Radiologic Evaluation of Pediatric Inflammatory Bowel Disease

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Introduction

Radiologic imaging is a vital component of disease evaluation in the patient with inflammatory bowel disease (IBD). Imaging techniques are useful at initial presentation to help establish the diagnosis and to assess the location, extent, inflammatory activity, and severity of disease. These modalities are also very important for disease monitoring during and after treatment, in selecting appropriate treatment options, planning surgical strategies, and for assessing complications of disease and effects of therapeutic interventions.

Despite ongoing advances in imaging technology, conventional plain radiographs and contrast studies such as the upper gastrointestinal (UGI) series and the small bowel follow-through are still important tools in the evaluation of IBD. In recent years, cross-sectional imaging techniques such as ultrasound (US), computer tomography (CT), and magnetic resonance imaging (MRI) have added an extra dimension and a deeper perspective to our understanding of this disease.

Advances in imaging technology have brought newer generation CT scanners and MRI techniques that allow rapid acquisition of high-resolution images of diseased bowel with three-dimensional rendering. Imaging techniques have also enhanced our understanding of the various extraintestinal disease manifestations. This chapter will discuss the current role of these various modalities in the clinical management of pediatric patients with Crohn disease (CD) and ulcerative colitis (UC), and review some of the emerging techniques that may yield more detail and improve on the accuracy of current methods.

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Crohn Disease

The hallmark of CD is segmental, transmural bowel involvement with a chronic relapsing course, and the propensity to affect any portion of the gastrointestinal tract. The disease may be limited to a single segment of bowel, commonly the terminal ileum. However, multiple segments may be affected, with intervening normal bowel, known as "skip lesions." Also, CD may be complicated by perianal disease, strictures, fistulas, and abscesses. This clinical pattern is closely mirrored by the radiologic findings. With several imaging modalities available, the clinical condition of the patient and the clinical question to be answered should determine which imaging techniques are employed.

Imaging Techniques

Plain Radiographs

Abnormalities in plain abdominal radiographs consistent with IBD are present in two-thirds of pediatric patients but these are nonspecific findings such as mural thickening, dilatation, and abnormal pattern of gas and feces [1]. As such, the plain film has little role in the initial evaluation of the patient with CD. However, plain films remain the first-line investigation in the patient with an acute abdomen, in whom dilated bowel loops and air–fluid levels indicate acute intestinal obstruction, and pneumoperitoneum signifies intestinal perforation. For example, toxic megacolon affecting patients with Crohn colitis usually manifests as dilated colon.

Contrast Studies

Despite the plethora of new imaging techniques, no radiologic test has replaced conventional contrast studies as the gold standard for the diagnosis of CD, although cross-sectional imaging (CT and MR enterography) does have the advantage for improved detection of extraenteric complication, with MR enterography having the potential to be used as a radiation-free alternative for the evaluation of patients

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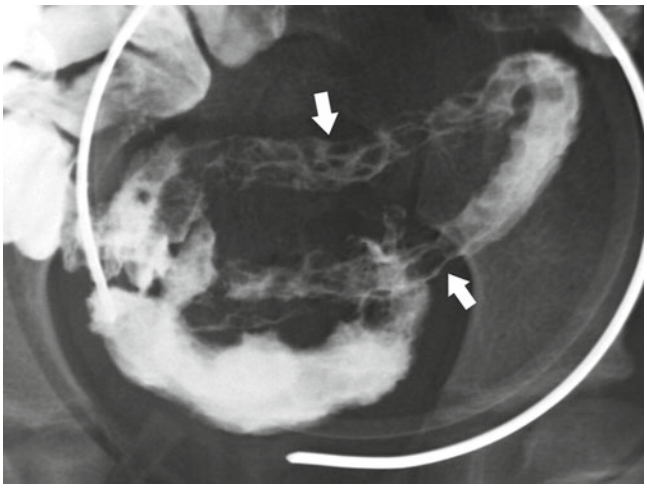

Fig. 19.1 Compression view of the right lower quadrant from SBFT demonstrates a long segment of narrowed, ulcerated and nodular appearing ileum giving the characteristic "cobblestone" appearance (*arrows*). Loop separation caused by thickening of bowel walls and mesentery inflammation

with CD. Conventional contrast studies allow direct mucosal assessment in the hand of the experienced radiologist. The UGI series is an excellent modality in which contrast is administered by mouth (or through a tube) for mucosal assessment of the stomach and duodenum. The small bowel follow through (SBFT) is performed as a continuation of the UGI examination. Additional contrast is administered or ingested, and the contrast is followed through the jejunum and ileum into the right colon. Fluoroscopic compression images of the small intestine, specifically the terminal ileum, are obtained (Fig. 19.1). A small bowel enteroclysis examination involves direct injection of contrast and methylcellulose via a nasojejunal catheter placed under fluoroscopic guidance. A double contrast view of the small intestine is obtained, providing better distension and superior mucosal detail. However, the SBFT is often chosen instead of the enteroclysis study because the latter is more unpleasant for the patient, involves a higher radiation dose, and is more difficult to perform. The barium enema (BE), using a single or double contrast technique, may be used to evaluate the colon. If reflux across the ileocecal valve is obtained, it also may provide a double contrast view of the terminal ileum. The ability to visualize the terminal ileum is critical, as it is frequently affected in CD. However, given the common availability of endoscopic assessment, patient discomfort with BE, and the risk for complications such as toxic megacolon, BE has been largely replaced by colonoscopy.

Early changes of CD include aphthous lesions, a coarse granular pattern, nodularity, and fold thickening, which may progress to deeper ulceration, cobblestoning, and fissuring. In the colon, ulceration occurs within a background of normal-appearing mucosa. Inflammatory edema produces mucosal elevations seen more commonly in the colon than the small bowel. In the patient with more severe CD, mucosal distortions and pseudopolyps may occur due to the elevation of submucosa at the margins of healing ulcers. As inflammation spreads in transmural and circumferential dimensions, the radiologic findings progress to strictures and shortening, with the most severe cases producing the characteristic "string sign." In addition, bowel may be noted to adhere to adjacent loops or to other viscera and deep ulcers may extend to create fistula. The finding of discontinuous, patchy, and asymmetric colonic mucosal changes is a hallmark of CD.

Contrast studies are limited in their ability to image extraluminal extension of disease or extraintestinal manifestations. Only indirect assessment of bowel wall thickening or mesenteric involvement can be made. Mesenteric inflammation, thickening, and fibrosis may cause separation and shortening of bowel loops. Mesenteric lymphadenopathy may appear as extraluminal masses indenting the bowel wall.

