Imaging for Inflammatory Bowel Disease

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KEYWORDS

• Imaging • Inflammatory bowel disease • Crohn's disease • Ulcerative colitis
• CT enterography • MRI • MRE

KEY POINTS

- Plain abdominal radiographs can diagnose complications from inflammatory bowel disease and should be a first imaging study in critically ill patients to evaluate for free intraperitoneal air.
- Upper gastrointestinal series with small bowel follow through (SBFT) is useful in diagnosing stricturing Crohn's disease, and upper gastrointestinal series with SBFT may diagnose fistulas related to Crohn's disease.
- Abdominal computed tomographic (CT) scanning is usually the preferred initial radiographic imaging study in patients with inflammatory bowel disease; CT scans can evaluate the entire gastrointestinal tract and other intra-abdominal organs.
- MRI is a noninvasive, nonionizing imaging modality useful in evaluating intestinal and extraintestinal pathology, particularly in Crohn's disease.
- Capsule endoscopy (CE) provides state-of-the-art imaging of the mucosal lining of the intestines, particularly in the small bowel; CE is an expensive test but is outpatient, noninvasive, with no nonionizing radiation.

PLAIN RADIOGRAPHS

Introduction

Plain abdominal radiographs still play a role in imaging for inflammatory bowel disease (IBD) including diagnosing dilation, obstruction, bowel perforation, bowel wall thickening, or loss of haustral markings. Radiographs can be portable, are widely available, quick, painless, inexpensive, and have low radiation dose exposure making them a good initial diagnostic test in some scenarios (**Table 1**). However, plain radiographs do not give much detailed information and cannot make a definitive diagnosis of IBD.

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Table 1
Clinical relevance of plain radiograph findings

Plain Radiograph Findings	Clinical Relevance
Free air (pneumoperitoneum)	Perforated viscous
Thumbprinting	Colitis (ischemic, ulcerative, or infectious)
Megacolon	Colon dilated >6 cm, concern for perforation
Tubelike/lead-pipe/featureless	Chronic ulcerative colitis

Radiographs use invisible electromagnetic energy beams to produce images of internal tissues, bones, and organs on film. Standard radiographs are performed for many reasons. Abdominal radiographs may be taken with the patient in the upright position (erect abdominal view), lying flat with the exposure made from above the patient (supine abdominal view), or lying flat with the exposure made from the side of the patient (cross-table lateral view). The left side-lying position (left lateral decubitus view) may be used for patients who cannot stand erect.

A plain flat and upright abdominal radiograph should be the first imaging study in critically ill patients in whom a perforation is suspected. Perforation is identified by free air on an upright abdominal radiograph (**Fig. 1**) and should be ordered on any patient with acute onset abdominal pain. These images can be performed in most settings with portable radiograph machines and are widely available.

Patients with ulcerative colitis may exhibit "thumbprinting" on a plain abdominal radiograph. On radiograph the distance between loops of bowel is increased because of thickening of the bowel wall from inflammation (**Fig. 2**). Although classically described with ischemic colitis, this finding is also noted in other forms of colitis, including ulcerative and infectious colitis.[1]

Patients with fulminant colitis may be followed with serial abdominal radiographs to diagnose "toxic megacolon." Toxic megacolon is defined as dilation greater than 6 cm and is an indication for emergent surgical intervention to prevent perforation. Chronic

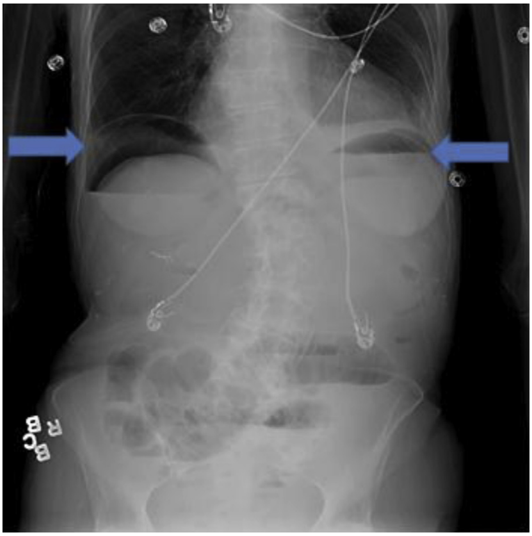

Fig. 1. An upright abdominal radiograph in a patient with known Crohn's disease and acute onset of abdominal pain. *Arrows* indicate pneumoperitoneum.

