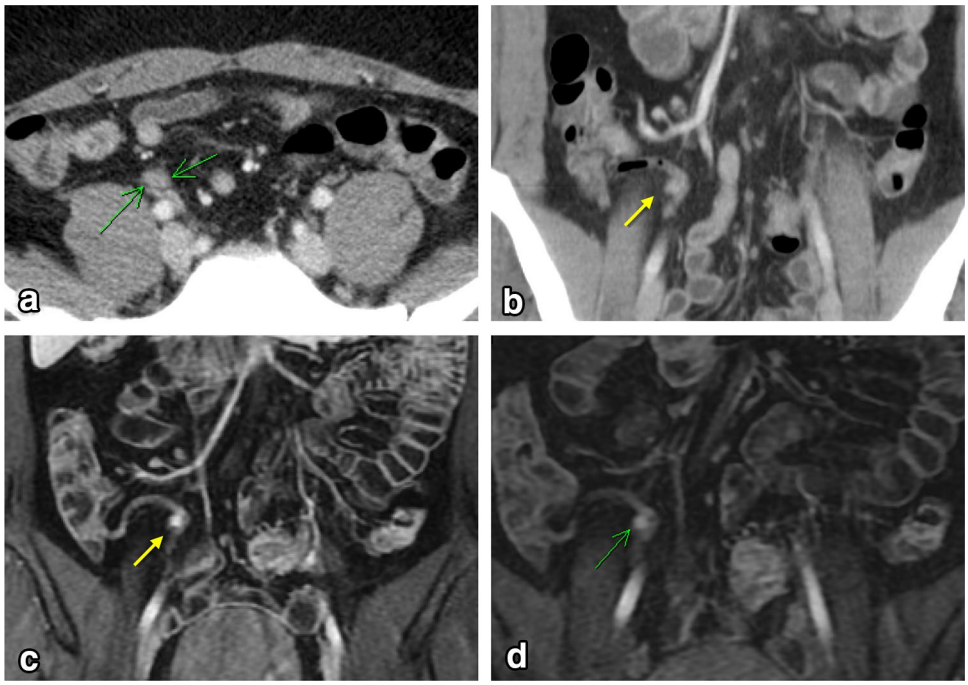

Fig. 6 42-year-old female with chronic abdominal pain and normal colonoscopy. Axial (**a**) and Coronal (**b**) CECT, and Axial (**c**) and Coronal (**d**) contrast-enhanced MRI revealed an enhancing nodule at the appendiceal tip, first diagnosed as carcinoid and later confirmed to be endometriosis at surgery

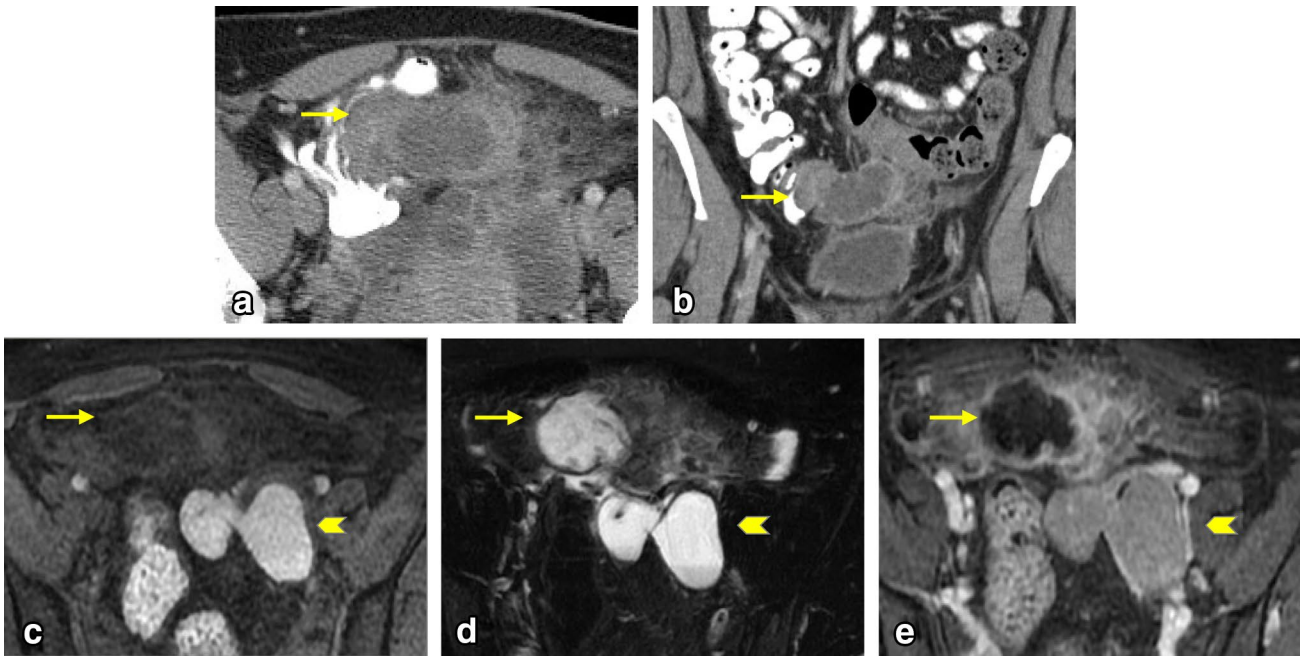

Fig. 7 37-year-old female with a known history of endometriosis presenting with right lower quadrant pain. Axial (**a**) and Coronal (**b**) contrast-enhanced CT of the abdomen demonstrate a fluid-filled dilated appendix (arrows). Axial T1-weighted pre-contrast MR (**c**), Axial T2-weighted fat suppressed MR (**d**), and post-contrast T1-weighted MR images (**e**) demonstrate an appendicular mucocele (arrows) proven on histopathology caused by obstruction of the appendicular lumen by endometriotic implants. Note the left ovarian endometrioma (notched arrowheads)