Computer Tomography

Computer tomography (CT) still is the most widely used cross-sectional imaging modality in patients with CD given its wide availability. Its major role in children with CD is in the evaluation of disease extent and in assessing for complications, particularly in the acute situation. CT enteroclysis has been shown to be more accurate than SBFT in the diagnosis of CD, but neither is able to detect the early mucosal changes of CD [2]. Additionally, as with any enteroclysis study, this technique requires the introduction of a nasojejunal tube, generally not well accepted in the pediatric population. Changes readily detected by CT include bowel wall thickening, luminal narrowing, and mesenteric involvement. Mesenteric findings include thickening due to fibrofatty infiltration, lymphadenopathy, and fatty encroachment of the affected loop of bowel.

Patients with known CD, who present with new acute symptoms suspicious for complications or a deteriorating clinical course, are best imaged with CT to assess for progressive disease or the onset of complications such as obstruction, fistulae, abscesses, or malignant change (Fig. 19.2). Extraintestinal manifestations of CD in the hepatobiliary, pancreatic, urinary, and musculoskeletal systems are also readily assessed by CT. Specific CT findings of complications and extraintestinal manifestations of CD are discussed below.

The sensitivity of CT scan in patients with CD is increased by optimal opacification and distension of the bowel by administering oral contrast at an age- and weight-appropriate dose, or by the enteroclysis technique. Bowel wall thickening greater than 3 mm in pediatric patients is generally considered abnormal [3]. Given that this young patient population

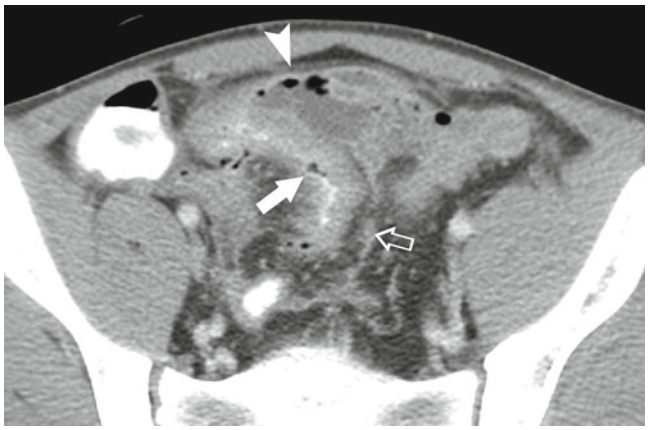

Fig. 19.2 Oral and intravenous contrast enhanced CT image of the pelvis. A thickened loop of small bowel containing intraluminal contrast (*white arrow*) marginates an intra-abdominal abscess containing fluid and air (*arrow head*). An enhancing fistulous tract is seen extending to the base of the abscess cavity (*open arrow*)

frequently undergoes multiple studies, the current trend is moving toward MRI evaluation in the non-acute setting, thus minimizing exposure to ionizing radiation.

Magnetic Resonance Imaging

MRI offers unique advantages to the pediatric patient because, in addition to being noninvasive, it avoids exposure to ionizing radiation. In many cases, MRI can replace or complement CT because its excellent soft tissue contrast and three-dimensional capabilities are ideal properties for imaging the bowel [4]. In the past, motion artifacts often limited MRI, but this problem has been largely overcome by the recent introduction of respiration-suspended sequences. Other technological advances, including improved coils, fat suppression, use of oral agents and intravenous gadolinium, powerful gradient systems, and ultrafast pulse sequences have led to overall improvement in gastrointestinal imaging. Optimal image quality depends greatly on adequate luminal distension with contrast medium. Without enteric contrast, MRI has produced inconsistent results in children with CD [5, 6].

The method of enteric contrast administration has proved to be a critical factor because oral ingestion of contrast agents that do not provide adequate bowel distention such as routine positive contrast agents or water, while patient-friendly, produces inadequate luminal distension, downgrades the image quality, and may limit the ability to detect early or minimal disease. The two techniques found to have the greatest success to evaluate for CD of the small bowel include MR enteroclysis and MR enterography utilizing a negative contrast agent that provides adequate bowel distention. The choice of oral contrast agent for MR enterography varies with institution. However, at our institution, we utilize VoLumen, a low-concentration barium (0.1% weight/volume) that contains sorbitol to aid in bowel distention.

Magnetic resonance enteroclysis requires duodenal intubation to permit volume challenge, which causes reflex bowel atony and produces superb contrast for evaluating luminal, transmural, and extramural changes. It has been postulated that by combining the advantages of enteroclysis with three-dimensional cross-sectional imaging, MR enteroclysis has been touted as the only imaging modality that can provide comprehensive diagnostic information on small bowel CD [4]. However, routine use of MR enteroclysis in children has not been widely adopted because of the need to insert a duodenal tube fluoroscopically, entailing exposure to ionizing radiation and, the potential need for intravenous sedation.

Prospective comparison of MR enterography and CT enterography in the evaluation of small bowel CD has been performed [7] with the sensitivities for detecting active small bowel disease found to be similar (90.5% vs. 95.2%, respectively). Although MR enterography had a slightly lower sensitivity and specificity, this difference was not statistically significant for the 30 patients who underwent both imaging studies. However, image quality across the study cohort was better with CT enterography. In another study [8], MR enterography demonstrated good sensitivity in the detection of active CD and found good correlation between MR and CT enterography in the evaluation of wall thickening with mucosal hyperenhancement and the presence of the comb and halo signs. While CT enterography was found to be superior in the detection of fibrofatty proliferation and mesenteric lymph nodes, MR enterography was superior in the evaluation of fistulas. Currently, however, because MR enterography has a diagnostic effectiveness comparable to that of CT enterography [9], the trend is increasing toward MR enterography as a radiation-free alternative for the evaluation of patients with CD. Indeed, one study [10] concluded that MR enterography can be substituted for CT as the first-line imaging modality in pediatric patients with CD. This viewpoint is based on the ability of MR enterography to detect intestinal pathologic abnormalities in both small and large bowel as well as extraintestinal disease manifestations. Furthermore, MR enterography provides an accurate noninvasive assessment of CD activity and mural fibrosis and can aid in formulating treatment strategies for symptomatic patients and assessing therapy response [10].

