American College of Radiology
ACR Appropriateness Criteria®
Crohn Disease

Variant 1: **Suspected Crohn disease, no prior Crohn diagnosis. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CT abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢
CT enterography	Usually Appropriate	☢☢☢☢
MR enterography	Usually Appropriate	O
MRI abdomen and pelvis without and with IV contrast	May Be Appropriate	O
CT abdomen and pelvis without IV contrast	May Be Appropriate	☢☢☢
Fluoroscopy small-bowel follow-through	May Be Appropriate	☢☢☢
MRI abdomen and pelvis without IV contrast	May Be Appropriate	O
US abdomen and pelvis	May Be Appropriate	O
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT enteroclysis	Usually Not Appropriate	☢☢☢☢
Fluoroscopy contrast enema	Usually Not Appropriate	☢☢☢
MR enteroclysis	Usually Not Appropriate	O
Radiography abdomen	Usually Not Appropriate	☢☢
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
HMPAO WBC scan	Usually Not Appropriate	☢☢☢

Variant 2: **Known Crohn disease, suspected acute exacerbation.**

Procedure	Appropriateness Category	Relative Radiation Level
CT enterography	Usually Appropriate	☢☢☢☢
MR enterography	Usually Appropriate	O
CT abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	May Be Appropriate	O
CT abdomen and pelvis without IV contrast	May Be Appropriate	☢☢☢
MRI abdomen and pelvis without IV contrast	May Be Appropriate	O
CT enteroclysis	May Be Appropriate	☢☢☢☢
Fluoroscopy small-bowel follow-through	May Be Appropriate	☢☢☢
MR enteroclysis	May Be Appropriate	O
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢
Fluoroscopy contrast enema	Usually Not Appropriate	☢☢☢
Radiography abdomen	Usually Not Appropriate	☢☢
US abdomen and pelvis	Usually Not Appropriate	O
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
HMPAO WBC scan	Usually Not Appropriate	☢☢☢

Variant 3: **Known Crohn disease, disease surveillance; monitoring therapy.**

Procedure	Appropriateness Category	Relative Radiation Level
MR enterography	Usually Appropriate	O
CT enterography	Usually Appropriate	☢☢☢☢
CT abdomen and pelvis with IV contrast	May Be Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	May Be Appropriate	O
CT abdomen and pelvis without IV contrast	May Be Appropriate	☢☢☢
CT enteroclysis	May Be Appropriate	☢☢☢☢
Fluoroscopy small-bowel follow-through	May Be Appropriate	☢☢☢
MR enteroclysis	May Be Appropriate	O
MRI abdomen and pelvis without IV contrast	May Be Appropriate	O
US abdomen and pelvis	May Be Appropriate	O
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢
Fluoroscopy contrast enema	Usually Not Appropriate	☢☢☢
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
Radiography abdomen	Usually Not Appropriate	☢☢
HMPAO WBC scan	Usually Not Appropriate	☢☢☢

CROHN DISEASE

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Summary of Literature Review

Introduction/Background

Crohn disease (CD) is a chronic inflammatory disorder involving the gastrointestinal tract, typically characterized by episodic flares and times of remission. Over the past several decades, there has been an increasing incidence of this disease [1-3]. Any portion of the gastrointestinal tract or alimentary tract may be involved, but the small bowel alone is affected in about a third of patients, the colon alone in a somewhat higher percentage of patients, and combined involvement of the colon and the small bowel is seen in less than a third of patients [4,5]. Perianal disease is another not uncommon manifestation [6]. Pathologically, CD is characterized by transmural granulomatous inflammation [7]. Although the bowel may return to normal after an acute flare, underlying structural damage progressively occurs over time with recurrent bouts of inflammation, leading to stricture formation, penetrating sinuses or fistulas, or a combination of the two [8].

The diagnosis of CD is based on a combination of clinical, laboratory, endoscopic, histological, and imaging findings [7,9]. No single diagnostic test allows unequivocal diagnosis. The imaging characteristics and distribution of disease provide supportive evidence for the diagnosis of CD. In addition, imaging is complementary to endoscopic techniques such as ileocolonoscopy, which allows diagnosis of disease when endoscopy is negative because of intramural disease without associated mucosal activity or because of a lack of colonic and distal ileal involvement [10].

Disease activity has been traditionally determined by clinical factors including patient symptoms and laboratory tests in which indices, such as Crohns Disease Activity Index, help to determine management. There is growing evidence, however, that active inflammation can exist despite clinical resolution of symptoms [11-13] and that complete mucosal healing represents a better treatment target for long-term outcomes than reliance on clinical symptoms [13]. In this regard, both endoscopy and imaging are becoming central tools in CD to detect such inflammation [13,14]. They are complementary in nature with differing advantages [9]. Colonoscopy with ileal intubation allows direct visualization of mucosal inflammation and ulceration and the possibility of biopsy. Cross-sectional imaging, such as CT enterography or MR enterography, allows evaluation of disease proximal to the ileum beyond the reach of the colonoscope as well as detection of transmural disease with overlying normal mucosa that may be not apparent at direct optical inspection.

Special Imaging Considerations

Oral contrast plays a key role in the assessment of CD for cross-sectional imaging modalities, including CT and MR (with or without enterography technique). Without adequate bowel distention, peristalsis or collapse can obscure or mimic disease. Neutral and biphasic contrast agents are used in CT enterography and MR enterography, respectively, to allow evaluation of mucosal enhancement by detecting subtle inflammation that is often obscured with positive contrast agents. Optimal distention of the bowel during CT enterography and MR enterography is obtained by administered large volumes (1300–1800 cc) over a specific time period (30–60 minutes) with imaging conducted at 60 minutes [15]. In addition, the oral agent also is formulated to decrease absorption in the ileum,

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which occurs with water, allowing for increased distal luminal distention. If the patient cannot tolerate the oral contrast requirements of the enterography technique, CT can still be performed but with a loss of sensitivity. Although positive oral contrast often obscures the presence of subtle inflammation, it has been shown to improve detection of potential complications related to ongoing CD, including abscess formation, fistula and sinus tract formation, compared with neutral agents [16]. Thus, in some circumstances, positive luminal contrast may be the preferred agent at a standard CT to detect such complications.

CT enterography or MR enterography involves oral ingestion by the patient, whereas CT enteroclysis and MR enteroclysis involves placement of a nasoduodenal tube to allow oral contrast infusion directly into the small bowel at a predetermined rate. These procedures are more invasive and may not be well tolerated by acutely ill patients. The technical demands of the enteroclysis protocol related to placement of a nasoduodenal tube and the need for radiologist monitoring throughout the procedure have been negative impediments to widespread use. Bowel distention of the jejunum is typically less at enterography than at enteroclysis but is considered acceptable with good technique [17,18].