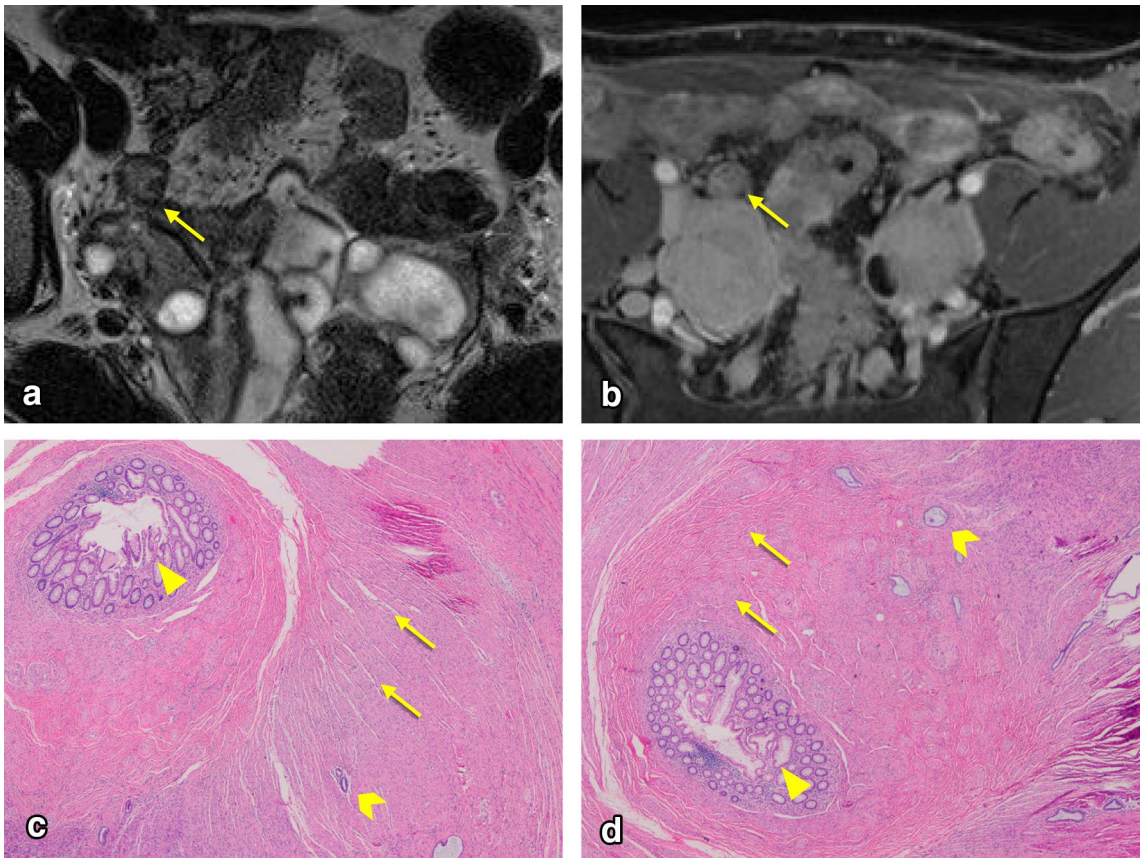

Fig. 8 T2-weighted Axial MR (**a**) shows appendicular endometriosis as a hypointense rim of thickening within the appendix with delayed enhancement on post-contrast imaging (**b**). Microscopic appearance of appendicular endometriosis (**c**, **d**) showing the appendiceal lumen (arrowhead) and endometrial glands and stroma (notched arrow heads) with surrounding muscularis layer hypertrophy (arrows)

"outside-in" fashion. Typically, the nodules appear to extend from the gastric outer surface into the muscularis propria, often sparing the mucosal layer [24, 25]. The imaging findings on computed tomography provide less uniform features across reports, varying from homogenous and hypodense submucosal masses to large, irregular, exophytic masses composed of heterogeneously enhancing soft tissue [23].

Case reports describing gastric endometriosis were all noted to be retrospectively diagnosed by histopathology following surgical excision of the tissue (Fig. 1). Interestingly, in two of the reported cases, the stomach was found to be involved concomitantly with the transverse colon, another rare location for endometriosis [23, 26]. The physical proximity and presence of the gastrocolic ligament bridging the two structures could explain the spread of endometriotic tissue in contiguity from the stomach to the transverse colon or vice versa [23, 26]. Finally, in one of these patients, endometriotic tissue extended from the original gastric mass and infiltrated the spleen [25]. To our knowledge, this is the only reported case describing splenic infiltration of endometriosis by contiguous extension.

Imaging of endometriosis involving the small bowel

Small bowel involvement by DIE is less prevalent and more challenging to detect on imaging than that of the rectosigmoid colon [27]. Ileal involvement is described in 4.1–16.9% of the patients with multi-segmental small bowel involvement, and in up to 55% of patients that have rectal implants [9, 28]. Detection of small bowel endometriosis can be particularly difficult on routine pelvic MRI exams intended to stage pelvic organ involvement due to the small field of view [27, 29]. Therefore, in addition to a high degree of suspicion and focused attention to the right lower quadrant on a pelvic MRI, including additional sequences such as large field of view coronal T1 and T2-weighted sequences would help screen for small bowel involvement. In patients with history suggestive of small bowel involvement, adding magnetic resonance enterography (MRE) as part of the work-up could also be recommended to the referring physician. MRE when performed with optimal bowel distention has shown better accuracy for diagnosing multifocal and multicentric bowel endometriosis than conventional MRI [12].