The technique for MR enterography begins with the oral ingestion of contrast, but the type of oral contrast used again is controversial and is usually institution-specific. Again, at our institution the utilization of VoLumen, low-concentration barium that contains sorbitol to aid in bowel distention, has been well tolerated and shown to produce good quality images. The patient is asked to ingest three 450 mL bottles over approximately 1–1½h as tolerated, with each bottle being ingested over approximately 20 min. The field of view includes the abdomen and majority of the pelvis to evaluate

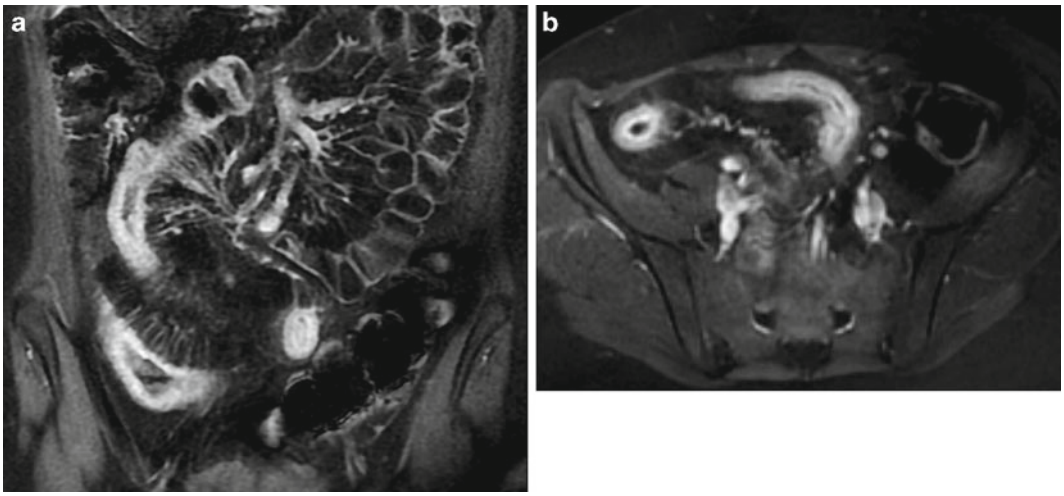

Fig. 19.3 Coronal (**a**) and axial (**b**) post-gadolinium T1-weighted sequences illustrating mucosal hyper enhancement and wall thickening along a segment of bowel with active inflammation

the entirety of the small bowel. Imaging of the bowel begins with coronal T2 single-shot fast-spin echo imaging, which is reviewed by the radiologist to ensure adequate oral preparation with contrast reaching the colon. If adequate, the remainder of the MR enterography protocol is performed including axial T2-weighted axial diffusion-weighted sequence to evaluate for restricted diffusion in areas of pathologic edema, coronal pre-gadolinium T1-weighted, and dynamic steady-state free precession imaging in the coronal plane to evaluate for bowel peristalsis. The evaluation is enhanced utilizing intravenous glucagon to inhibit bowel motion in preparation for the longer post-gadolinium sequences following the administration of IV contrast. These include axial, coronal, and sagittal T1-weighted sequences to evaluate enhancement pattern. MR findings of active CD affecting the small bowel include mucosal hyper enhancement, wall thickening (Fig. 19.3a, b), restricted diffusion (Fig. 19.4), ulcers, mesenteric hypervascularity (Comb sign, Fig. 19.5), mesenteric inflammation, and reactive mesenteric nodes. Fibrostenotic lesions (Fig. 19.6a, b) may show homogenous T2 hyperintensity, uniform contrast enhancement, and minimal adjacent inflammatory changes. Complications of CD include penetrating disease and bowel obstruction, sinus tracts, fistulas, and abscess formation [11].

In addition to MR enterography in the assessment of IBD, we currently also use MRI of the pelvis for the evaluation of complex perianal disease, as discussed below.

Ultrasound

The lack of ionizing radiation and noninvasive nature of US make it an ideal method of evaluation in children. In addition, for routine US imaging, bowel cleansing is not required, nor is enteric or intravenous contrast. However,

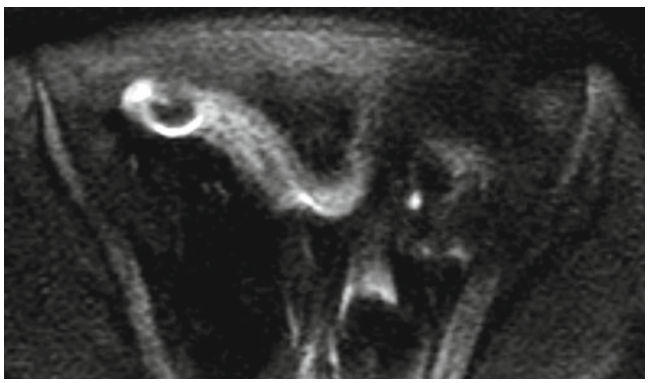

Fig. 19.4 Axial diffusion-weighted sequence demonstrates an area of restricted diffusion consistent with pathologic edema along a segment of affected bowel

because it is operator dependent, its role in patients with CD is currently generally limited to the evaluation of complications, particularly abscesses, and extraintestinal disease manifestations. It is rarely used for primary diagnosis. Affected bowel segments demonstrate wall thickening, lack of peristalsis, and poor stratification of the different layers (Fig. 19.7a) [12]. Similar to adults, US findings in children with CD show good correlation with endoscopy [13]. The most promising use of US may be in the ongoing evaluation of disease activity as well as response to treatment. In children, the sonographic value of bowel wall thickening as an index of increased disease activity has been demonstrated [14, 15]. With moderate–severe disease, the predictive value of increased bowel wall thickening greater than 2.5 mm in the ileum as an index of active disease was 88% (82% for colon >3 mm) [14]. Assessment of disease severity can also be enhanced by measuring the vessel density in

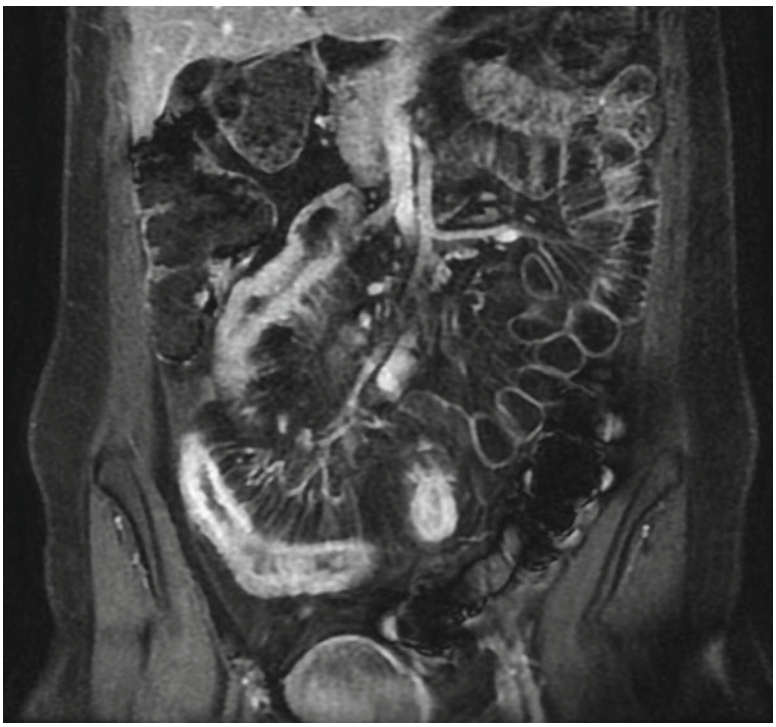

Fig. 19.5 Coronal post-gadolinium T1-weighted sequence demonstrates mesenteric hypervascularity consistent with prominent vasa recta subtending a segment of affected bowel (Comb sign)