Discussion of Procedures by Variant

Variant 1: Suspected Crohn disease, no prior Crohn diagnosis. Initial imaging.

In this clinical variant, the patient is not known to have an established diagnosis of CD. Although there are differential diagnostic possibilities, CD is determined to be one of the leading causes for the patient's condition. In this clinical scenario, the patient can present with a range of severity from an indolent presentation in which the individual is relatively well to an acutely ill one with severe pain, leukocytosis, vomiting, and/or diarrhea. The individual may or may not be able to tolerate the large amounts of oral contrast needed for specialized imaging protocols (ie, enterography or enteroclysis techniques) depending on the severity of presentation. In cases in which the patient cannot tolerate the oral contrast requirements, enterography or enteroclysis by CT or MR would then not be possible options.

CT Enterography

CT enterography represents a CT examination with a specialized protocol. Neutral contrast by mouth is given in large amounts over a set time to promote optimal distention of the small bowel [19-21]. Combined with other technical modifications, including thin collimation, multiplanar reconstruction, and intravenous (IV) contrast, this protocol maximizes the technique to depict inflammatory changes in the small bowel related to CD [20,22,23].

It is difficult to precisely determine the test characteristics in CD exactly because of the lack of a true reference standard. However, the overall diagnostic performance for CT enterography is excellent. When an endoscopic standard is utilized, sensitivity for CD ranges from 75% to 90%, with a specificity of >90% [24-27]. Compared with other imaging modalities, CT enterography represents an optimal option for most patients [21,27-31]. The diagnosis of acute inflammation is made through visualization of thickened small bowel with mural stratification as well as extraenteric processes including engorged vasa recti/vasculature and surrounding inflammatory stranding [25,26,32-34]. Because CT enterography is a cross-sectional imaging modality, assessment for alternative diagnoses, as well for the possible complications of CD including obstruction, abscess, and fistula, can be made [28,35-37]. With its intrinsic high spatial resolution and reproducible quality, state-of-the-art CT enterography represents one of the main imaging methods for initial diagnosis of small-bowel CD. At many United States medical centers and practices, a combination of CT enterography and ileocolonoscopy has been advocated as the diagnostic algorithm of choice at initial presentation [38]. Ileocolonoscopy can assess for colonic and distal ileal involvement and permits biopsies. The addition of CT enterography allows for assessment of the entire small bowel, including the distal ileum, and is helpful in establishing a CD diagnosis in cases in which the terminal ileum and colon are not involved or when intramural disease is predominant, which may not be apparent at endoscopy.

For this variant in which the patient does not have an established diagnosis for CD and other entities remain in the differential, the cross-sectional/global nature of this CT-based modality allows potential diagnosis of an entity mimicking a CD presentation and adds to the utility of CT enterography.

Ultimately, the decision to select CT enterography versus a standard CT abdomen and pelvis examination is dependent on the acuity and severity of presentation. For more indolent presentations in which the patient is able to tolerate large volumes of oral contrast, CT enterography is preferred because it is can detect more subtle findings of CD compared with a standard CT with positive oral contrast. In contrast, in the acute presentation in which the patient is severely ill and unable to tolerate the large volume requirements, a standard CT (without or with oral contrast) may be the preferred choice. Presumably, any findings of CD would not be subtle in this situation.

CT Abdomen and Pelvis

Standard abdomen and pelvis CT with IV contrast with a routine protocol (ie, without neutral oral contrast enterography technique) can be useful in the initial presentation of a patient with CD without a known prior diagnosis, particularly in the instance of an acutely ill individual who may be unable to tolerate large amounts of oral contrast for an enterography protocol. Standard CT also allows for alternative diagnoses that may mimic CD such as appendicitis in this variant. This adds to the potential utility of this modality for this variant. However, if the patient is able to tolerate the oral contrast requirements of CT enterography, optimizing bowel technique improves examination performance over standard CT and should be preferred.

Although standard abdomen and pelvis CT can be done either with or without the administration of IV contrast, it is evident that many of the processes, such as mural enhancement associated with CD require IV contrast for optimal assessment. Without IV contrast, such processes can only be inferred by associated findings, such as wall thickening, which may not occur in mild inflammation. In fact, the importance of contrast can be underscored by the emphasis on determining the optimal timing of imaging following IV contrast administration as opposed to comparisons between IV contrast and noncontrast CT [22]. A prior meta-analysis that evaluated CT performance included studies that were all conducted with IV contrast [25]. There is a clear consensus that noncontrast CT holds poorer performance compared against a CT with IV contrast.

Standard CT abdomen and pelvis with IV contrast can provide evidence of inflammation of an affected gastrointestinal segment. Although there may be less than optimal bowel distention with positive luminal contrast (compared with volume loading techniques) and positive contrast may obscure subtle stratified mural enhancement and more subtle areas of active inflammation, CT with positive luminal contrast can identify wall thickening, luminal narrowing, and adjacent inflammatory changes that may be seen in CD [39]. In addition to assessing for inflammation, standard CT with IV contrast can also evaluate for CD complications, including bowel obstruction, fistula formation, and abscess formation, and positive luminal contrast is preferable to no oral contrast in this scenario. Sensitivities for CT-based evaluation for stenosis/obstruction range from 85% to 94% with very high specificities [40,41]. Sensitivities for abscesses are also very good, ranging from 86% to 100% [27,36]. There is more variable performance for fistula detection with sensitivities ranging from 68% to 100% [27,40,42]. One study showed a very low sensitivity of 20% for enteroenteric fistulas in their series [40]. Thus, in the acute setting, standard CT with IV contrast is a suitable option for assessment. On the other hand, if the patient is relatively well and able to tolerate the oral contrast requirements of CT enterography, the optimized bowel protocol increases sensitivity for more subtle inflammation.

CT Enteroclysis

CT enteroclysis is a CT-based examination in which a nasoduodenal tube is placed to allow controlled distention of the small bowel. Typically, neutral contrast is continuously infused into the small bowel during CT, and IV contrast is also given. This procedure typically allows for better distention of the small bowel compared with oral ingestion at CT enterography [43,44]. Because of the active infusion, stenoses are more readily determined [43].