Fig. 2. Radiograph of ulcerative colitis "thumbprinting." *Arrows* show thickened colon wall.

ulcerative colitis may appear as a "tubelike" or "lead-pipe" colon with loss of haustral markings and a "featureless" colon on plain radiograph.

Contrast Radiologic Studies

Upper gastrointestinal series with small bowel follow through

Upper gastrointestinal series with small bowel follow through (SBFT) involves ingestion of a barium solution with subsequent radiologic imaging of the small intestine with fluoroscopy and radiograph. Features of Crohn's disease involving the small bowel include narrowing of the lumen with nodularity and ulceration, a "string" sign from advanced narrowing or with severe spasm, a cobblestone appearance, fistulas and abscess formation, and separation of bowel loops suggesting transmural inflammation with bowel wall thickening. Gastroduodenal Crohn's disease may manifest as gastric antral narrowing and stricturing of the duodenum.

Double-contrast barium enema

Double-contrast barium enema is performed by inserting a tube in the rectum, instilling barium to outline the colon and rectum, then passing air through the tube to enhance the detail. Finally, multiple radiographs are obtained from different views. Patients must take laxatives before the study. In patients with mild ulcerative colitis, findings on double-contrast barium enema may consist of a fine granular appearance of the colon as a result of mucosal edema and hyperemia, or a diffusely reticulated pattern with superimposed punctate collections of barium in microulcerations. In chronic or severe disease, there may be spiculated collar button ulcers, shortening of the colon, loss of haustral folds, narrowing of the luminal caliber, pseudopolyps, and filiform polyps. Barium enema should be avoided in patients who are severely ill because it may complicate toxic megacolon, and those with an obstruction because perforation may occur. Advantages include low-risk procedure, less expensive than other tests, and no sedation necessary as with colonoscopy. Disadvantages are preprocedure laxative preparation, discomfort from the test, and radiation exposure.

ABDOMINAL COMPUTED TOMOGRAPHIC AND COMPUTED TOMOGRAPHY ENTEROGRAPHY

Abdominal computed tomographic (CT) scanning is the preferred initial radiographic imaging study in patients with IBD. It allows detailed evaluation of the entire gastrointestinal tract and associated findings, such as abscesses and fistulas. In addition, it allows evaluation of other intra-abdominal organs that may exhibit extraintestinal manifestations of IBD, such as dilated hepatic ducts in the liver of patients with primary sclerosing cholangitis.

A CT scan is an imaging method that uses x-rays to create pictures of cross-sections of the body. The patient lies on a narrow table that slides into the center of the CT scanner. Modern "spiral" scanners can perform the examination by rotating the x-ray beam around the patient without stopping. A computer creates separate images of the body area, called slices. These images are stored, viewed on a monitor, or printed on film. Three-dimensional models of the body area are created by stacking the slices together in multiple configurations.

CT scanning is not a very sensitive test for detecting the mucosal abnormalities of mild or early ulcerative colitis. Inflammatory pseudopolyps may be seen in well-distended bowel. In areas of mucosal denudation, abnormal thinning of the bowel may also be evident. A cross-section of the inflamed and thickened bowel has a target appearance with concentric rings of varying attenuation, also known as mural stratification.[2] More advanced ulcerative colitis often has a hallmark finding of diffuse colonic wall thickening (>3 mm). Benefits of CT are the ability to evaluate intraluminal and extraluminal disease, guide and monitor response to treatment, and detect complications.

CT may suggest the diagnosis of Crohn's disease with thickening of small bowel, especially the terminal ileum. Fig. 3 shows an axial-view CT scan of a patient with Crohn's disease. Fig. 4 is a coronal-view CT scan of another patient with Crohn's disease.