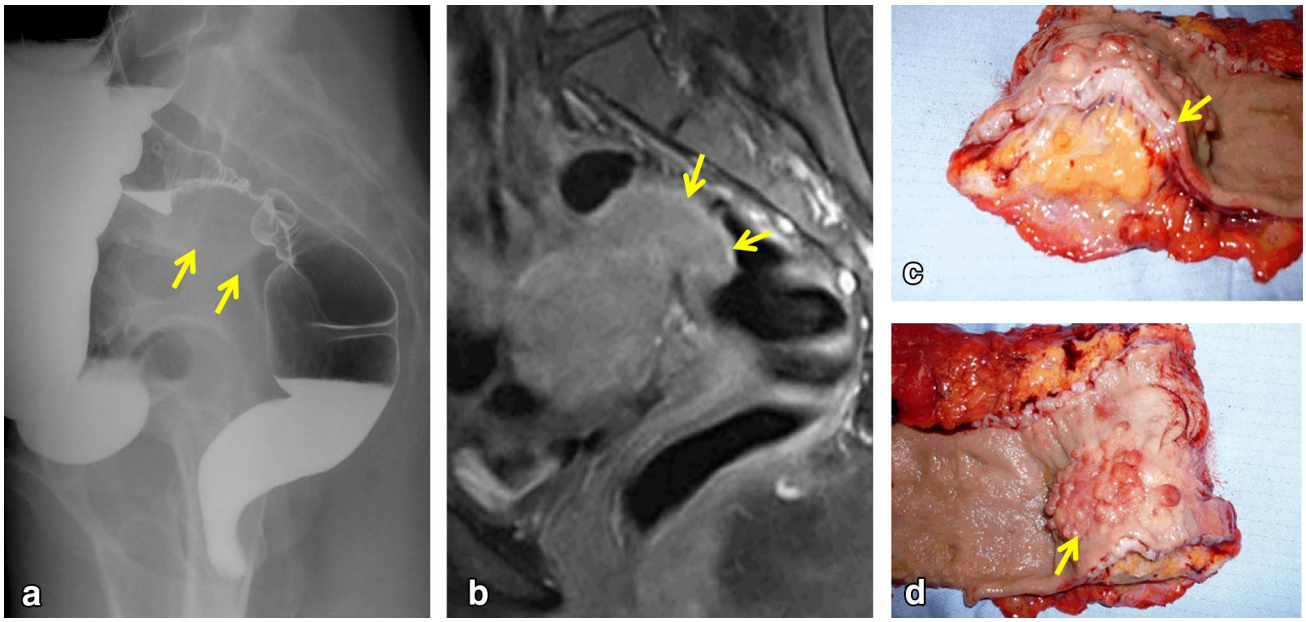

Fig. 9 Double-contrast barium enema (**a**) shows rectosigmoid endometriosis as an extrinsic mass (arrows) resulting in luminal narrowing. Corresponding Sagittal T1-weighted post-contrast image (**b**) shows delayed enhancement of the fibrotic lesion (arrows). Gross specimen (**c**, **d**) from rectosigmoid resection showing indurated, erythematous mucosa, and deeper fibrotic lesion extending inwards from the serosal surface (arrows)

Endometriotic implants have been described along the entire length of the small intestine [30, 31]. The terminal ileum is, however, the most common site of small bowel involvement, occurring within 10 cm of the ileocecal valve, and comprising approximately 5% of all cases of bowel endometriosis [19, 31, 32] (Fig. 2). Endometriosis involving the terminal ileum may be misdiagnosed as one of the more common entities involving this segment of the small bowel, such as inflammatory bowel disease, mesenteric ischemia, or a neoplasm. Recurrent small bowel obstruction in young women is a rare but severe manifestation of ileocecal endometriosis [32–34] (Fig. 3).

Double-contrast barium enema was one of the earliest tests used to image patients with known endometriosis presenting with gastrointestinal symptoms. Ileal involvement was noted by retrograde filling of the ileum which showed non-specific annular lesions with spiculated folds [31]. Ultrasound has a very limited role in detection of small bowel endometriosis. CT enterography has been used to demonstrate ileal and ileocecal involvement by virtue of better luminal distention with improved visualization of mural imaging findings such as tethering, annular thickening, and plaque-like lesions [23, 28]. In contrast to CT enterography, MRE offers the advantage of improved small bowel wall imaging without radiation. Adequate small bowel luminal distention is the most important factor enabling optimal visualization of DIGIE lesions. Rousset et al. found that 3.0-T MR enterography with bowel preparation can have up to a 100% positive predictive value in the detection of bowel lesions above the rectosigmoid junction [35].

Small bowel lesions manifest themselves on MRI as loss of the normal T2-hypointense signal of the bowel wall with nodular and irregular thickening, which may be associated with tethering of adjacent bowel segments (Fig. 4). Punctate hyperintense foci on fat suppressed pre-contrast T1-weighted images corresponding to intra-lesion hemorrhage, although rare, increase the specificity of the diagnosis if present [36]. Implants often demonstrate delayed enhancement after intravenous gadolinium injection, thereby enabling differentiation from enteric content (Fig. 5). The role of diffusion-weighted imaging in small bowel endometriosis has not been fully explored and will not be described here in detail. It is important to remember that superficial small bowel involvement is not an imaging diagnosis and, therefore, recognition of implants on MRE implies DIE. Since the surgical management of small bowel involvement is often resection, describing depth of small bowel wall involvement is not as important as describing the location and multiplicity of bowel segments involved.

An important differential diagnosis for endometriosis of the distal/terminal ileum on imaging is Crohn's disease. Because of their shared relapsing inflammation, both of these conditions result in chronic and often multifocal inflammatory changes across the bowel wall, which may include mural thickening and fibrosis with strictures that narrow the luminal diameter [30, 37]. Although definitive diagnosis is achieved

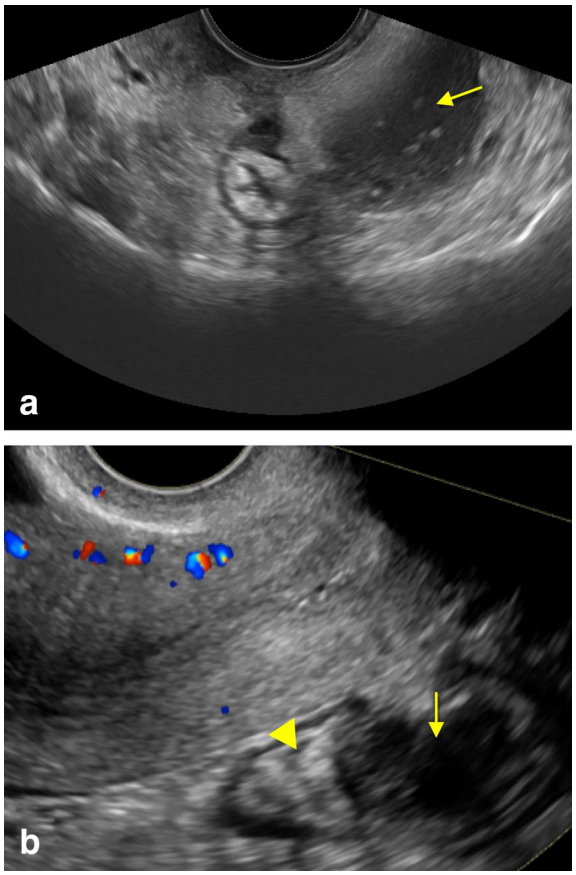

Fig. 10 Transvaginal ultrasound image (**a**) demonstrating a hypoechoic deposit (arrow) with punctate hyperechoic foci within it, located within the cul-de-sac. Transvaginal color Doppler ultrasound (**b**) displaying a hypoechoic mass of similar appearance (arrow) in a different patient located over the anterior surface of the rectum within the posterior cul-de-sac, note the lack of vascularity surrounding the lesion. Arrowhead points to the rectum