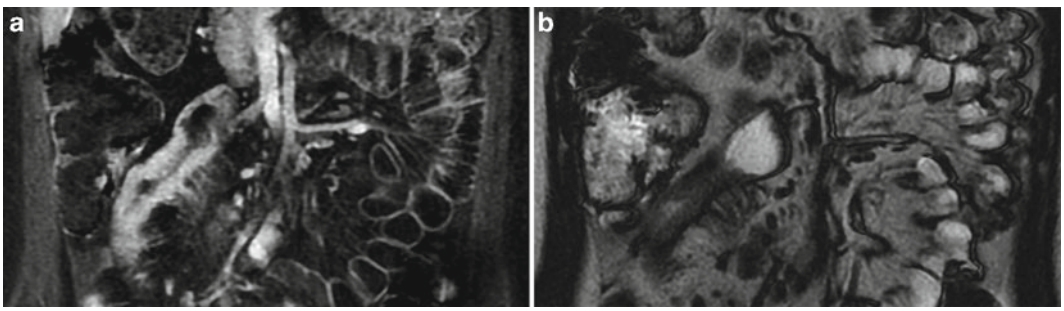

Fig. 19.6 Coronal post-gadolinium T1-weighted sequence revealing a fibrostenotic lesion showing homogenous T2 hyperintensity, uniform contrast enhancement, and minimal adjacent inflammatory changes. Dynamic sequences (not shown) showed non-peristalsis along this involved segment

the affected bowel segment using color Doppler US (Fig. 19.7b) [16]. When incorporated into a clinical protocol, US may reduce the need for contrast studies [14, 17]. In expert hands, US has been used to assess fistulae and strictures, and also monitor postoperative disease recurrence [18].

There are a number of limitations to the use of US in CD. Although the assessment of terminal ileal disease with US is quite good, the proximal small bowel and distal portions of the colon are poorly imaged. In addition, superficial lesions as seen in early disease can be missed in both children and adults [13].

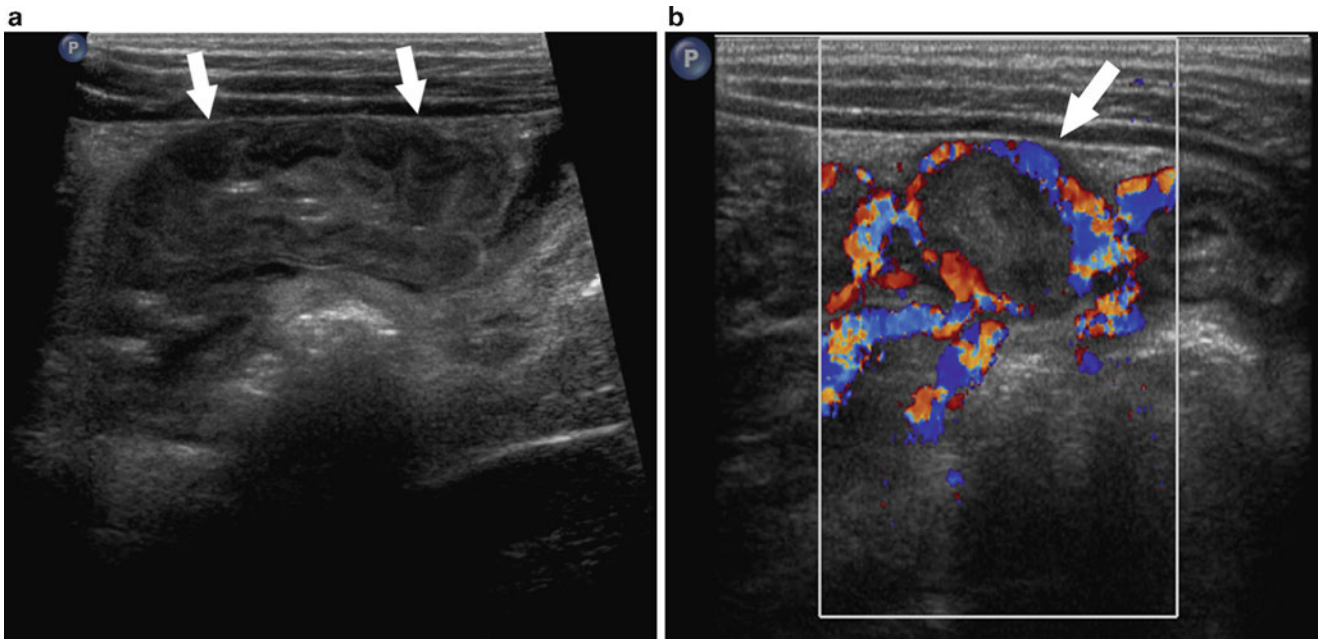

Fig. 19.7 (**a**) Longitudinal ultrasound of the right lower quadrant demonstrates a segmental region of thickened, hypoechoic small bowel (*arrows*). (**b**) Transverse Doppler image demonstrates hyperemia of bowel wall (*arrow*)

Ulcerative Colitis

Ulcerative colitis is a chronic, idiopathic, inflammatory disease of the rectal and colonic mucosa that is characterized by mucosal inflammation, edema, and ulceration. Several distinguishing features permit clinical and radiological distinction from CD. As a rule, UC nearly always affects the rectum and extends proximally to involve a variable length of colon in a contiguous fashion. Other than the occasional "backwash ileitis" of the terminal ileum, the small bowel is not affected. On rare occasions, variants with transmural involvement or without rectal inflammation also occur. Radiologic features of UC are quite distinct, although in the majority of cases, diagnosis is dependent on clinical presentation, laboratory tests, and findings on colonoscopy and biopsy.

Imaging Techniques

Plain Radiographs

The nonspecific finding of mucosal edema occasionally noted on plain films is rarely helpful for diagnosis. However, in the patient presenting acutely with symptoms of toxic megacolon, the plain film shows marked colon dilatation and is adequate for monitoring response to treatment and the potential onset of bowel perforation.