There have been few studies evaluating performance in recent years. Although bowel distention of the jejunum is improved with CT enteroclysis, the distention at CT enterography is considered acceptable [17,18], and CT enterography has been more generally utilized over CT enteroclysis because the procedure is better tolerated by patients. As with all imaging modalities, it is difficult to precisely determine the test characteristics in CD exactly because of the lack of a true reference standard. However, the overall diagnostic performance for CT enteroclysis is excellent (ie, >85% sensitivity, >90% specificity) [45-47], and this examination has been used as a reference standard for other modalities in various studies [41,47]. The diagnosis of acute inflammation is made through visualization of thickened small bowel with mural stratification as well as extraenteric processes, including engorged vasa recti/vascular and surrounding inflammatory stranding [43,44]. Because CT enteroclysis is a cross-sectional imaging modality, assessment for alternative diagnoses as well as for the possible complications of CD, including obstruction, abscess, and fistula, can be made [43]. Although the bowel optimization at CT enteroclysis allows excellent examination performance, equivalent to highest-performing modalities, CT enteroclysis is not typically suitable in the acute setting in which the patient is ill. It is not uncommon that they cannot tolerate the requirements of this somewhat invasive examination. In a scenario in which the CD is a diagnostic consideration among others without a prior established diagnosis of inflammatory bowel disease, the discomfort and risks of duodenal intubation and active contrast infusion often outweighs the increased diagnostic performance gained, arguing against its use in this situation.

MR Enteroclysis

MR enteroclysis is a MR-based examination in which a nasoduodenal tube is placed to allow controlled distention of the small bowel. Typically, biphasic enteral contrast (low signal on T1 and high signal on T2) is infused over time prior to MRI, and IV contrast is given during the MR examination. The technical demands of this more invasive examination are greater but typically allow for better distention of the small bowel compared with oral ingestion with an enterography technique [48].

There have been few studies evaluating performance of this technique in recent years because it is not a widely utilized examination. Although bowel distention of the jejunum is typically less at enterography than with enteroclysis, distention achieved with enterography is considered acceptable [17] and has been more widely utilized compared with MR enteroclysis. As with all imaging modalities, it is difficult to precisely determine the test characteristics in CD exactly because of the lack of a true reference standard. However, the overall diagnostic performance for MR enteroclysis is excellent and at least equivalent to MR enterography [49]. One comparison study between these two modalities demonstrated statistically better detection of superficial mucosal abnormalities over MR enterography but no difference for stenoses and fistulas [50]. Although the bowel optimization at MR enteroclysis allows excellent examination performance, equivalent to the highest-performing modalities, MR enteroclysis is not typically suitable in the acute setting in which the patient is ill. Often, they cannot tolerate the requirements related to placement of the nasoduodenal tube and active infusion of contrast. In addition, the evaluation for alternative diagnoses mimicking CD may be more difficult or limited.

MR Enterography

MR enterography combines contrast-enhanced MRI scanning using fast imaging techniques with an enterography protocol to optimize bowel distension [38]. As described with CT enterography, this requires the patient to ingest a large volume of oral contrast in a set time. Additionally, the use of glucagon or prone imaging may help to decrease bowel peristalsis and thus artifact. MR enterography holds excellent test performance characteristics (see below) equivalent to other optimized modalities, such as CT enterography. The ability to diagnose alternative diagnoses may be decreased in cases when a CT-based option may be preferable, depending on the level of patient acuity and ability to hold still. Severely ill patients are less likely to be able to hold still for the duration of MRI examination, leading to increased artifact and poorer image quality. In addition, if ill, the patient may not be able to tolerate the required large volumes of contrast required at MR enterography.

MR enterography can accurately display bowel-wall changes in early CD [51-54]. Characteristic bowel-wall changes suggesting active inflammation include bowel-wall thickening, high T2 mural signal, mural hyper enhancement with mural stratification, and hyperemic vasa recta [55-64]. MR cine imaging is potentially useful, allowing for assessment of decreased bowel motility in the affected segments with CD [65]. Besides inflammation, MRI can detect complications for CD, including obstruction, abscess, or fistula. MRI may also depict alternative diagnoses such as appendicitis, although this may be more difficult than at CT. Similar to CT enterography, the performance of MR enterography for CD is very good. Rates of sensitivity and specificity are 77% to 82% and 80% to 100%, respectively [24,66,67], and test performance characteristics for active inflammation and complications are similar to CT enterography [27,28,35,40,68,69]. However, the quality of MRI examinations is much more variable and is dependent on patients' ability to hold still, leading to increased interobserver variation as opposed to CT enterography [27,35,70-72]. Overall, MRI is more prone to respiratory and bowel-motion artifact, despite the use of glucagon, which may lead to suboptimal examinations and more difficult interpretations, particularly in acutely ill patients. Because of these limitations, it is best to start with a CT enterography as the initial evaluation in suspected CD.

MRI Abdomen and Pelvis

Standard MRI with a routine protocol (ie, MRI without and with IV contrast and without oral contrast enterography technique) can detect evidence of CD if the patient cannot tolerate large volumes of oral contrast (ie, acutely ill patients). However, the lack of bowel optimization technique decreases evaluation of more subtle findings. One study (n = 100) reported a sensitivity of 50% to 86% and specificity of 93% to 94% for wall thickening [73]. Thus, standard MR may be an option when oral contrast requirements at enterography cannot be tolerated.

For CD complications, the diagnostic ability of MRI is similar to standard CT with IV with similar reported sensitivities and specificities in various series [27,40,58,72]. The sensitivity for stenosis/obstruction ranges from 87% to 92% with high specificities; detection performance remains high for abscesses, with sensitivity ranging from 86% to 100%. As with CT, the detection for fistulas is more variable, ranging from 40% to 100%. Because of

the superior soft-tissue contrast, perianal disease including fistulation to the perineum is best evaluated at MRI, using a small field of view and focused examination [74-76].

Standard MRI without IV contrast has been investigated because of emerging concerns with IV gadolinium use and potential long-term accumulation in the body and brain. Noncontrast techniques, such as diffusion-weighted imaging (DWI), have been used to evaluate evidence for CD. There is growing literature examining its promise in detecting active disease versus quiescent disease for complication evaluation and disease monitoring, although many of the studies involve DWI in the context of enterography technique [77]. One study without enterography technique [48] reported a sensitivity of 49% to 82% and specificity of 85% to 93% for DWI, although lower specificities have been reported at meta-analysis [78]. Overall, DWI appears to have moderate sensitivity but low specificity leading to increased false positives for disease activity [77]. Thus, the current consensus is that noncontrast only techniques such as DWI can be done but there is likely improved performance with the information gained from post-IV contrast series.

Severely ill patients are less likely to be able to hold still for the duration of an MRI examination, leading to increased artifact and poorer image quality. In these instances, other options may be preferable, particularly CT enterography or standard abdomen and pelvic CT.