by histopathological demonstration of granulomas in Crohn's disease versus endometrial stroma and glandular elements for endometriosis [38, 39], MRI features can favor one differential over the other. Long segmental uniform T2- hypointense wall thickening; mucosal hyperenhancement; surrounding mesenteric inflammation, including engorged vasa-recta and the "comb-sign" of active ileitis with development of interloop fistulae or extraluminal abscesses favor Crohn's disease. On the contrary; nodular T2-hypointense small bowel wall thickening; shorter multifocal involvement; small T2-hyperintense cystic foci within T2-hypointense nodules; punctate T1-hyperintense foci on pre-contrast T1-weighted sequences and delayed post-contrast enhancement of bowel wall thickening without associated mucosal hyperenhancement—all favor endometriosis. Although chronic DIGIE can manifest with fibrosis and tethering of adjacent bowel loops, interloop fistulae and abscess formation are not typically seen with small bowel endometriosis.

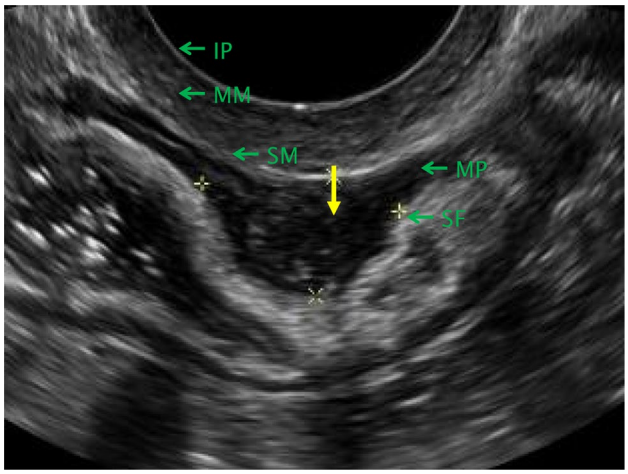

Fig. 11 Lower endoscopic ultrasound of the rectum, labeled for reference [*IP* interphase, hyperechoic, *MM* mucosa and muscularis mucosae, hypoechoic, *SM* submucosa, hyperechoic, *MP* muscularis propria, hypoechoic, *SF* serosa and perirectal fat, hyperechoic] and showing the appearance of bowel endometriosis as a hypoechoic mass (arrow) with echogenic foci within the rectal muscularis propria [MP] with intact hyperechoic submucosa [SM]

Imaging of appendiceal endometriosis

Appendiceal endometriosis (AE) has been found in varying proportions ranging from 2.6% to as high as 44% in patients undergoing laparoscopy for symptoms consistent with pelvic endometriosis [14, 40–42]. Patients with AE are more likely to have advanced stages of endometriosis and multicentric involvement (> 3 organs), large right-sided endometriomas, and bladder or colon involvement [14, 42]. Patients with superficial implants are typically asymptomatic and undetectable pre-operatively, while those with deep infiltrative endometriosis reaching the muscular layer of the appendix are commonly seen on imaging [43]. Although acute appendicitis has been considered the most common manifestation of AE, exact incidence of this occurrence has not been thoroughly studied and presentation may vary from mild pain to acute or chronic right-lower quadrant pain, small bowel obstruction, intussusception, melena, or intestinal perforation [44, 45].

Recognizing endometriosis of the appendix prospectively on imaging is especially important in the present times, given the practice of non-surgical management of acute appendicitis with antibiotics alone. Endometriosis is more commonly found in the body and tip of the appendix [20] (Fig. 6). The assessment of AE lesions by ultrasound has been described using both a transabdominal and a transvaginal approach (TVUS). On TVUS with bowel preparation, endometriosis of the appendix has been identified as nodular hypoechoic lesions or irregular thickening of the wall of the appendix [20]. Transabdominal sonography should