CT enterography (CTE) uses oral contrast, intravenous contrast, and thin-cut multiplanar CT image acquisitions. Neutral oral contrast is used to distend the small bowel allowing for better evaluation of the wall of the small bowel, which is difficult to see with standard barium solutions. It is useful for the evaluation of suspected or known Crohn's disease and can detect dilation, obstruction, fistulas, and abscesses. Fig. 5 shows thickening of the small bowel as seen in Crohn's disease. These studies should be used when clinically indicated because there is increasing concern for repeated exposure to radiation from CT scanning performed in patients with IBD.[3]

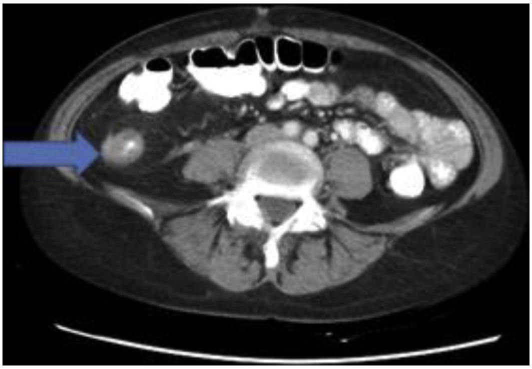

Fig. 3. Axial view CT scan of a patient with Crohn's disease. The *arrow* shows the thickened terminal ileum with contrast filling the narrowed lumen.

Fig. 4. Coronal view CT scan of another patient with Crohn's disease. The *thin arrow* points to the thickened and inflamed terminal ileum; the *thick arrow* points to the inflamed hepatic flexure colon.

The cumulative radiation dose of multiple CT scans over decades may increase cancer risk in patients with IBD. In one study, 371 patients with Crohn's disease were examined for radiation exposure from radiographic studies over 5 years.[4] The mean cumulative radiation exposure was 14 mSv, with a range of 0 to 303 mSv. Although most patients had a low radiation exposure, 27 patients (7%) had a

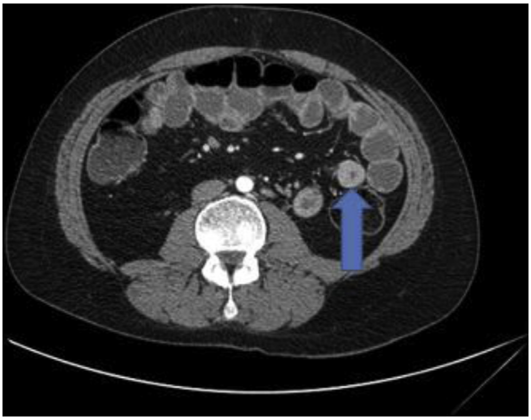

Fig. 5. Thickening of the small bowel as seen in Crohn's disease. The *arrow* points to the thickened small bowel loop.

cumulative exposure of more than 50 mSv (a cutoff suggesting a high risk of complications from radiation exposure). We advocate judicious use of studies using ionizing radiation, especially in children and young adults.

MRI

MRI and associated techniques, such as magnetic resonance enterography (MRE), are noninvasive, nonionizing imaging modalities used to evaluate gastrointestinal conditions, such as IBD. Current technology allows for fast-sequence, multiplanar, high-resolution imaging of soft tissues, such as the small and large bowel. In IBD, these images provide useful anatomic and functional information of the intestines and surrounding structures. At present, MRI technology is most useful for assessing small bowel disease and perineal disease including fistulas and sinus tracts.[5,6] This modality also allows clinicians to evaluate extraintestinal structures, such as the pelvic floor,[5] and help surgeons plan for operative interventions. The application of MRI technology to diagnosing IBD and informing treatment plans continues to grow and surgeons should be familiar with its advantages and disadvantages over other imaging modalities (**Box 1**).