Contrast Enema

Given the availability of colonoscopy and its ability to obtain tissue for histologic assessment, as well as the discomfort of BE, contrast studies of the colon are less commonly performed than in the past. However, if needed, it can be used for confirming the diagnosis, evaluating extent and severity of disease, and detecting complications. The earliest change seen on the air-contrast study is a fine granular pattern of the colonic mucosa, which may be associated with blunting and broadening of the haustral folds due to mucosal edema. As the disease progresses, mucosal irregularity increases (Fig. 19.8). Subsequently, ulcers appear and begin to extend deeper, undermining the submucosa and forming flask-shaped or "collar-button" ulcers. Extensive mucosal ulceration may leave islands of residual inflamed mucosa that are recognized as "inflammatory pseudopolyps." In contrast to CD, these changes are contiguous, circumferential, and symmetric with no skip lesions. With long-standing disease, the colonic wall becomes rigid, shortened, and narrow due to fibrosis of the submucosa, giving the appearance of the "lead pipe" colon.

A contrast enema should be administered with extreme caution in the patient with an acute presentation. A physical examination to exclude peritoneal signs and a plain film to rule out toxic megacolon and free air should be performed prior to a BE, as any of these findings would be a contraindication.

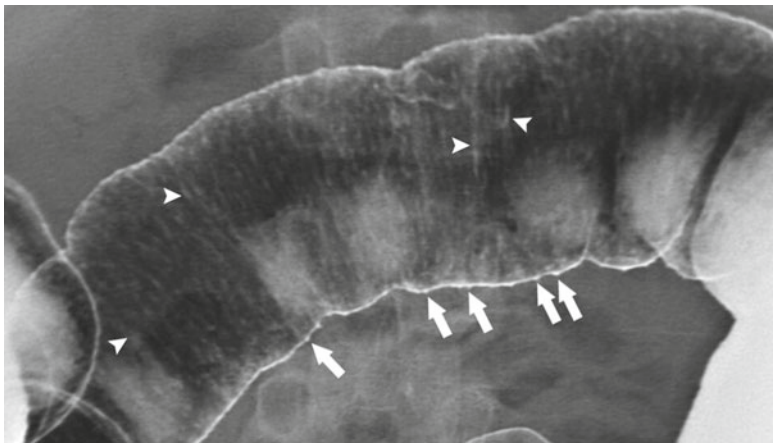

Fig. 19.8 Image (ACBE–UC). Anterior image of the transverse colon from ACBE demonstrating granular mucosa with early ulcerations seen in profile (*arrows*) and en face (*arrow heads*)

CT

CT may be useful in differentiating UC from CD, and it has the advantage of being able to visualize bowel wall as well as adjacent structures [19]. Adequate preparation for the CT examination is important. When optimal colonic imaging is desired, oral contrast should be given sufficient time to opacify the entire small bowel and colon, and if necessary additional rectal contrast should be administered. Early mucosal changes are difficult to detect on CT, but in chronic disease, bowel wall thickening and luminal narrowing is readily seen [20]. However, these rather nonspecific findings overlap with those of other colitides including Crohn colitis [19, 21]. Characteristic CT features in UC include a symmetric, contiguous wall thickening involving the rectum and extending proximally in a contiguous manner. Small bowel changes and skip lesions are absent. Thickening of the mesentery or mesenteric lymphadenopathy are rare, but proliferation of perirectal fat can occur.

MRI

Characteristic findings of MRI in the active stage of UC include loss of haustral markings, thickening, and contrast enhancement of the colonic wall [22, 23]. As with CT, these findings overlap those of CD. The few early pediatric studies available reveal inconsistencies in the ability of MRI to differentiate UC from CD [5, 6]. However, a diagnosis of UC was supported when disease progressed from the rectum proximally with mucosal enhancement and a low-signal submucosal stripe [5].

Recent advances in contrast-enhanced MRI among the pediatric population indicate that gadolinium-enhanced-MRI favorably compares with endoscopy as a means to differentiate between CD and UC. However, endoscopy has the clear advantage in allowing tissue samples to be obtained for histologic evaluation, and thus cannot yet be replaced by MRI [6]. While MRI can detect the presence of colonic disease, at present, it seems more promising for characterizing small bowel disease related to IBD. Also, the ability of MRI to categorize disease into either CD or UC with high specificity remains a challenge.

US

As previously noted, US has the advantages of being cheap, noninvasive, and lacking in ionizing radiation, but its principal finding of increased bowel wall thickness is nonspecific and cannot distinguish between UC and CD. In addition, early mucosal changes are not detected with US and the difficulty in visualizing the rectosigmoid limits its ability to evaluate the true extent of the disease. In the few pediatric studies, there appears to be a consensus that the appropriate role of US is in the monitoring of disease activity and assessing response to treatment [14, 24, 25]. With moderate–-severe disease, the predictive value of increased bowel wall thickening greater than 3 mm in the colon as an index of active disease was 82% [14].

Indeterminate Colitis

Patients with IBD whose clinical, endoscopic, pathologic, and radiologic presentation cannot easily be differentiated into CD or UC are assigned the diagnosis of indeterminate colitis (IC). Indeterminate colitis appear to be more common in children compared to adults, with a prevalence rate of nearly 30% recently reported in a cohort of 250 children with IBD [26].

One study has shown that the probability of making a definitive diagnosis of either CD or UC increases with age

[11]. Careful radiologic evaluation may play a significant role in subsequent reclassification of patients with IC. The distinction between CD and UC may be important in selecting appropriate treatment and in determining prognosis.

Demonstration of small bowel inflammation, skip lesions, and mesenteric extension usually indicates CD, particularly in the absence of colonic disease. Patients classified as IC usually have normal small bowel imaging on the SBFT and CT. As noted previously, newer techniques such as US, radionuclide scans, and MRI may demonstrate small bowel disease, particularly in the distal ileum. Again, MR enterography is becoming a promising technique and with recent advances in imaging, the detection of IBD has improved for both small bowel and colonic disease. However, in isolated colonic disease, the ability to distinguish UC and CD with high specificity remains a challenge. When extensive colonic disease is present, the finding of terminal ileal inflammation may be misleading because some patients with UC may have "backwash ileitis."

Although the colon is usually accessible for endoscopic evaluation, cross-sectional imaging with CT or MRI may demonstrate transmural involvement, extension into mesenteric fat, fistulae, or abscesses, which may prompt a more definitive reclassification as CD. Using US to differentiate between CD and UC have so far proved unreliable in children, although it may be useful for monitoring disease activity [13, 15, 27].