Radiography Abdomen

Radiographs of the abdomen are limited in the initial diagnosis for CD. The ability to directly visualize bowel pathology is limited, and evidence for CD is instead inferred indirectly. Radiographs may be useful in severely ill presenting patients to evaluate for the presence of bowel perforation or obstruction.

Fluoroscopy Small-Bowel Follow-Through and Fluoroscopic Enteroclysis

Historically, fluoroscopic contrast examinations of the gastrointestinal tract have been the primary imaging methods of choice in the diagnosis of CD. Small-bowel follow-through (SBFT; with or without per oral pneumocolon) and enteroclysis can be used to evaluate the small bowel for evidence of thickening and active disease [50,79]. In addition, internal fistulas can be detected [80], although other extramural complications, such as abscess formation, are only indirectly visualized, which leads to decreased detection [27]. It has become evident; however, with the emergence of specialized cross-sectional imaging modalities, that the performance of contrast fluoroscopy is not as accurate for active disease as compared to these other examinations [18,42,46,81,82]. Both SBFT and enteroclysis are hampered by their 2-D perspective, whereby pathology can be obscured because of overlapping bowel loops [18,82,83]. On the other hand, the real-time assessment for a fixed versus pliable nature of a segment of bowel can provide important ancillary information. Depending on institutional and surgeon preference, there may be a role in delineating the preoperative anatomy for the surgeon, although there has been a marked decline in fluoroscopic use over recent years.

In addition, fluoroscopic examinations may not be tolerated in acutely ill patients because of the oral contrast requirements for these procedures.

Fluoroscopy Contrast Enema

Colonoscopy is the preferred initial examination of the colon in patients suspected of having inflammatory bowel disease primarily involving the colon as opposed to the small bowel [9]. Colonoscopy is superior to the barium enema for the detection of early inflammatory changes and has largely replaced it as the initial diagnostic examination [9]. Particularly in an acutely ill patient, a contrast enema may be technically challenging because of the need for retrograde contrast instillation.

US Abdomen and Pelvis

Transabdominal ultrasound (US) is a potential effective option in the initial diagnosis of CD [84,85]. The technique requires a systematic survey pattern of the entire bowel with graded compression (ie, overlapping vertical sweeps with a high-frequency 5–17 MHz linear transducer) [11]. Sensitivities for disease detection range from 75% to 94%, with specificities of 67% to 100% for CD with demonstration of wall thickening [66,86-88]. The threshold for abnormal thickening is typically set at 4 mm. Besides wall thickening, findings include alteration of the US gut signature, presence of fat wrapping, and vascular changes [89-92]. US contrast and Doppler techniques appear helpful in determining inflammation [93-95]. In addition, the real-time assessment of bowel pliability and peristalsis can be helpful in the diagnostic evaluation. Transperineal or endoanal US is also helpful at assessing perianal fistulous disease related to CD [96].

However, patient factors such as obesity and guarding, especially in the acutely ill scenario, may preclude adequate compression with the US probe. In addition, large amounts of shadowing gas may obscure bowel, preventing an optimal examination. Location of bowel involvement affects diagnosis with higher sensitivities for terminal ileal involvement detection as compared with more proximal small bowel disease [87]. False-positive diagnoses of abscesses are more likely at US [97]. The determination for alternative etiologies may also be decreased as compared with CT or MRI.

HMPAO WBC Scan

Leucoscintigraphy or Tc-99m-hexamethyl propylene amine oxime-labeled white blood cell (Tc-99m HMPAO WBC) scan have demonstrated good sensitivities and specificities for intestinal inflammation in the 79% to 85% and 81% to 98% range, respectively [98]. Proponents contend that leucoscintigraphy is useful in the diagnosis and evaluation of activity of extent of disease [99] with performance results equivalent to cross-sectional imaging [28]. However, the disadvantages of this examination, such as the decreased ability to depict and therefore detect alternative diagnoses and the complicated time-consuming technical aspects (ie, labeling and handling of blood products) have limited its use in initial diagnosis. Furthermore, leucoscintigraphy is limited in alternative diagnoses mimicking CD.

FDG-PET/CT Skull Base to Mid-Thigh

The addition of metabolic information from PET with the morphologic anatomic imaging of CT or MR shows promise. It may be helpful to better assess the level of active inflammation from fibrosis [100,101]. Studies also show improved assessment in the colon in a murine animal model [102], which points to potential future usefulness because the colon is less well evaluated at both CT enterography and MR enterography. At this point, there are few large-series published clinical studies but small series show promising results [103,104].

Variant 2: Known Crohn disease, suspected acute exacerbation.

In this clinical variant, there is an established diagnosis of CD. Here, the patient presents with acute worsening of symptoms attributable to known disease. The concern is for an active flare or for the development of a complication of CD (ie, obstruction, abscess, fistula development). The clinical suspicion of an alternative diagnosis mimicking CD is low.

CT Abdomen and Pelvis

Standard abdomen and pelvis CT with IV contrast with a routine protocol (ie, without oral contrast enterography technique) can be useful in the suspected exacerbation of CD. Although the imaging findings of an acute flare in a known CD patient are typically not subtle (ie, not the situation of subtle mucosal enhancement in a clinically asymptomatic patient undergoing treatment monitoring), optimizing the bowel by enterography technique leads to improved detection of inflammation and should be pursued if the patient can tolerate the oral contrast. On the other hand, CT with positive luminal contrast (without enterography technique) can identify wall thickening, luminal narrowing, and adjacent inflammatory changes that may be seen in CD [19]. In addition, the complications of abscess formation or fistula formation can be detected at standard IV contrast CT in which the positive oral contrast may improve detection of complications. Sensitivities for abscesses are very good, ranging from 86% to 100% [27,36]. There is more variable performance for fistula detection with sensitivities ranging from 68% to 100% [27,40,42]. One study showed a very low sensitivity of 20% for enteroenteric fistulas in their series [40].

Although standard abdomen and pelvis CT can be done either with or without the administration of IV contrast, it is evident that many of the processes seen with an acute flare in CD require IV contrast for optimal assessment. Without IV contrast, such processes can only be inferred by associated findings, such as wall thickening. In fact, the importance of contrast can be underscored by the emphasis on determining the optimal timing of imaging following IV contrast administration as opposed to comparisons between IV contrast and noncontrast CT [22]. A prior meta-analysis that evaluated CT performance included studies that were all conducted with IV contrast [25]. There is clear consensus that noncontrast CT holds poorer performance compared against a CT with IV contrast.