Technique

MRI generates images by spatially localizing signal intensities from water molecules excited by oscillating magnetic fields. The theory was pioneered in the 1970s by Dr Paul Lauterbur at Stony Brook University and Dr Peter Mansfield at the University of Nottingham, England and won them the 2003 Nobel Prize in Physiology or Medicine. At appropriate resonance frequencies, excited hydrogen atoms emit radiofrequency signals that are captured by receiving coils. The rate at which these atoms return to equilibrium states helps determine differences between tissue types. Image contrast is controlled by varying the time between signal detection and magnetization to produce T1 (spin-lattice) and T2 (spin-spin) images. T1-weighted imaging is useful for assessing fatty tissue, liver lesions, and morphologic information. T2-weighted imaging better assesses edema and inflammation. Contrast agents, usually chelates of gadolinium, are administered intravenously to improve imaging quality. MRI contrast agents have far fewer nephrotoxic effects than intravenous CT contrast agents.[7]

Patients are placed either prone or supine on a sliding table that advances into a magnetic bore of varying strength, typically rated 1.5 T in medical applications with commercial ranges of 0.2 to 7 T. Because of the strong magnetic field, all patients are prescreened for MRI-unsafe devices and objects, either attached or implanted including metallic material. Ear plugs or audio systems are often used to minimize the loud noise level generated from the oscillating magnetic coils. Because multiple imaging sequences are obtained, the entire examination can last from 20 to 60 minutes.

Box 1
MRI

Advantages	Disadvantages
Differentiates active inflammation from fibrosis	Cost
Nonionizing radiation, noninvasive	Time-consuming
Excellent soft tissue resolution	Less available than CT
Provides structural and functional anatomy	Need experienced radiologists
Provides information on extraintestinal pathology	—
MRI contrast less toxic than CT intravenous contrast	—

Postprocessing workstations receive the image sets and construct multiplanar views for radiographic interpretation. Several sequences including T2-weighted, gadolinium-enhanced T1-weighted, and fast-imaging with steady-state precession provide the most diagnostic information relevant to IBD, such as active inflammation.

MRE is an MRI with the addition of bowel-distending luminal contrast. MRE is similar to CTE in its intent to detect luminal and submucosal pathology but completely avoids the use of ionizing radiation. Unlike MR enterolysis where contrast agents are introduced via a nasojejunal tube, patients undergoing MRE drink a large volume (1–1.5 L) of a water-based oral contrast agent that promotes bowel distention. To maintain distention and provide the clearest lumen-to-bowel wall contrast, osmotic viscous agents, such as mannitol, are also administered to decrease water absorption. These oral mixtures are administered 20 to 30 minutes before imaging. MRE then requires an additional 30 to 45 minutes of table time. Although it takes longer to perform than CTE, MRE produces high-quality images with comparable results with other types of enterographies.

Indication for Use

Current evidence supports the use of MRI as an imaging modality in evaluating patients with Crohn's disease. Its chief strength is the ability to discern active inflammation from fibrosis in abnormal and thickened bowel.[8] Active inflammation appears bright on T2 single-shot fast spin echo sequences because of increased water within inflamed bowel walls and has a layered pattern of enhancement on T1 sequencing because of gadolinium specificity for active disease.[9] Distinguishing between the two pathophysiologic processes has direct therapeutic implications. Fibrotic bowel, for example, reflects permanent physical changes and is likely irreversible with additional medical therapy. Surgery with resection is favored. On the contrary, active inflammation in a segment of bowel suggests that permanent, physical changes have not occurred and more aggressive medical therapy may be effective (**Fig. 6**). In this situation, surgery is not the recommended first-line intervention. Imaging modalities, such as SBFT and even CT scans, cannot readily distinguish between these detailed characteristics of the bowel wall. MRI therefore has special ability in the evaluation of small bowel Crohn's disease because it can significantly alter treatment plans from medical to surgical or vice versa.

The advantages of MRI over conventional methods, such as SBFT, were reported in a recent prospective study comparing MRI with SBFT in 30 adult patients with recurrent Crohn's disease.[10] Although SBFTs demonstrated strictures and enteric fistulas, MRI identified active inflammation within those strictures based on transmural changes, vascular effects, and lymph node enlargement. MRI also identified extraintestinal abnormalities, such as gallstones and liver lesions. Based on these radiographic findings, the authors concluded that SBFT is a reasonable diagnostic tool to use in Crohn's disease, but if available, MRI should be the preferred imaging choice in assessing recurrent Crohn's disease. Whether the overall treatment plan and outcomes of these patients were affected by these additional MRI findings was not examined.