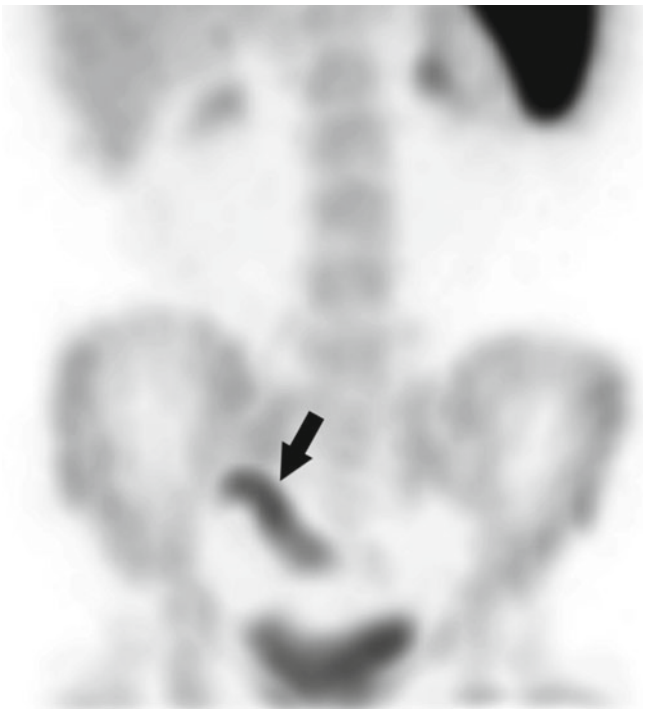

Fig. 19.9 3D volume rendered image from a Tc-HMPAO WBC scan of the abdomen demonstrates intense focal activity in the right lower quadrant (*arrow*) compatible with the diagnosis of active inflammatory bowel disease of the distal small bowel

Other Radiologic Modalities in IBD

White Blood Cell Scan

Radionuclide-labeled autologous White Blood Cell (WBC) reinjected intravenously are taken up by inflamed tissues and can then be detected by a gamma camera scan (Fig. 19.9). Within a few minutes of injection, the labeled WBC marginates in inflamed bowel and usually increases in intensity over a period of 2–4 h. The WBC scan is a helpful diagnostic tool for the detection of inflammation and abscesses. Soon after it was introduced, the ^{111}In-labeled WBC scan was shown to be highly sensitive in patients with IBD [28]. Subsequently, Technetium TC 99m Hexamethyl propylene amine oxime (^{99m}Tc HMPAO) labeled WBC scan was adopted because of ready availability, longer shelf life, lower radiation dose, and superior image resolution [29]. Most pediatric studies indicate that a positive WBC scan is highly predictive of IBD. However, false-negative studies can occur in very early disease or in patients who are in remission due to recent steroid treatment [29–31]. Negative scans have also been observed in children with proximal small bowel disease.

Localization of tracer activity can be a useful aid in differentiating children with CD from those with UC. Uptake localized to the small bowel or a more widespread but discontinuous bowel activity correlates highly with CD, whereas in UC the characteristic finding is a continuous pattern of uptake involving the rectum with a variable proximal extension in the colon [29, 32–34]. The WBC scan can also be a reliable indicator of disease activity. A "scan score" calculated by comparing uptake of tracer in affected bowel segments with iliac crest bone marrow activity correlated much better with clinical disease activity than did the erythrocyte sedimentation rate [35]. In the follow-up of patients with known IBD, a negative scan indicates remission and may prompt changes in treatment [29]. The WBC scan may be useful in several areas of clinical decision-making in children with known IBD. A positive WBC scan can identify ileal inflammation when ileoscopy is not feasible [36]. The finding of small bowel activity or skip areas of colonic involvement could help to establish the diagnosis of CD in patients previously assigned the diagnosis of IC [29]. In cases of luminal narrowing, a positive WBC scan may help distinguish active inflammation from fibrosis.

The WBC scan is attractive for children because it is associated with much less radiation exposure than contrast studies. However, scintigraphy has several limitations including false-positive studies in the presence of gastrointestinal bleeding and inability to define anatomic detail including strictures and fistulae [29, 30]. It is also time-consuming, and drawing sufficient blood for labeling can be a challenge in younger children.

Positron Emission Tomography

Positron emission tomography (PET) is a functional imaging technique that has been applied to the detection of inflamed areas of bowel. The high metabolic activity of inflamed tissue results in the uptake of the glucose analog, fluoro-2-deoxy-D-glucose (FDG), which has been radiolabeled with a positron-emitting isotope such as fluorine-18 (F-18). It is transported into cells at a rate proportional to the glycolytic activity of the cell. Within an hour of the intravenous injection of F-18 labeled FDG, the scan is performed, with a total image acquisition time of less than a half hour. PET scanning detects inflamed bowel in children with a reported accuracy similar to the WBC scan [37, 38]. As compared to the WBC scan, PET is faster and does not require blood to be drawn. However, PET scans depend on equipment and expertise that may not be generally accessible. Given the limited availability and the paucity of pediatric studies, PET has a minimal role in the evaluation of pediatric IBD at the present time.

Evaluation of Complications

Perianal Disease

Perianal disease occurs in over one-third of patients with CD but is not associated with UC. Diagnosis of external manifestations, such as skin tags, fissures, ulcerations, and simple perianal abscesses, requires only a careful inspection and digital rectal examination as appropriate. Additional information on complex abscesses, fistulae, and strictures can be obtained by performing an examination under anesthesia (EUA) with procto-sigmoidoscopy and with imaging studies.

Anatomic classification of perianal disease is enhanced by use of modern imaging techniques especially MRI and endoscopic ultrasound (EUS) [39–41]. Anal fistulography has been largely abandoned because of patient discomfort, poor accuracy, and inability to visualize the anal sphincter anatomy [42, 43]. CT is also unreliable in assessing perianal fistulae due to its poor intrinsic contrast resolution that limits its ability to define the anatomy of the levator muscle [44, 45]. Because CT entails exposure to ionizing radiation, it is also disadvantageous in children.

Both MRI and EUS appear to be highly accurate in demonstrating anal sphincter anatomy and in illustrating the relationship of abscesses and fistulae to the levators [39–41, 46–48]. Detailed and accurate demonstration of the anatomic relationships has significant implications for the surgical management of perianal disease [39, 49]. In patients with recurrent fistula-in-ano following initial operative intervention, subsequent surgery guided by MRI reduced further recurrence by 75% [50]. Similarly, among a group of patients undergoing infliximab therapy for fistula-in-ano, EUS was accurate in identifying a subset of patients who could discontinue treatment without recurrence of fistula drainage [51]. Both MRI and EUS have also been used to accurately define the perineal body and demonstrate anovaginal and rectovaginal fistulae [52–54]. While reports present conflicting accounts of the superiority of one technique over the other, the most accurate assessment of perianal disease has been obtained when any two out of the three techniques (EUA, MRI, and EUS) were combined [55]. However, the method chosen should take into account both the cost and the equipment and expertise available at individual institutions [56].