CT Enteroclysis

CT enteroclysis is a CT-based examination in which a nasoduodenal tube is placed to allow controlled distention of the small bowel. Typically, neutral contrast is continuously infused into the small bowel during CT, and IV contrast is also administered. This procedure typically allows for better distention of the small bowel compared with oral ingestion at CT enterography [43,44]. Because of the active infusion, stenoses are more readily determined [43].

The overall diagnostic performance for CT enteroclysis is excellent (ie, >85% sensitivity, >90% specificity) [45-47], and this examination has been used as a reference standard for other modalities in various studies [41,47]. However, it is important to remember that detection of subtle evidence for CD is not needed in this clinical variant in which the patient is presenting acutely with a suspected flare or complication. Similar to other CT-based options, the assessment for the possible complications of CD, including obstruction, abscess, and fistula, can be made because of its underlying cross-sectional nature without additional advantage from the dedicated enteroclysis protocol.

In this specific variant, CT enteroclysis may be limited because it is dependent on the clinical acuity or severity of presentation. With a significant acute flare or complication, the patient would poorly tolerate CT enteroclysis because of the marked demands on the patient related to the placement of the nasoduodenal tube and need for active infusion of oral contrast. Here, the risks outweigh the added benefits of optimized bowel visualization, and this imaging choice should be avoided when acutely ill. If, however, the patient is relatively asymptomatic, CT enteroclysis may be an appropriate option with excellent diagnostic performance.

CT Enterography

CT enterography represents a CT examination with a specialized protocol. Neutral contrast by mouth is given in large amounts over a set time period to promote optimal distention of the small bowel [19-21]. Combined with other technical modifications, including thin collimation, multiplanar reconstruction, and IV contrast, this protocol maximizes the technique to depict inflammatory changes in the small bowel related to CD [20,22,23].

CT enterography is well suited to evaluate a potential acute flare or complication of CD. However, if the patient cannot tolerate the contrast requirements of the enterography technique, standard CT may be an option (although less sensitive, the findings of an acute flare are likely not subtle if the patient is acutely ill and unable to tolerate the contrast volume of CT enterography). The overall diagnostic performance for CT enterography is excellent. When an endoscopic standard is utilized, sensitivity for CD ranges from 75% to 90%, with a specificity of >90% [24-27]. The diagnosis of acute inflammation is made through visualization of thickened small bowel with mural stratification, as well as extraenteric processes that include engorged vasa recti/vasculature and surrounding inflammatory stranding [25,26,32-34]. Because CT enterography is a cross-sectional imaging modality, assessment for the possible complications of CD, including obstruction, abscess, and fistula, can be made similar to the ability of standard CT abdomen and pelvis [28,35-37].

Ultimately, the decision to select CT enterography versus a standard CT abdomen and pelvis is dependent on the ability to tolerate the oral contrast requirements of CT enterography. CT enterography is more sensitive for bowel changes related to CD than standard CT given the oral contrast optimization. However, the findings of CD in an acute flare are often not subtle and can be seen at standard CT. In addition, the complications including abscess or fistula formation may be easier seen at standard CT with positive oral contrast.

MR Enteroclysis

MR enteroclysis is a MR-based examination in which a nasoduodenal tube is placed to allow controlled distention of the small bowel. Typically, biphasic enteral contrast (low signal on T1 and high signal on T2) is infused, and IV contrast is given. There have been few studies evaluating performance in recent years. The overall diagnostic performance for MR enteroclysis is excellent and at least equivalent to MR enterography [49]. One comparison study between these two modalities demonstrated statistically better detection of superficial mucosal abnormalities over MR enterography but no difference for stenoses and fistulas [50].

In this specific variant, MR enteroclysis may be limited dependent on the clinical acuity or severity of presentation. With a significant acute flare or complication, the patient would poorly tolerate MR enteroclysis because of the marked demands on the patient related to the placement of the nasoduodenal tube and need for active infusion of oral contrast. Here, the risks outweigh the added benefits of optimized bowel visualization, and this imaging choice should be avoided when acutely ill. In addition, patients are likely unable to hold still, leading to increased artifact and poorer image quality. If, however, the patient is relatively asymptomatic, MR enteroclysis may be an appropriate option with excellent diagnostic performance.

MR Enterography

MR enterography combines contrast-enhanced MRI scanning using fast imaging techniques with an enterography protocol to optimize bowel distension [38]. As described with CT enterography, this requires the patient to ingest a large volume of oral contrast in a set time period. Additionally, the use of glucagon or prone imaging may help to

decrease bowel peristalsis and thus artifact. MR enterography holds excellent test performance characteristics (see below) equivalent to other optimized modalities, such as CT enterography.

The performance of MR enterography for CD is very good. Rates of sensitivity and specificity are 77% to 82% and 80% to 100%, respectively [24,66,67]; MR enterography can accurately display bowel-wall changes in CD [51-54]. Characteristic bowel-wall changes suggesting active inflammation include bowel-wall thickening, high T2 mural signal, mural hyper enhancement with mural stratification, and hyperemic vasa recta [55-64]. MR cine imaging is potentially useful, allowing for assessment of decreased bowel motility in the affected segments with CD [65]. Besides inflammation, MRI can detect complications for CD that include obstruction, abscess, or fistula. Test performance characteristics for complications are similar to CT enterography [27,28,35,40,68,69]. Overall, MRI is more prone to respiratory and bowel-motion artifact, despite the use of glucagon, which may lead to suboptimal examinations and more difficult interpretations.

MRI Abdomen and Pelvis

Standard MRI with a routine protocol (ie, MRI without and with IV contrast and without oral contrast enterography technique) can detect evidence of CD if the patient cannot tolerate large volumes of oral contrast. However, the lack of bowel optimization decreases evaluation of inflammation compared with MR enterography with optimized bowel technique. One study (n = 100) reported a sensitivity of 50% to 86% and specificity of 93% to 94% for wall thickening [73]. For CD complications, the diagnostic ability of MRI is similar to its CT counterpart with similar reported sensitivities and specificities in various series [27,40,58,72]. The sensitivity for stenosis/obstruction ranges from 87% to 92% with high specificities; detection performance remains high for abscesses, with sensitivity ranging from 86% to 100%. As with CT, the detection for fistulas is more variable, ranging from 40% to 100%. Because of the superior soft-tissue contrast, perianal disease, including fistulation to the perineum, is best evaluated with MRI, using a small field of view, focused examination [74-76].