MRE and CTE have comparable diagnostic yields in assessing small bowel disease in Crohn's disease.[11] Both require luminal distention with oral contrast agents and can similarly identify disease localization, wall thickening, bowel wall enhancement, enteroenteric fistulas, and mesenteric lymphadenopathy.[12] Although CTE may provide higher-resolution image quality, MRE is an acceptable alternative as a diagnostic tool and most importantly does not use ionizing radiation. Because many patients with IBD are young, their lifetime risk of radiation from repeat imaging, such as CT

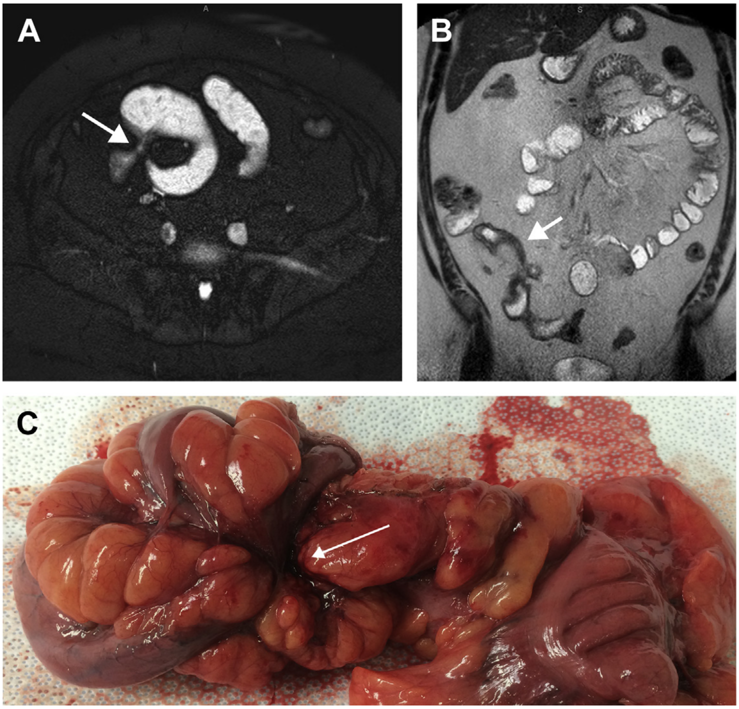

Fig. 6. MRI of abdomen (T2-weighted) of patient with Crohn's disease with enteroenteric fistulas and obstructing fibrosis (*arrows*) of the distal ileum in (*A*) axial (T2) and (*B*) coronal (T2) planes. Minimal active inflammation was observed and the patient underwent surgical resection of the distal ileum and cecum, which confirmed dense fibrosis and interloop fistulas (*C*).

scans, is substantial and unrealized.[13] In children with known IBD, MRI is now recommended as first-line imaging versus CT, which should be reserved only in emergency situations or when MRI is contraindicated.[14,15]

MRI is superior to other imaging modalities including CT in detecting perineal fistulas and sinus tracts with reported sensitivities of more than 80%.[16–18] Additional studies have shown that MRI is more accurate than an experienced surgeon's assessment of fistulas in the operating room and can detect tracts that would otherwise go undetected.[19,20] Although routine MRI scanning for anorectal fistulas is likely not necessary, in difficult Crohn's cases MRI can delineate complex and high fistulas (**Fig. 7**). MRI is less effective for mapping short, superficial fistula tracts. The preoperative assessment of fistula anatomy can guide surgeons during surgical interventions by better visualizing the relationships of the fistula to the internal sphincter muscle and pelvic floor. In equivocal cases, MRI can even exclude the presence of a fistula. These diagnostic data better inform treatment decisions in IBD cases, such as Crohn's disease, and many would argue that for perineal disease, MRI of the pelvis has become the imaging gold standard.