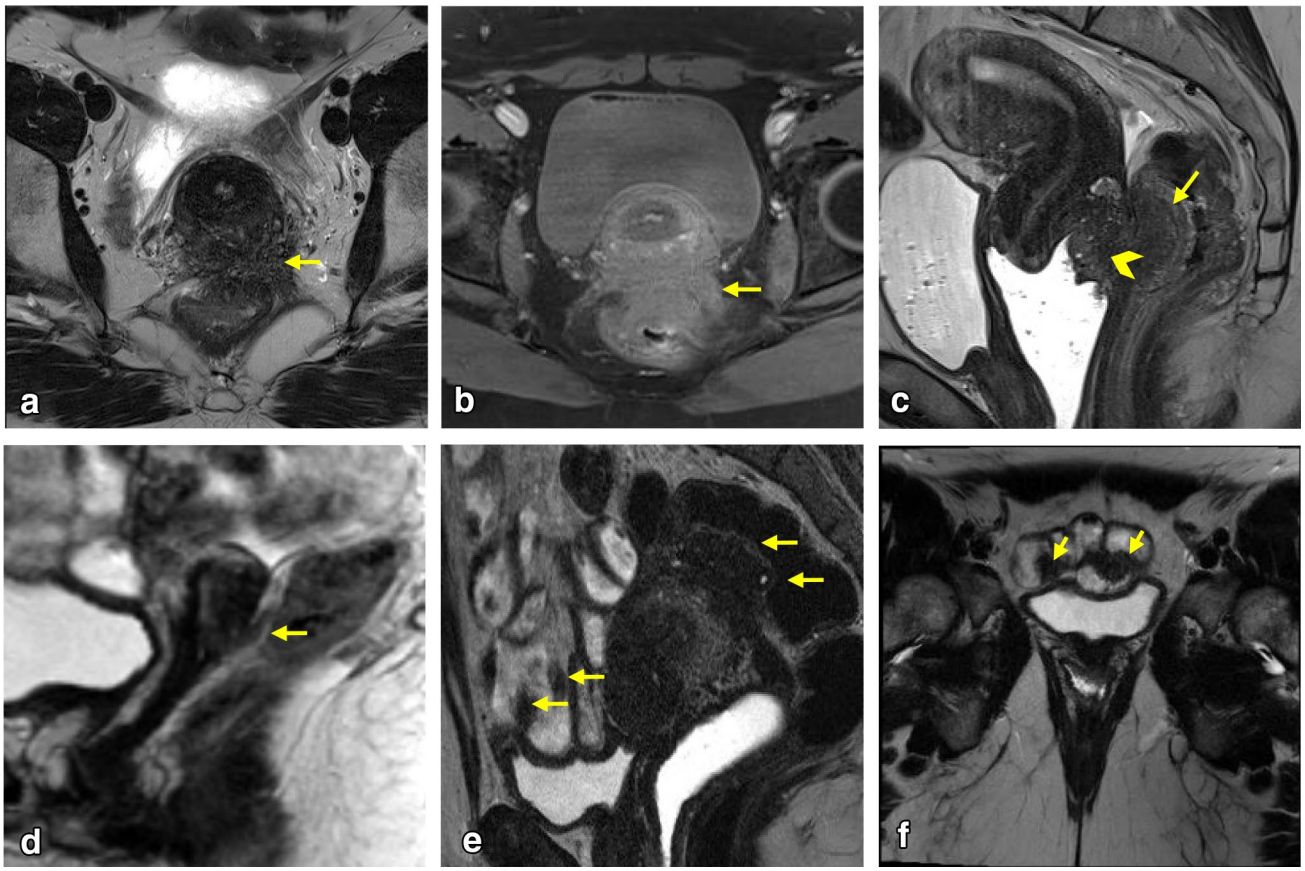

Fig. 12 **a**–**d** Retrocervical involvement is most commonly associated with uterosacral ligament involvement (**a** and **b** arrows) and may extend inferiorly to vaginal cuff (**c** notched arrowhead), rectovaginal septum posteriorly to the rectal wall (**c**, **d**) in addition to small bowel involvement (**e**, **f**—arrows)

Table 1 Magnetic resonance imaging sequences for gastrointestinal endometriosis

Sequence/plane	What to look for	FOV(mm)	Phase direction	Slice/skip	Matrix
Scout; triplane	Adequate coverage of the iliac crest to pubic symphysis				
T2TSE without fat sat coronal/oblique coronal	Fibrotic plaques in the wall of the rectum and sigmoid	360	R/L	5/0	320/70%
Axial 3D spoiled turbo gradient echo Dixon		360	A/P	3.3–3.5	320/70%
T2 TSE/FSE sagittal	Obliteration of rectovaginal space; fibrotic plaques within bowel wall; "mushroom cap" sign	220	A/P	3/10%	288/80%
T2 TSE/FSE axial oblique w or w/o fat sat	Evaluation of appendix; other small bowel located in the pelvis	220	R/L	3/0%	384/80%
Diffusion-weighted (DWI) axial b = 0,50,800	Improved lesion detection	360	A/P	5/0	128/100%
3D Spoiled turbo gradient echo with fat sat dixon axial	T1-hyperintense hemorrhagic products	360	A/P	3.3–3.5	320/70%
3D spoiled turbo gradient echo, with fat saturation post gad ± subtraction axial; coronal; sagittal	Improved lesion visualization by detection of enhancing plaques	260/340/360	Ax & Cor; R/L; Sag: A/P	3.0–3.5	256/70%; 288/100%; 320/70%

FOV field of view, *T2* T2-weighted MRI, *DWI* diffusion-weighted imaging, *R* right, *L* left, *A* anterior, *P* posterior

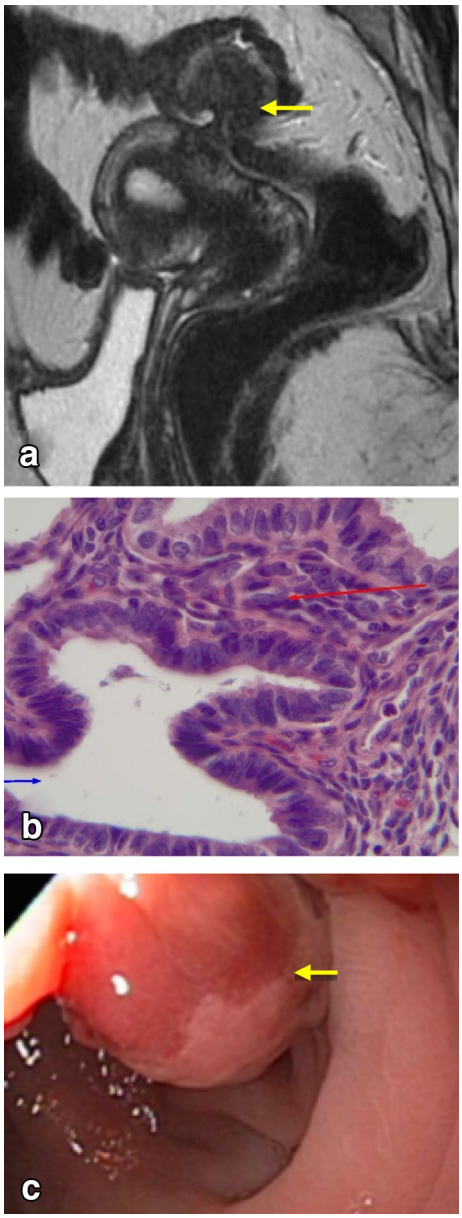

Fig. 13 Sagittal T2-weighted MR image (**a**) shows stalk-like fibrotic thickening at the torus uterinus with a "mushroom cap" sign caused by deep infiltrative endometriosis into the adjacent rectosigmoid (arrow). On histopathologic review, the rectosigmoid implant extends up to the submucosa (**b**-arrow). **c** On sigmoidoscopy, this mushroom cap appearance noted on imaging was found as a bulging mass preoperatively (arrow)

be directed at identifying signs of inflammation or luminal obstruction since appendiceal endometriosis has been known to present with US findings resembling acute appendicitis, often associated with a mucocele secondary to obstruction [46–51]. AE may manifest on CT as an enlarged appendix involved by soft tissue (hypodense) masses, luminal dilation with a targetoid enhancement pattern or focal nodules within the appendiceal body [37, 52] (Fig. 7a, b). There is not much literature describing the MR appearance of AE. In our experience, the range of imaging on MRI include discrete serosal hyperintense foci on pre-contrast T1-weighted images to nodular lesions that appear hypointense on T2-weighted imaging, occupying the tip or body of the appendix (Fig. 8). Luminal obstruction may manifest with a dilated, fluid or hemorrhage filled appendix that appears tubular with either hyper or isointense signal on pre-contrast T1-weighted images and hyperintense signal on T2-weighted images, respectively, resembling an appendicular mucocele (Fig. 7c, d, e). This is commonly associated with surrounding inflammatory changes, often with tethering of adjacent segments of small bowel, occasionally with bowel obstruction.