Standard MRI without IV contrast has been investigated because of emerging concerns with IV gadolinium use and potential long-term accumulation in the body and brain. Noncontrast techniques such as DWI have been used to evaluate evidence for CD. There is growing literature examining its promise in detecting active disease versus quiescent disease, for complication evaluation, and disease monitoring, although many of the studies involve DWI in the context of enterography technique [77]. One study without enterography technique [48] reported a sensitivity of 49% to 82% and specificity of 85% to 93% for DWI, although lower specificities have been reported at meta-analysis [78] Overall, DWI appears to have moderate sensitivity but low specificity, leading to increased false positives for disease activity [77]. Thus, the current consensus is that noncontrast-only techniques such as DWI can be done, but there is likely improved performance with the information gained from post-IV contrast series.

In this specific variant, MR may be limited. Acutely ill patients are less likely to be able to hold still for the duration of an MRI examination, leading to increased artifact and poorer image quality. In these instances, other options may be preferable, particularly CT enterography or standard abdomen and pelvic CT.

US Abdomen and Pelvis

Transabdominal US can be an option in CD [84,85]. Technique requires a systematic survey pattern of the entire bowel with graded compression (ie, overlapping vertical sweeps with a high-frequency 5–17 MHz linear transducer) [11]. Sensitivities for disease detection range from 75% to 94%, with specificities of 67% to 100% for CD with demonstration of wall thickening [66,86-88]. The threshold for abnormal thickening is typically set at 4 mm. Besides wall thickening, findings include alteration of the US gut signature, presence of fat wrapping, and vascular changes [89-92]. US contrast and Doppler techniques appear helpful in determining inflammation [93-95]. The real-time assessment of bowel pliability and peristalsis can be helpful in the diagnostic evaluation. Transperineal or endoanal US is also helpful at assessing perianal fistulous disease related to CD [96].

However, patient factors such as obesity and guarding may not allow adequate compression with the US probe or large amounts of shadowing gas may obscure bowel, preventing an optimal examination. Location also affects diagnosis in which higher sensitivities for terminal ileal involvement are seen compared with more proximal small bowel [87]. False-positive diagnoses of abscesses are more likely at US [97].

Radiography Abdomen

Radiographs of the abdomen are limited in the evaluation of an acute flare or complication of CD. The ability to directly visualize bowel pathology is limited, and evidence for CD is instead inferred indirectly. There is little role for radiographs if the patient is not acutely ill. Radiographs may be useful in severely ill presenting patients for presence of bowel perforation or evidence for obstruction.

Fluoroscopy Small-Bowel Follow-Through and Fluoroscopic Enteroclysis
Historically, fluoroscopic contrast examinations of the gastrointestinal tract have been the primary imaging methods of choice in the evaluation of CD. SBFT (with or without per oral pneumocolon) and enteroclysis can be used to evaluate the small bowel for evidence of thickening and active disease [50,79]. In addition, internal fistulas can be detected [80], although other extramural complications, such as abscess formation are only indirectly visualized, which leads to decreased detection [27]. It has become evident; however, with the emergence of specialized cross-sectional imaging modalities, that the performance of contrast fluoroscopy is not as accurate for active disease compared with these other examinations [18,42,46,81,82]. Both SBFT and enteroclysis are hampered by their 2-D perspective, whereby pathology can be obscured because of overlapping bowel loops [18,82,83]. On the other hand, the real-time assessment for a fixed versus pliable nature of a segment of bowel can provide important ancillary information. Depending on institutional and surgeon preference, there may be a role in delineating the preoperative anatomy for the surgeon, although there has been a marked decline in fluoroscopic use over recent years.

Fluoroscopy Contrast Enema
Colonoscopy is the preferred examination of the colon in patients suspected of having inflammatory bowel disease [9]. It is superior to the barium enema for the detection of early inflammatory changes and has largely replaced it as the initial diagnostic examination [9]. Although contrast enemas can detect fistulas to other organs and sinus tracts, it is poor for abscess determination given its non-cross-sectional nature.

HMPAO WBC Scan
Leucoscintigraphy, or Tc-99m-HMPAO WBC scan, have demonstrated good sensitivities and specificities for intestinal inflammation in the 79% to 85% and 81% to 98% range, respectively [98]. Proponents contend that leucoscintigraphy is useful in the diagnosis and evaluation of activity and extent of disease [99] with performance results equivalent to cross-sectional imaging [28]. However, the disadvantages of this examination, such as the decreased ability to depict and therefore detect alternative diagnoses and the complicated time-consuming technical aspects (ie, labeling and handling of blood products), have limited its use in evaluation.

FDG-PET/CT Skull Base to Mid-Thigh
The addition of metabolic information from PET with the morphologic anatomic imaging of CT or MR shows promise. It may be helpful to better assess the level of active inflammation from fibrosis [100,101]. Studies also show improved assessment in the colon in a murine animal model [102], which points to potential future usefulness because the colon is less well evaluated with both CT enterography and MR enterography. At this point, there are few large-series published clinical studies, but small series show promising results [103,104].

Variant 3: Known Crohn disease, disease surveillance; monitoring therapy.

In this clinical scenario, the purpose of the imaging evaluation is to determine the presence or absence of disease activity in a relatively well CD patient (ie, mildly symptomatic to asymptomatic) in order to help determine medical management. This is important because promoting situations of complete mucosal healing has been associated with sustained clinical remission, reduced hospitalization rates, and decreased need for surgery [12,13,105]. As with endoscopy, imaging may better direct treatment based on objective findings because it is known that subjective symptomatology and other clinical parameters have shown poor correlation with disease activity [106]. Secondly, when CD strictures are detected, imaging can help determine whether the narrowing is predominantly due to active inflammation or due to fibrosis. This distinction is critical because the former responds to medical interventions, whereas the latter would be better treated surgically. Because of the cost and significant complications of agents such as infliximab, empiric treatment with these agents to make this distinction (ie, does treatment improve the stenosis) is less attractive.

CT Abdomen and Pelvis
Standard abdomen and pelvis CT with IV contrast with a routine protocol (ie, without oral contrast enterography technique) can detect evidence for active CD. CT with positive luminal contrast can identify wall thickening, luminal narrowing, and adjacent inflammatory changes that may be seen in CD [39]. However, mucosal enhancement is obscured and subtle enhancement may be missed without the bowel optimization present with enterography technique. The decreased performance compared against other modalities with optimized bowel protocol would argue against its use in this clinical variant in which the patient is relatively well and able to tolerate the increased oral contrast volumes. Standard abdomen and pelvis CT without IV contrast is further hampered when evidence of increased vascularity seen with IV contrast use is not available.