The role of MRI in diagnosing and treating chronic ulcerative colitis (CUC) is less clear. Early studies suggested that MRI was comparable with endoscopy in distinguishing CUC from Crohn's and in assessing disease severity when compared with tissue biopsies.[6] These findings are contradicted by more recent studies in children

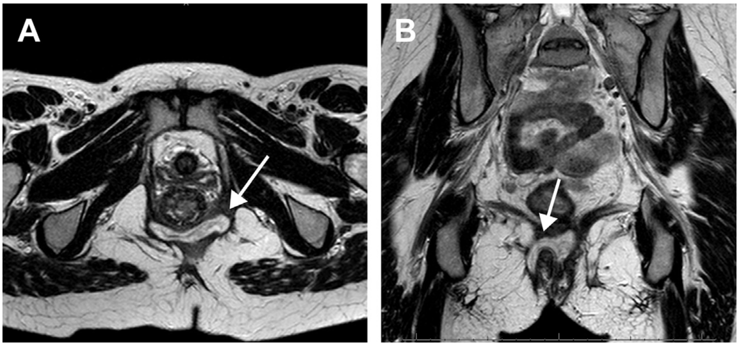

Fig. 7. MRI of pelvis (T2-weighted) showing in (*A*) axial and (*B*) coronal views a complex Crohn fistula with transsphincteric components and posterior bilateral extension in the intersphincteric plane (*arrows*).

demonstrating that MRI could not distinguish between Crohn's and CUC unless the terminal ileum was involved.[21] Comparisons of MRI with colonoscopy suggest that MRI can detect more fistulas arising from the colon than endoscopic evaluation, but these cases were likely related to Crohn's disease involving the colon instead of CUC.[22] Until more studies establish the clinical benefit of MRI over endoscopy in the evaluation of the colon, there is at present a limited role of MRI in evaluating CUC.

Limitations

MRI is significantly more expensive than plain radiograph, ultrasound (US), and CT. The costs arise from the at least $1 million average price for a 1.5-T MRI scanner, lifetime equipment maintenance, facility charges, and professional charges for radiologists. Cost-effectiveness research comparing MRI with other modalities is sparse, but available studies have suggested that the high cost may be justifiable in the long-term for certain situations, such as patients who are at high-risk for intravenous contrast agents[23] or in young patients who have more life-years to be exposed to radiation.[13] For the young IBD population, repeat imaging is common and MRI may therefore be cost-effective when balanced against the costs of complications from excess radiation exposure.

MRI technology is far less available than imaging modalities, such as CT scans. In 2010, the Centers for Disease Control and Prevention estimated that the United States had 26.5 MRI units versus 34.3 CT units per million population.[24] Smith-Bindman and colleagues[25] analyzed electronic records from six large integrated US health systems and found that MRI use increased from 17 to 65 MRIs per 1000 enrollees from 1996 to 2010. Concurrently, CT scans increased from 52 to 149 CTs per 1000 enrollees, more than twice the rate of MRI use. Widespread adoption of MRI is increasing but limited by available MRI units and experienced radiologists who can interpret results, such as MREs. As a result, CT technology, such as CTEs, is more commonly used in the evaluation of IBD.

Future Direction

MRI will be increasingly used in the diagnosis and management of IBD especially in Crohn's disease. Although its role in CUC remains to be determined, MRI has demonstrated clear benefit in assessing perineal disease for fistulas and sinus tracts. Its diagnostic use in assessing Crohn's small bowel disease is also becoming increasingly evident when compared with other imaging modalities. For young patients who will undergo repeat imaging, MRI likely has long-term benefit with its avoidance of ionizing radiation. As MRI continues to progress in availability and technique, future studies will need to more firmly establish its cost-effectiveness on diagnosis, treatment, and outcomes compared with the other available imaging modalities for IBD.

ULTRASOUND

US for IBD requires high-frequency (5–17 MHz) linear array probes for the US machine. High-frequency linear-array probes provide increased spatial resolution of the intestinal wall, which is essential for the assessment of wall diameter and wall layer discrimination. Compounding technology allows image reconstruction using signal responses from different frequencies or from viewing in different directions that results in an increase in contrast resolution and border definition of bowel wall architecture. Color or power Doppler imaging and contrast-enhanced US provide detailed information on mural and extraintestinal vascularity, which reflects inflammatory disease activity.[26]

For US diagnosis of IBD, one must understand of the anatomic location of Crohn's disease and ulcerative colitis. US does not provide a continuous and complete examination of the small and large bowel. The ileocecal region and the sigmoid colon can be identified in all patients. The left and right colon is adequately evaluated in most patients. The colonic flexures (especially the left flexure) are more difficult to visualize because of their cranial position and ligamentous fixation to the diaphragm. The transverse colon is identified in most patients, but complete examination is not easy to achieve because of its variable anatomy. The rectum and anal region cannot be visualized accurately by the transabdominal route because of their pelvic location. Transperineal US is useful in the evaluation of the perianal region and the distal rectum.[26,27]