Imaging of rectosigmoid endometriosis

Colonic involvement at the level and distal to the rectosigmoid junction is the most common manifestation of GIE, estimated to occur in 33% of women with DIE [10, 11, 53]. Common clinical presentations include: painful defecation during menses, dysmenorrhea, changes in stool caliber and blood in stools [54, 55]. Digital rectal exam may aid in the detection by palpation of a hard or tender nodule on the posterior vaginal fornix or anterior rectal wall in women presenting with the appropriate clinical scenario [11]. Sigmoidoscopy typically demonstrates a submucosal nodular lesion protruding into the lumen.

Imaging has been shown to be very accurate in diagnosing this subtype of endometriosis [53].

Double-contrast barium enema used previously is now obsolete (Fig. 9). By virtue of its location in the posterior pelvic compartment and ease of access through the vaginal or anal canal, transvaginal/transrectal ultrasound are often used as the first line test in the imaging of posterior compartment pelvic endometriosis [56]. However, efficacy is best only in the hands of trained personnel with expertise in evaluating endometriosis. Additionally, the use of intrarectal or vaginal ultrasound gel or saline with the purpose of increasing acoustic visibility has been advocated, although evidence regarding their diagnostic aid is mixed [57]. The five bowel wall layers can be well visualized by ultrasound. The first hyperechoic layer is not a true layer and forms the interface between the lumen and the mucosa; the next hypoechoic layer corresponds to the mucosa followed by the hyperechoic submucosa, the hypoechoic muscularis propria, and finally the hyperechoic interface between the muscle layer and the serosa [58]. DIE of the rectosigmoid colon starts as a surface process extending from the serosa inwards to involve multiple bowel wall layers; often sparing the mucosa. These appear as nodular or plaque-like deposits that are hypoechoic in comparison to all, but especially, the muscular layer, and often presents with punctate foci of increased echogenicity, the etiology of the latter is not

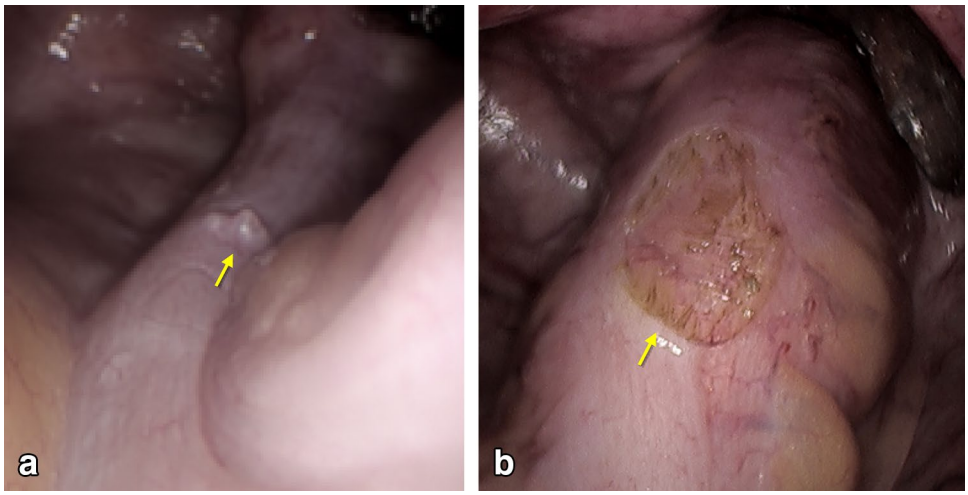

Fig. 14 Surgical picture showing (**a**, arrow) deep infiltrative endometriosis on the bowel surface and (**b**, arrow) same location after surgical shaving