CT Enteroclysis

CT enteroclysis is a CT-based examination in which a nasoduodenal tube is placed to allow controlled distention of the small bowel. Typically, neutral contrast is infused and IV contrast given. Because of the active infusion, stenoses are more easily determined [43]. There have been few studies evaluating performance in recent years. The overall diagnostic performance for CT enteroclysis is excellent (ie, >85% sensitivity, >90% specificity) [45-47], and this examination has been used as a reference standard for other modalities in various studies [41,47].

The diagnosis of acute inflammation is made through visualization of thickened small bowel with mural stratification as well as extraenteric processes, including engorged vasa recti/vasculature and surrounding inflammatory stranding [43,44]. Similar to CT enterography, the ability to detect even mild inflammation makes it useful in monitoring therapy. CT enteroclysis has been shown to be helpful in assessing the status of disease in CD patients post resection at the anastomosis [107]. However, the determination between active disease and fibrosis in a stricture remains difficult based on enhancement characteristics only [108]. Because CT enteroclysis is a cross-sectional imaging modality, assessment for alternative diagnoses as well for the possible complications of CD including obstruction, abscess, and fistula can be made [43]. Although CT enteroclysis represents one of the modalities with highest disease detection capabilities, the invasive nature with nasoduodenal tube insertion and active infusion of contrast may make it less favorable from a patient perspective, unless a mild stricture without definite proximal dilation is the clinical question and active distention is needed to confirm this stricture [9]. In addition, the need for repeated examinations over time makes this a less attractive choice in this clinical variant.

CT Enterography

CT enterography represents a CT examination with a specialized protocol. Neutral contrast by mouth is given in large amounts over a set time period to promote optimal distention of the small bowel [19-21]. Combined with other modifications, including thin collimation, multiplanar reconstruction, and IV contrast, this protocol maximizes the technique to depict inflammatory changes in the small bowel related to CD [20,22,23]. Although the diagnostic performance is excellent (see below), the need for repeated examinations over time makes this a less attractive choice in this clinical variant.

The overall diagnostic performance for CT enterography is excellent. When an endoscopic standard is utilized, sensitivity for CD ranges from 75% to 90%, with a specificity of >90% [24-27]. The diagnosis of acute inflammation is made through visualization of thickened small bowel with mural stratification as well as extraenteric processes including engorged vasa recti/vasculature and surrounding inflammatory stranding [25,26,32-34]. Because of an excellent performance profile, CT enterography is able to assess for mucosal healing similar to MR enterography to help guide therapy [109]. One series (n = 63) demonstrated that CT enterography was able to detect wall changes, and influenced the treatment of CD patients [110]. However, regarding strictures, CT enterography has been considered poor in its ability to distinguish between active and fibrotic contributions to the stricture based on the presence or absence of above-mentioned findings (ie, mural hyper enhancement, thickening, engorged vasa recta, surrounding soft tissue thickening, etc) [108].

MR Enteroclysis

MR enteroclysis is a MR-based examination in which a nasoduodenal tube is placed to allow controlled distention of the small bowel. Typically, biphasic enteral contrast (low signal on T1 and high signal on T2) is infused, and IV contrast is given. There have been few studies evaluating performance in recent years. The overall diagnostic performance for MR enteroclysis is excellent and at least equivalent to MR enterography [49]. One comparison study between these two modalities demonstrated statistically better detection of superficial mucosal abnormalities over MR enterography but no difference for stenoses and fistulas [50].

In this specific variant, MR enteroclysis theoretically holds the same advantages as outlined for MR enterography because the difference between the two is related to active distention via the nasoduodenal tube at MR enteroclysis versus distention from oral ingestion at MR enterography. Thus, the ability to evaluate mucosal healing as well as assessment of strictures for active disease versus fibrosis as documented at MR enterography should be equivalent at MR enteroclysis [48]. However, the invasive nature with nasoduodenal tube insertion and active infusion of contrast may make it less favorable from a patient perspective, unless a mild stricture without proximal dilation is the clinical question and active distention is needed to confirm this stricture [9].

MR Enterography

MR enterography combines contrast-enhanced MRI scanning using fast imaging techniques with an enterography protocol to optimize bowel distension [38]. Similar to the case of CT enterography, this bowel optimization

technique requires the patient to ingest a large volume of oral contrast in a set time period. Additionally, the use of glucagon or prone imaging may help to decrease bowel peristalsis and thus artifact. MR enterography represents an ideal modality for repeated use to monitor therapy given its excellent test characteristics. Given the relatively well status of the patient, they are often able to hold still, and quality examinations are more likely to be consistently obtained.

The performance of MR enterography for CD is very good. Rates of sensitivity and specificity are 77% to 82% and 80% to 100%, respectively [24,66,67]; MR enterography can accurately display bowel-wall changes in CD [51-54]. Characteristic bowel-wall changes suggesting active inflammation include bowel-wall thickening, high T2 mural signal, mural hyper enhancement with mural stratification, and hyperemic vasa recta [55-64]. MR cine imaging is potentially useful, allowing for assessment of decreased bowel motility in the affected segments with CD [65]. Besides inflammation, MRI can detect complications for CD including obstruction, abscess, or fistula. Test performance characteristics for complications are similar to CT enterography [27,28,35,40,68,69].

MR enterography has been shown to correlate with response to therapy and mucosal healing [111,112]. One prospective multicenter study (n = 48) showed 90% accuracy of ulcer healing determination at MR enterography, utilizing ileocolonoscopy as the reference standard [113]. In addition, MR is able to utilize natural tissue contrast at T2W imaging to help in the determination between active inflammation and fibrosis, which is not possible with CT-based modalities. DWI, magnetization transfer imaging, and cine sequences at MR enterography can also be helpful. [111].

MR enterography without IV contrast has been investigated because of emerging concerns with IV gadolinium use and potential long-term accumulation in the body and brain. Noncontrast techniques such as DWI have been used to evaluate evidence for CD. There is growing literature examining its promise in detecting active disease versus quiescent disease for complication evaluation and disease monitoring [77]. Overall, DWI appears to have moderate sensitivity but low specificity, leading to increased false positives for disease activity [77]. Thus, the current consensus is that noncontrast only techniques such as DWI can be done but there is likely improved performance with the information gained from post IV contrast series.

MRI Abdomen and Pelvis

Standard MRI with a routine protocol (ie, without and with IV contrast and without oral contrast enterography technique) can detect evidence of CD if the patient cannot tolerate large volumes of oral contrast. However, the lack of bowel optimization decreases evaluation of inflammation. Thus, the key question of quiescent disease versus low levels of continuing inflammation central to this variant is not answered to the same confidence as with MR enterography (with optimized bowel technique). One study (n = 100) reported a sensitivity of 50% to 86% and specificity of 93% to 94% for wall thickening [73].