US is used for small bowel imaging of IBD more frequently in Europe and at some centers in the United States. The sensitivity and specificity vary depending on operator experience, but are reported to be between 75% and 88%, and 93% and 97%, respectively.[28–30] Sonographic features suggesting small bowel involvement with Crohn's disease include bowel wall thickening and stiffness, and changes in the bowel wall stratification, but intestinal gas frequently obscures the bowel wall. Mucosal abnormalities are not detectable by US. The clinical role of US in ulcerative colitis is less well established as compared with Crohn's disease.

Future Directions

Small intestine contrast US is a new technique in which a nonabsorbable contrast solution (eg, polyethylene glycol 3350) is given orally before abdominal US. As with all US tests, small intestine contrast US sensitivity and specificity highly depends on the experience of the operator and is not commonly performed at this time.[31]

CAPSULE ENDOSCOPY

Wireless capsule endoscopy (CE) is an advanced imaging technique that is being increasingly used in the evaluation of IBD. Developed originally to evaluate small bowel for sources of occult bleeding with Food and Drug Administration approval in 2001, CE is emerging as an alternative method to evaluate the small bowel in IBD, particularly in Crohn's disease. Among patients with Crohn's disease, more than 30% have small bowel involvement only and 40% have both small bowel and colon involvement.[32] In many situations, the diagnosis of IBD, such as Crohn's disease, may be unclear. When traditional diagnostic attempts, such as endoscopy or SBFT, fail or are equivocal, CE may be considered an alternative modality to aid with the diagnosis and evaluation of the small bowel.

Technique

CE is a painless and radiation-free technique that requires no patient sedation. Additional benefits of CE include its ease-of-administration in the outpatient setting and patient satisfaction. Patients swallow an approximately 11 × 26 mm pill that contains a video camera, LED lights, a radio transmitter, and battery (**Fig. 8**). The pill transits through the small bowel in approximately 4 hours and colon in 24 to 48 hours before being excreted. Video images up to six frames per second are wirelessly transmitted to a portable device and downloaded to a computer. Equipment costs including the capsule ($500) are estimated to total $20,000 to $33,000.[33] In most cases, an experienced gastroenterologist reviews the series of images, which takes 30 minutes to 2 hours.[34] The first capsule developed was called the PillCam SB (Given, Yoqnem, Israel), which has now been updated to the third-generation PillCam SB3 with wider viewing angles and automatic light control. In 2007, Olympus (Lake Success, NY) developed a competing capsule (EndoCapsule), which may have longer battery life but comparable diagnostic yield compared with the PillCam.[35] A third pill approved by the Food and Drug Administration in 2013 called the (MiroCam, Seoul, Korea) uses a novel mode of transmission called electric field propagation to transmit images. Comparisons with EndoCapsule demonstrated similar diagnostic yields in 50 patients but the concordance between the two models was only 68%.[36] These studies illustrate a technical limitation in that pills often tumble through the small bowel and transmit an incomplete picture of the luminal surface.

History

One of the first reports of CE being used specifically in patients with IBD was in 2003.[37] Fireman and colleagues[37] used CE to evaluate 17 patients with normal colonoscopies and small bowel radiographs but clinical suspicion for Crohn's disease. Twelve (71%) patients were found to have mucosal changes, such as erosions, ulcers, and strictures, which were visually consistent with Crohn's. Other case studies have further demonstrated that CE can visually confirm small bowel lesions in 43% to 65% of

Fig. 8. Capsule endoscopy pill.

patients with completely negative colonoscopies and small bowel radiographs.[38–40] These early studies suggested that CE was sensitive in detecting mucosal abnormalities and might be useful in aiding diagnosis for equivocal cases in Crohn's disease.