Enteric Fistula and Intraabdominal Abscesses

The incidence of enteric fistula and intraabdominal abscess in children with CD is approximately 10% each, with a cumulative incidence of up to 30% each in adult patients [57–59]. Intraabdominal abscesses are commonly evaluated with CT or US, and both modalities are also very effective in providing image guidance for percutaneous drainage of abscesses (Fig. 19.2) [60–62] Abscesses frequently develop in the abdominal wall, peritoneal cavity, retroperitoneum or iliopsoas, and subphrenic region [59]. Abscesses occurring between loops of bowel (interloop abscesses) are common. In half of patients, the abscess cavity occurs near an anastomosis following surgical resection.

Radiologic demonstration of enteric fistula can be challenging. Fistula usually arises from the extension of primary small bowel or colonic disease into adjacent mesentery, nearby bowel, skin, or the viscera of the genitourinary system. Fistula tracts can also extend into solid organs, muscle, or spine. Most commonly, fistulae arise from the terminal ileum and penetrate into the cecum or adjacent small bowel (Fig. 19.10a, b). These communications are difficult to define with standard contrast imaging due to overlap of bony structures and contrast-filled bowel, or because tissue edema prevents outlining of the fistulous tract with contrast. Enteroclysis is more sensitive for demonstrating fistula than the SBFT examination. CT is more useful for demonstrating fistula tracks, although it is only possible to determine whether a tract is patent when it has been opacified by contrast. The CT is also an excellent modality for evaluating fistulae with concomitant abscesses.

Other cross-sectional imaging modalities such as the MRI and US may also be useful in imaging enteric fistulae. MR is vastly superior for detecting enteric fistulae and intraabdominal abscesses compared to enteroclysis, and it appears to be at least as sensitive as CT scan (Fig. 19.11) [63, 64]. Although US is probably comparable to enteroclysis in detecting fistulae, there is insufficient experience with this technique to recommend its routine use at the present time [12].

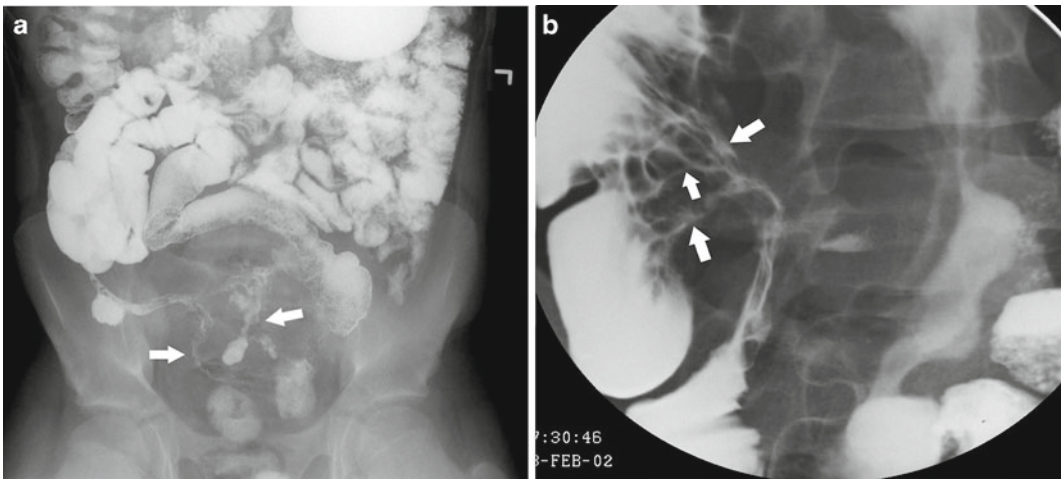

Fig. 19.10 (**a**) An overhead radiograph of the abdomen from a SBFT demonstrates narrowed segment of diseased small bowel from which arise multiple fistulae (*arrows*). Contrast is seen in the rectum consistent with enterocolic fistulae formation. (**b**) Image (SBFT—TI fistula). Coned view of the terminal ileum from SBFT demonstrates multiple fistulous tracts arising from the terminal ileum and extending to the cecum (*arrows*)

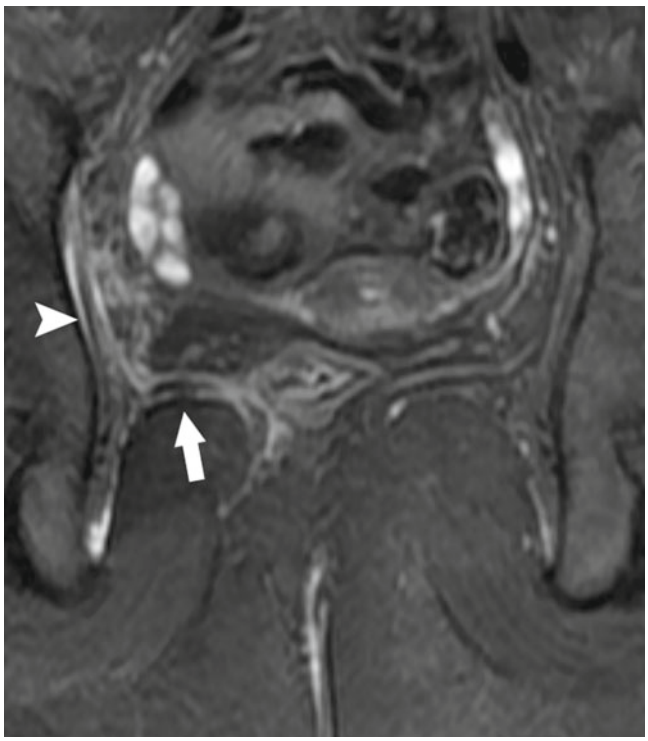

Fig. 19.11 Coronal T2—weighted fat suppressed image of the pelvis demonstrates T2 bright linear fistulous tract arising from the right side of the rectum at the level of the levator musculature (*arrow*). T2 bright inflammatory changes are seen to extend deep into the pelvis along the obturator internus muscle (*arrow head*)

One of the most dramatic manifestations of enteric fistula is involvement of the genitourinary tract. Most commonly, communication develops between the terminal ileum and the bladder, but may extend to involve the ureters, uterus, and vagina [65]. Bladder fistulae occur more frequently in males who do not have the protective shield of the uterus. Clinically, bladder fistulae present with pneumaturia and recurrent urinary tract infections. Bladder and vaginal fistulae are often difficult to visualize with conventional cystography or BE. The most sensitive imaging technique for bladder fistulae is CT with adequate oral contrast. The finding of air within the bladder in the absence of recent instrumentation is diagnostic of either a fistula or infection with a gas-forming organism. If the primary aim of the CT study is to detect fistulae, intravenous contrast should not be given so that any contrast material subsequently noted in the bladder or vagina confirms the diagnosis [65, 66].