The literature on mucosal healing and MR has centered on MR enterography as opposed to standard MR without enterography protocol. MR enterography has been shown to correlate with response to therapy and mucosal healing [111,112]. One prospective multicenter study (n = 48) showed 90% accuracy of ulcer healing determination at MR enterography, utilizing ileocolonoscopy as the reference standard [113]. In this specific clinical scenario, the patient is typically able to tolerate enterography technique, and consequently, bowel optimization should be undertaken as opposed to standard MRI for this situation.

For CD complications, the diagnostic ability of MRI is similar to its CT counterpart with similar reported sensitivities and specificities in various series [27,40,58,72]. The sensitivity for stenosis/obstruction ranges from 87% to 92% with high specificities; detection performance remains high for abscesses, with sensitivity ranging from 86% to 100%. As with CT, the detection for fistulas is more variable, ranging from 40% to 100%. Because of the superior soft-tissue contrast, perianal disease including fistulation to the perineum is best evaluated at MRI, using a small field-of-view, focused examination [74-76].

Standard MRI without IV contrast has been investigated because of emerging concerns with IV gadolinium use and potential long-term accumulation in the body and brain. Noncontrast techniques such as DWI have been used to evaluate evidence for CD. There is growing literature examining its promise in detecting active disease versus quiescent disease for complication evaluation and disease monitoring, although many of the studies involve DWI in the context of enterography technique [77]. One study without enterography technique [48] reported a sensitivity of 49% to 82% and specificity of 85% to 93% for DWI, although lower specificities have been reported at meta-analysis [78]. Overall, DWI appears to have moderate sensitivity but low specificity, leading to increased false positives for disease activity [77]. Thus, the current consensus is that noncontrast only techniques such as DWI can

be done, but there is likely improved performance with the information gained from post IV contrast series. This reason, as well as the lack of a bowel distention optimization protocol, makes standard MRI without IV contrast less useful in this clinical variant.

US Abdomen and Pelvis

Transabdominal US can be effective option in CD [84,85]. However, in this variant, it may not be optimal given that areas of the abdomen may not be assessed because of shadowing bowel. However, there is emerging literature that US may be useful in therapy monitoring of CD patients [114,115]. In addition, contrast-enhanced US may be helpful in distinguishing between inflammatory and fibrotic disease [95].

The technique requires a systematic survey pattern of the entire bowel with graded compression (ie, overlapping vertical sweeps with a high-frequency 5–17 MHz linear transducer) [11]. Sensitivities for disease detection range from 75% to 94%, with specificities of 67% to 100% for CD with demonstration of wall thickening [66,86-88]. The threshold for abnormal thickening is typically set at 4 mm. Besides wall thickening, findings include alteration of the US gut signature, presence of fat wrapping, and vascular changes [89-92]. US contrast and Doppler techniques appear helpful in determining inflammation [93-95]. Like MRI, US holds advantages such as evaluating more proximal small bowel segments [116]. In addition, the real-time assessment of bowel pliability and peristalsis can be helpful in the diagnostic evaluation. Transperineal or endoanal US is also helpful at assessing perianal fistulous disease related to CD [96].

Patient factors such as obesity and guarding may not allow adequate compression with the US probe or large amounts of shadowing gas may obscure bowel, preventing an optimal examination. Location also affects diagnosis in which higher sensitivities for terminal ileal involvement are seen compared to more proximal small bowel [87]. False positive diagnoses of abscesses are more likely at US [97].

Radiography Abdomen

Radiographs of the abdomen are limited in the evaluation for CD. The ability to directly visualize bowel pathology is limited, and evidence for CD is instead inferred indirectly. There is little role for radiography in this clinical variant.

Fluoroscopy Small-Bowel Follow-Through

Historically, fluoroscopic contrast examinations of the gastrointestinal tract have been the primary imaging methods of choice in the evaluation of CD. SBFT (with or without per oral pneumocolon) and enteroclysis can be used to evaluate the small bowel for evidence of thickening and active disease [50,79]. In addition, internal fistulas can be detected [80], although other extramural complications such as abscess formation are only indirectly visualized, which lead to decreased detection [27]. It has become evident; however, with the emergence of specialized cross sectional imaging modalities, that the performance of contrast fluoroscopy is not as accurate for active disease as compared with these other examinations [18,42,46,81,82]. Thus, there is little evidence to support its use in this specific clinical variant in which the inflammation may be very subtle.

Both SBFT and enteroclysis are hampered by their 2-D perspective, whereby pathology can be obscured because of overlapping bowel loops [18,82,83]. On the other hand, the real-time assessment for a fixed versus pliable nature of a segment of bowel can provide important ancillary information. Dependent on institutional and surgeon preference, there may be a role in delineating the preoperative anatomy for the surgeon, although there has been a marked decline in fluoroscopic use over recent years.

Fluoroscopy Contrast Enema

Colonoscopy is the preferred initial examination of the colon in patients suspected of having inflammatory bowel disease [9]. It is superior to the barium enema for the detection of early inflammatory changes and has largely replaced it as the diagnostic examination [9].

HMPAO WBC Scan

Leucoscintigraphy or Tc-99m-HMPAO WBC scan have demonstrated good sensitivities and specificities for intestinal inflammation in the 79% to 85% and 81% to 98% range, respectively [98]. Proponents contend that leucoscintigraphy is useful in the diagnosis and evaluation of activity and extent of disease [99], with performance results equivalent to cross-sectional imaging [28]. However, the disadvantages of this examination, such as the decreased ability to depict and therefore detect alternative diagnoses and the complicated time consuming technical aspects (ie, labeling and handling of blood products), have limited its use in evaluation.

FDG-PET/CT Skull Base to Mid-Thigh

The addition of metabolic information from PET with the morphologic anatomic imaging of CT or MR shows promise. It may be helpful to better assess the level of active inflammation from fibrosis [100,101]. Studies also show improved assessment in the colon in a murine animal model [102], which points to potential future usefulness because the colon is less well evaluated at both CT enterography and MR enterography. At this point, there are few large series published clinical studies but small series show promising results [103,104].

Summary of Recommendations

- **Variant 1:** CT abdomen and pelvis with IV contrast, CT enterography, or MR enterography are usually appropriate for the initial imaging of suspected CD with no prior Crohn diagnosis. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 2:** CT enterography, MR enterography, and CT abdomen and pelvis with IV contrast are usually appropriate for the imaging of known CD with suspected acute exacerbation. These procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).
- **Variant 3:** MR enterography or CT enterography is usually appropriate for the disease surveillance and monitoring therapy of known CD. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging

examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document [117].

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."		

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