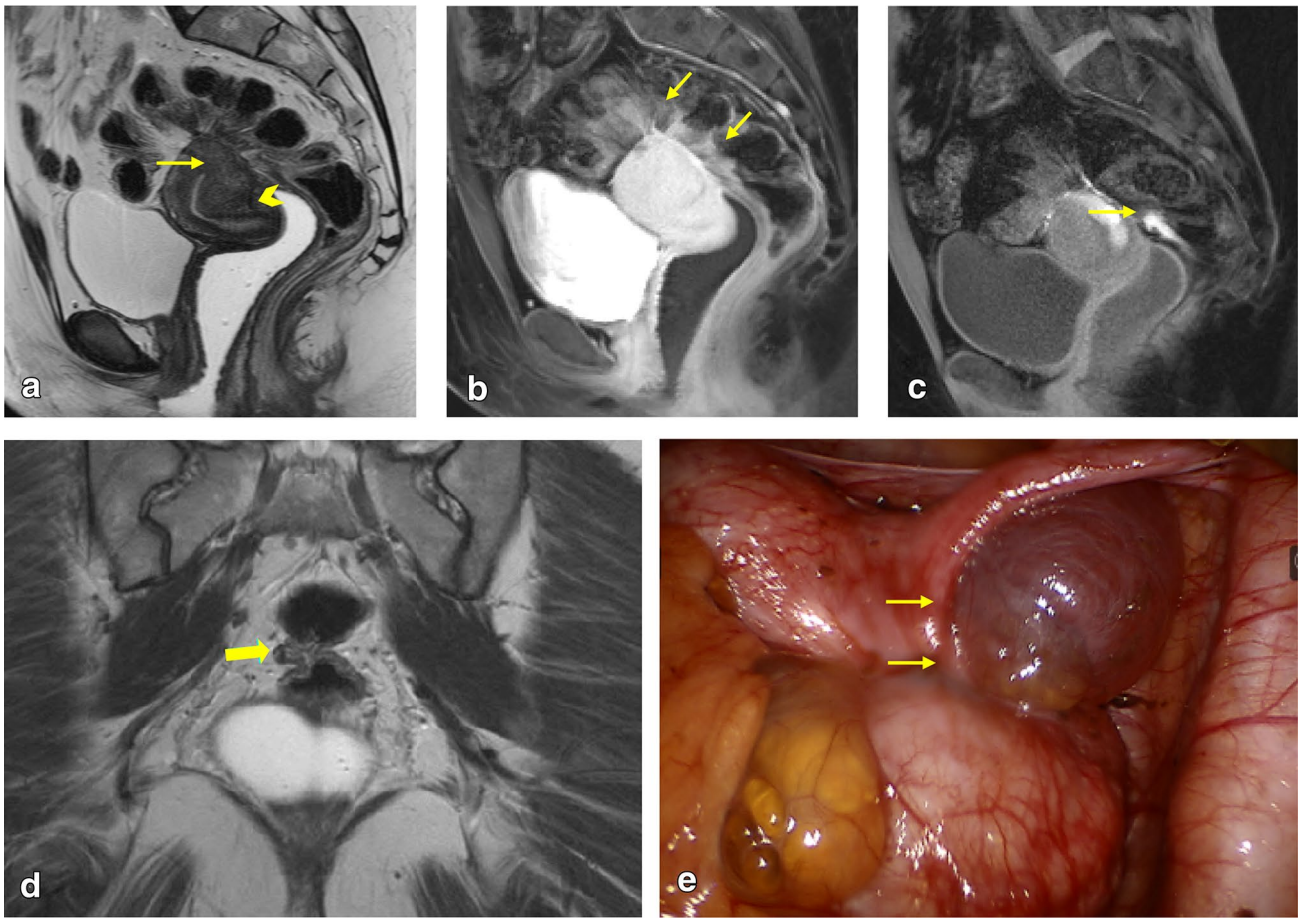

Fig. 15 30-year-old female found to have posterior cul-de-sac endometriosis. Sagittal T2-weighted MR image **a** shows a retroflexed and distorted uterine fundus (arrow) secondary to posterior cul-de-sac implants (arrowhead). Sagittal post-contrast MR **b** shows more extensive serosal tethering involving a long segment of the sigmoid colon draped over the uterus (arrow). Sagittal pre-contrast T1-weighted (**c**, arrow) image demonstrates a T-1 hyperintense endometriotic plaque on the rectosigmoid serosa and coronal T2-weighted (**d**, arrow) image showing concurrent narrowing of this segment. (**e**, arrows) show surface implants with small bowel tethering

Table 2 Elements to include in magnetic resonance imaging reporting

Number	Bowel segment involved	Points to be noted on the MRI report
1.	Stomach	1. Relationship to surrounding organs 2. Complications
2.	Small bowel	1. Location 2. Single or multifocal involvement 3. Length of segment/segments involved; 4. Lesion size 5. Adjacent structures involved 6. Proximity to the cecum/ileocecal valve 7. Relationship to the base of the appendix
3.	Rectosigmoid colon	1. Exact site 2. Distance of the distal-most extent of disease from the anal verge 3. Unifocal disease with lesion size > / < 3 cm 4. Multifocal (nodules in 2 cm length of bowel wall) 5. Satellite nodules (nodules > 2 cm apart) 6. Entire length of bowel segment involved 7. Degree of circumference (> / < ½ or 1/3) of rectosigmoid colon involved.

exactly known (Fig. 10a). Submucosal extension manifests as hypoechoic masses immediately beneath the hyperechoic bowel mucosa [59] with color Doppler demonstrating variable vascularity within these lesions (Fig. 10b).

There are a few interesting signs described for the ultrasonographic appearance of endometriosis involving the rectum. Retraction and adhesions attaching the anterior rectal wall to the posterior vaginal wall are common and have been described as solid, focal, tubular avascular lesions with slightly irregular margins that narrow towards one end, coined as *the comet sign* [60], sometimes with hypoechoic band like echoes radiating out from the main mass, called *the Indian headdress sign* [61]. The *sliding sign* is a dynamic sign elicited on TVUS where the tip of the transducer is used to apply pressure to the anterior rectal wall. Normally, the anterior rectal wall should slide along the posterior retrocervical and posterior fundal area [62] by transducer pressure; a negative *sliding sign* suggests obliteration of the pouch of Douglas due to adhesions in the retrocervical area involving the anterior rectum or rectosigmoid, and has been consistently shown to be accurate and useful pre-operatively. A negative *sliding sign* has been found to have a sensitivity of 85% and a specificity of 96% especially for those with expertise, with sensitivity reaching 100% for experienced sonologists [63–65] (Supplemental material, Videos 1 and 2). However, operator dependence and availability of a trained sonographer can be limiting factors for routine use of TVUS in the detection and staging of GIE distal to the rectosigmoid colon. Moreover, US provides a limited field of view when compared to MRI, thereby further limiting detection of the entire extent of the disease [13].

Transrectal ultrasound (TRUS)/transrectal endoscopic ultrasound may be considered in some patients as it also offers the opportunity of transrectal tissue sampling for histological confirmation [66, 67]. On TRUS, endometriotic deposits demonstrate a similar imaging appearance to that described above (Fig. 11).

MRI has been well studied for the assessment of rectosigmoid endometriosis and shown consistent accuracy in detection of lesions in the rectum and rectosigmoid, while offering an opportunity for disease mapping and an abdominal-pelvic survey demonstrating multifocal involvement [62, 63, 66–69] (Fig. 12). A recent systematic review and meta-analysis of the accuracy of TVUS and pelvic MRI findings for rectosigmoid endometriosis by Carvahal et al. concluded that both modalities displayed comparable diagnostic performance, including pooled values for sensitivity and specificity of 90% and 96% for MRI, and 90% and 96% for TVUS. This study highlights that either by themselves or combined, the use of TVUS and MRI is reasonable for the preoperative diagnosis of rectosigmoid endometriosis [70]. While laparoscopy is highly sensitive to detect the so called "powder burn" lesions of superficial endometriosis; MRI and TVUS score over laparoscopy in detecting implants in the pelvis located below the peritoneal reflection—especially those located in the vesico-vaginal and rectovaginal spaces. We wish to reiterate that TVUS is particularly effective only in trained hands, while MRI has no such limitation.