Bowel Obstruction and Perforation

The radiologic hallmark of bowel obstruction is dilatation of proximal bowel with paucity of gas distally. Air–fluid levels may also be noted in proximal bowel. If contrast examination is performed, contrast progression to distal bowel is reduced according to the degree of the obstruction. It is important to distinguish between partial obstruction where initial non-operative treatment may be appropriate and complete obstruction, where surgical intervention is often required. CT is helpful in evaluating the severity of intramural disease and any associated abscesses. The diagnosis of intestinal perforation is made when free extraperitoneal gas is detected by either plain film or CT. The radiologic signs of bowel obstruction or perforation in patients with CD are similar to the findings in other patients, and further details will be found in most general radiology textbooks.

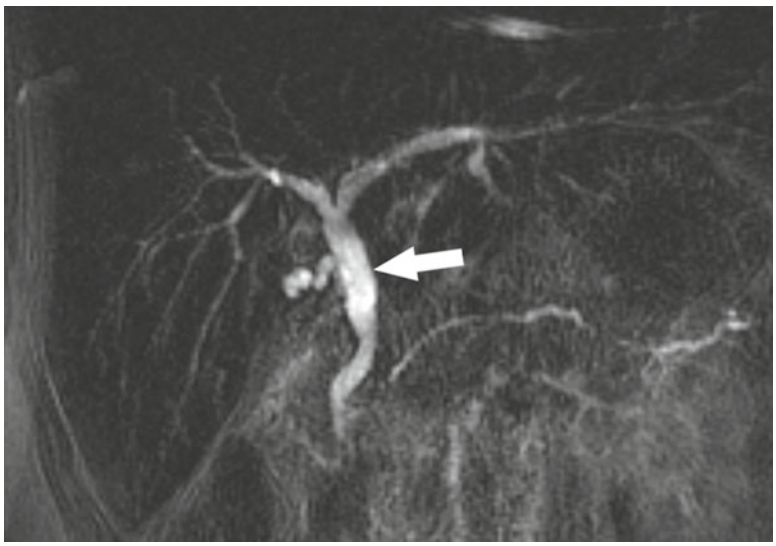

Fig. 19.12 MRCP maximum intensity projection (MIP) image of the biliary tree demonstrates common duct dilation (*arrow*) with patent left and right hepatic ducts

Toxic Megacolon

Toxic megacolon is a complication more frequently seen with UC, but may also occur in patients with severe CD. The clinical scenario is a patient with IBD presenting with an acute abdomen and signs of sepsis. Occasionally, toxic megacolon is the initial presentation of the patient with UC. The diagnosis should be made on a plain radiograph. Marked colonic dilatation with absent haustral pattern is seen, with the threshold for diagnosis depending on the child's age. In adolescents, the threshold is a colonic diameter >5 cm. Following initial medical treatment, serial films are obtained to monitor for progression and evidence of perforation. Colon contrast studies should be avoided as they increase the risk of perforation.

Extraintestinal Disease

Although IBD predominantly affects the gastrointestinal system, it is associated with a large number of extraintestinal manifestations that can significantly contribute to morbidity and affect the overall quality of life. Most commonly affected, as a direct pathophysiologic consequence of the disease, are the skin, eyes, and musculoskeletal and hepatobiliary systems. Ultimately, almost every organ system may be affected by either the secondary systemic effects of the disease or the adverse effects of treatment. Radiologic assessment of some of these systemic disorders is an important part of the comprehensive assessment of the patient with IBD. In addition to the brief account given below, detailed description of these systemic manifestations, including radiologic evaluation, will be found in the appropriate chapters in this book.

Hepatobiliary Disease

Gallstones

There is an overall increased incidence of gallstones in patients with IBD, but the association is far stronger with CD than UC. The best modality for detecting gallstones is US, although CT may be indicated in some situations.

Primary Sclerosing Cholangitis

Primary sclerosing cholangitis (PSC) is characterized by inflammatory fibrosis of the intra- and extrahepatic biliary ducts with progression to stricture, cholestasis, and cirrhosis (Fig. 19.12). In contrast to gallstones, PSC is more strongly associated with UC than CD. Although endoscopic retrograde cholangiopancreatography (ERCP) has high sensitivity for detecting early biliary changes, in children this procedure may require general anesthesia and depends on equipment and technical expertise that is not available to some pediatric centers. Magnetic resonance cholangiopancreatography (MRCP) is an alternative noninvasive method that produces similar cholangiographic images without exposure to ionizing radiation. However, due to lower sensitivity for detecting changes of PSC, ERCP should be considered when MRCP is negative but strong clinical suspicion persists [67].

Bone and Joint Disease

Osteopenia

Osteopenia and osteoporosis are well-known complications of chronic IBD with several potential mechanisms including cytokines activation, malnutrition, malabsorption, delayed puberty, and treatment with corticosteroids [68, 69]. Reduced

bone mineral density (BMD) causes skeletal fragility and increases the propensity for fractures in children with CD [70]. The most common method for the detection of osteopenia is the dual-energy X-ray absorptiometry (DEXA) scan. The BMD measured by DEXA scan of the lumbar spine, femoral neck, and radius is expressed as Z-scores, defined as the standard deviation of the measured BMD in relation to the mean for the child's age and sex. Presently, consensus is lacking on the normal ranges of Z-scores in children. In addition, when growth failure has occurred, correct assessment of BMD may require interpretation in terms of bone age or height age, rather than chronological age [71, 72]. The cost, limited availability, and difficult interpretation are some of the disadvantages to the use of DEXA in children [73]. Unfortunately, alternative means of measuring BMD in children either have low sensitivity (quantitative US) or entail a higher radiation dose (quantitative CT) [73, 74].

Future Trends

Emerging technological developments may soon alter the landscape for radiographic imaging of IBD. With advances in hardware and software leading to improved image resolution, cross-sectional imaging techniques may replace conventional contrast studies as the gold standard for small bowel evaluation in CD. While one of the most promising modalities is the MR enteroclysis combined with enteral contrast volume challenge [4], the MR enterography study is better tolerated in the pediatric population, and given its proven diagnostic effectiveness in the evaluation of CD, the trend is likely that MR enterography will substitute CT as the first-line imaging modality in the study of pediatric patients with CD. MRI will likely also play an increasing role in the differentiation of CD from UC, the follow-up of patients with IC, and the evaluation of disease activity and postoperative complications. MRI will likely also play an increasing role in the differentiation of CD from UC, the follow-up of patients with IC, and the evaluation of disease activity and postoperative complications [23]. Increased use of pelvic MRI may also lead to the development a pediatric perianal disease index, similar to one already described in adult patients with CD [75].

The now familiar technique of US may be put into increasing use as radiologists, and possibly gastroenterologists, begin to maximize its potential in the monitoring of disease activity and postoperative recurrence [12, 76].

One of the most exciting developments in the diagnostic assessment of IBD is the three-dimensional MRI and CT colonography, the so-called virtual endoscopy [77, 78].

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