Comparison of CE with other imaging modalities, such as small bowel enterography, SBFT,[41] and CTE,[42] consistently shows that CE can detect small bowel abnormalities that are missed by conventional tests (**Box 2**). In these cases, the detected mucosal lesions are often small and located in the proximal ileum or jejunum, areas that are poorly accessible with endoscopic techniques. These studies indicate that CE is a more sensitive test in detecting mucosal lesions compared with small bowel enterography, SBFT, and CTE. CE provided only visual documentation, however, and it remained unproven whether these abnormalities represented pathologic Crohn's disease because no biopsies were available for confirmation. Further research is needed to investigate whether the higher detection of mucosal abnormalities changes overall prognosis and therapeutic plans in IBD.

Indication for Use

Although CE has a clear role in the management of occult gastrointestinal bleeding,[43] there is no established role of this new technology in the present management of IBD. CE is at most a useful alternative method to evaluate the bowel in IBD when other conventional methods fail or are equivocal. Current best-practice recommendations are based on small, heterogeneous studies. A recent meta-analysis[44] that included 223 patients from 11 studies concluded that CE significantly increased diagnostic yields by 25% to 40% over barium studies and CT imaging. It is important to recognize that these higher diagnostic yields simply meant that a greater number of positive findings were detected. There was no gold standard diagnosis to confirm the clinical relevance of these findings. These challenges limit many of the studies on comparative effectiveness of CE in IBD.

Additional evidence needs to be accumulated before CE becomes first-line imaging in IBD. In 2008, Solem and colleagues[45] directly compared CE with CTE, ileocolonoscopy, and SBFT in 41 patients with suspected or known Crohn's disease. Each patient underwent all four tests in 4 consecutive days, which minimized the preparation required for each study. CE had the highest sensitivity (83%) but was not statistically significant when compared with the other three modalities. Calculated specificity was the lowest for CE (53%). Several patients (17%) had partial small bowel obstructive findings, but none experienced capsule retention. The authors were cautious in their recommendations for CE based on these findings and suggested that CE should not be used as a first-line diagnostic test in IBD. These findings are consistent with opinions that CE is more sensitive than conventional imaging modalities but specificity and positive predictive values are not fully established.[46]

Box 2
Wireless capsule endoscopy

Advantages	Disadvantages
Sensitive to identifying mucosal abnormalities	Specificity and positive predictive values not known
Useful test when other imaging modalities negative	Cost
Easy to administer	Requires experienced gastroenterologist to review
Nonionizing radiation	Capsule retention
No sedation required	Nontherapeutic, no biopsies possible

Limitations

Capsule retention is the most feared complication from CE. In one of the largest reported series of more than 900 patients evaluated for obscure bleeding, capsule retention occurred in 0.75% patients that required surgical intervention.[47] Capsule retention rates are higher in the IBD population, particularly among Crohn's disease with its associated strictures, and have been reported in the 1.4% to 6.7% range.[39,40,48] Generally, if there is concern for capsule retention, a plain abdominal radiograph at 14 days after capsule ingestion visualizes the pill. Known obstructions and stricturing disease are a relative contraindication for undergoing CE. As a result of these concerns for capsule retention, a "patency" capsule (M2A, Given Imaging) was developed with an impermeable but absorbable membrane of lactose/barium. The M2A patency capsule membrane dissolves in 40 to 100 hours[49] but studies have shown persistent complication rates of 3% to 13%, probably because the dissolution times are too long.[33] A newer version of the patency capsule, the Agile (Given Imaging), has been recently developed with earlier onset of membrane dissolution (<30 hours) after ingestion. The Agile patency capsule has been tested and found to be safe in small studies.[50]

Besides higher costs, additional limitation for CE includes its nontherapeutic capabilities. In its current technology, CE is purely diagnostic and can only take static images of the luminal intestinal wall. Positive findings, such as mucosal erythema or ulcerations, need to be correlated to clinical suspicion and no biopsies or tattooing are possible. If a test were positive, then additional, invasive testing may need to be performed.

Future Direction

At present, CE is an alternative imaging modality and adds to the armament of radiographic tools for clinicians to use in IBD. Several clinical questions remain to be answered with CE. These include better defining the role of CE in IBD therapy and its use in determining severity of disease, medical response to therapy, and clinical usefulness in managing indeterminate colitis and CUC.[51] Future studies need to investigate the comparative effectiveness of CE with other imaging modalities and account for patient preferences during diagnostic work-up with comparable tools.

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