Endometriotic implants in the rectosigmoid start as serosal deposits, but, with chronicity, erode through the subserosal layers towards the lumen, accounting for their characteristic appearance [10] described by some authors

as *fan-shaped* or *mushroom cap sign* [36, 71]. The *mushroom cap sign* is characteristic of DIE in the anterior wall of the rectum or rectosigmoid. Yoon et al. coined the term *mushroom cap sign* and attributed this particular appearance to the histopathologic evidence of muscularis propria hypertrophy and reactive fibrotic adhesions converging to the serosa [30, 71–73]. It is visualized on sagittal or axial T2-weighted MR images as a crescentic T2-hypointense nodule extending from the outer bowel surface into the underlying muscularis propria. Occasionally, this lesion may grow deeper in the direction of the lumen, involving the submucosal tissues and covered by the intact T2-hyperintense mucosal layer—all together resembling the cap of a mushroom (Fig. 13). The contents can also appear heterogeneous, with variable signal intensity interspersed in a radial fashion, giving it the appearance of a mushroom lamella below the cap or the ribs of a fan; at times correlating with high signal intensity foci on T1-weighted fat suppressed imaging [36, 71, 74].

Although CT is not as useful as US or MRI for rectosigmoid endometriosis, CT colonography has been shown to be a sensitive method to detect rectosigmoid implants and morphologic changes relating to cul-de-sac obliteration [75]. A 2013 study by Iosca et al. [76] demonstrated the utility of multi-slice computed tomography with colon water distention (MSCT-c) using a split-bolus technique to assess lesions from the cecum to the rectum. The split-bolus technique enables opacification of both ureters, thereby allowing visualization of extrinsic ureteric involvement.

MR imaging protocol for DIGIE

Since the rectosigmoid colon is the most common segment of bowel involved, we shall describe the MR protocol for imaging this segment which bears similarities to the MR Pelvis protocol used for imaging pelvic endometriosis. Additional screening sequences for the upper abdomen will also be described. In a patient with an established diagnosis of endometriosis presenting with small bowel symptoms, MR Enterography is a useful adjunct to map segments of small bowel involvement.

Patient preparation should include clear instructions and explanation of the procedure to ensure better patient compliance and thereby better image quality. Fasting for 3–4 h prior to the study and bowel preparation are variably practiced; rectal gel in the form of 60–180 ml of an aqueous gel administered on table by trained medical personnel is favored at many institutions. An antiperistaltic agent such as 0.5 mg- 1 mg of Glucagon (GlucaGen; Novo 18 Nordisk, Bagsvaerd, Denmark) administered as IM or IV slowly may help further by reducing bowel peristalsis. The strength of the MR magnet can either be 1.5T or 3.0T, based on availability. Although some places advocate endorectal coils for better delineation of rectosigmoid lesions; at our institution, we prefer a body phased array coil placed over the pelvis for better patient comfort and compliance. Please refer to Table 1 for MR sequences used and their utility.

Untangling the diagnostic enigma: what the surgeon wants to know

Successful therapeutic outcomes following surgical management of DIGIE depend upon robust pre-surgical imaging mapping of all the organ systems involved, as is commonly seen in this multi-system disease. A colorectal/general surgeon would support the gynecologic surgeon when bowel involvement is demonstrated on imaging [77].

Because of its rarity, prospective surgical experience with endometriosis in the stomach is limited. All reported cases have been managed by complete resection of the mass, with a 1-cm safety margin surrounding the lesion [24, 25]—then diagnosed as endometriosis at histopathology. Other than accurate imaging diagnosis of this entity and its complications, if any, there are no specific pre-surgical tips to be reported to the surgeon.

Small bowel endometriosis may manifest as superficial lesions seen only by laparoscopy; and typically treated with shaving. Small bowel resection is considered in patients with strictures presenting with multiple bowel obstructions. It is important to include the location; single or multifocal involvement and length of segment/segments involved; lesion size; adjacent structures involved; proximity to the cecum/ileocecal valve that might require ileocecectomy, and relationship to the base of the appendix- that might include an appendectomy. Surgical management varies from local excision versus segmental resection and anastomosis of multifocal lesions [78].

There are more numerous options for surgical management of the rectosigmoid colon, given that it is the most common segment involved as well as its ease of access via the anal canal [79]. Superficial implants—better recognized at laparoscopy than imaging–are treated by means of fulguration or vaporization. For DIGIE involving focal bowel wall less than 3 cm in length with depth of infiltration less than the muscularis propria, partial thickness excision and over-sewing of the resulting defect called shaving is undertaken. Shaving avoids opening the bowel lumen [80]. Discoid resection is an alternative in which the bowel lumen is purposefully opened for resecting deeper wall infiltrates, followed by bowel wall suturing [8] (Fig. 14). Selecting between shaving and discoid resection can be challenging in weighing the possible benefits and yield of [79] surgery against the known risks of dissecting the lumen of the bowel

[79]. Although reports are conflicting, some recommend that discoid resection is the procedure of choice for patients without preexisting luminal stenosis that present unifocal lesions of up to 3 cm in diameter involving up to 50% of the circumference of the anterior wall of the rectum and located within 15 cm of the anal verge for ease of access of the stapling device [81]. The "Rouen" technique is an alternative type of discoid resection developed to address larger lesions in the low rectum by combining laparoscopic and transanal full thickness lesion excision [79]. Segmental resection is considered the most radical approach of the three and should be reserved for large or multifocal nodules, or lesions involving > 50% of the bowel wall causing luminal narrowing [81]. For successful segmental resection the involved segment should lie at least 5 cm above the anal verge, so as to allow for primary re-anastomosis [81]. A combination of techniques may at times be necessary (Fig. 15).

To summarize, reporting of DIGIE of the rectosigmoid colon must include the exact site; distance of the distalmost extent of disease from the anal verge; unifocal disease with size of the lesion measuring less than or more than 3 cm; multifocal (multiple lesions in a span of 2 cm length of bowel wall) disease; lesions located more than 2 cm apart—called satellite lesions; entire length of bowel segment involved; circumference (less than ½ or 1/3) of rectosigmoid colon involved.

In order to support the surgeons' best-informed decision for selecting a particular treatment option, key imaging features to be included in the MRI report are described in Table 2.

Conclusion

Endometriosis affecting the gastrointestinal tract is a challenging diagnosis due to its polymorphic nature at clinical and radiological presentation. Knowledge of the spectrum of imaging manifestations of GIE supports effective preoperative assessment of patients with this condition thereby leading to successful surgical outcomes and better quality of life for the patient.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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