Pelvic Pain: Ultrasound of the Bowel

Caitlin T. McGregor, MD, FRCP

KEYWORDS

• Ultrasound • Bowel • Appendicitis • Diverticulitis
• Crohn's disease • Pelvis

RIGHT LOWER QUADRANT PAIN: GASTROINTESTINAL ULTRASOUND

Ultrasound (US) is a useful modality for women of reproductive age presenting with acute or chronic lower quadrant pain. It is superior to CT for the evaluation of the uterus and ovaries, does not involve radiation, and is widely available. The most recent American College of Radiology Appropriateness Criteria for acute pelvic pain in the reproductive age group states that transvaginal US should be used as the initial test when obstetric or gynecologic etiologies are suspected.[1] In the setting of a negative β-hCG result and a clinical suspicion of gastrointestinal (GI) or genitourinary disease, a CT scan is a useful first test.[1] Clinical diagnosis, however, can be especially challenging in reproductive women because gynecologic causes, such as tubo-ovarian abscess, ruptured ovarian cyst, and ovarian torsion, can have a similar presentation to GI tract disease. Pelvic pain, fever, nausea, vomiting, and an elevated white count are nonspecific. When a uterine or ovarian cause for a patient's symptoms is not found on US, a systematic search must be performed for nongynecologic causes, including diseases of the bowel. Correctly diagnosing both gynecologic and nongynecologic causes of pelvic pain on US allows appropriate triaging and correct initiation of medical versus surgical therapy. This avoids unnecessary radiation and laparotomy. An understanding of both transabdominal and transvaginal sonography of the GI tract is, therefore, essential in performing a complete pelvic evaluation of premenopausal women presenting to the US department with pelvic pain. This article includes a review of the anatomy of the GI tract and bowel wall in addition to the techniques used to perform a thorough evaluation of the bowel with US. GI causes of pelvic pain are then discussed, including appendicitis, diverticulitis, inflammatory bowel disease, epiploic appendagitis, omental infarction, and infection.

ANATOMY

The stratified appearance of the normal bowel wall on US reflects its histologic construction (**Fig. 1**). The innermost echogenic line corresponds to the interface between the mucosa and the lumen. The next concentric hypoechoic ring is the muscularis mucosa, followed by the echogenic submucosa and finally by the outermost hypoechoic muscularis propria. Histologically this muscular layer is composed of a longitudinal layer and a circular layer; however, these 2 layers are not resolved on US. The serosa is the outermost thin echogenic line but is not always visible because it blends in with the adjacent echogenic fat. This concentric arrangement is constant throughout the GI tract from the esophagus to the rectum, including the appendix. Of CT, MR imaging, and US, US is the only modality to resolve all 5 layers, which makes it particularly useful in evaluating the bowel.

Understanding the mesenteric attachments is important when evaluating the bowel by any modality. On US, knowledge of which segments are fixed in position and which segments are mobile aids in localizing the segment of interest. A mesentery is a double layer of visceral peritoneum that wraps around a segment of bowel and attaches it to the posterior abdominal wall. The small bowel mesentery attaches along the posterior abdominal wall in a line from the left side of L2 downwards and rightwards toward the

The author has nothing to disclose.
Division of Abdominal Imaging, Department of Medical Imaging, Sunnybrook Health Sciences Centre, University of Toronto, 2075 Bayview Avenue, Toronto, ON M4N 3M5, Canada
E-mail address: caitlin.mcgregor@sunnybrook.ca

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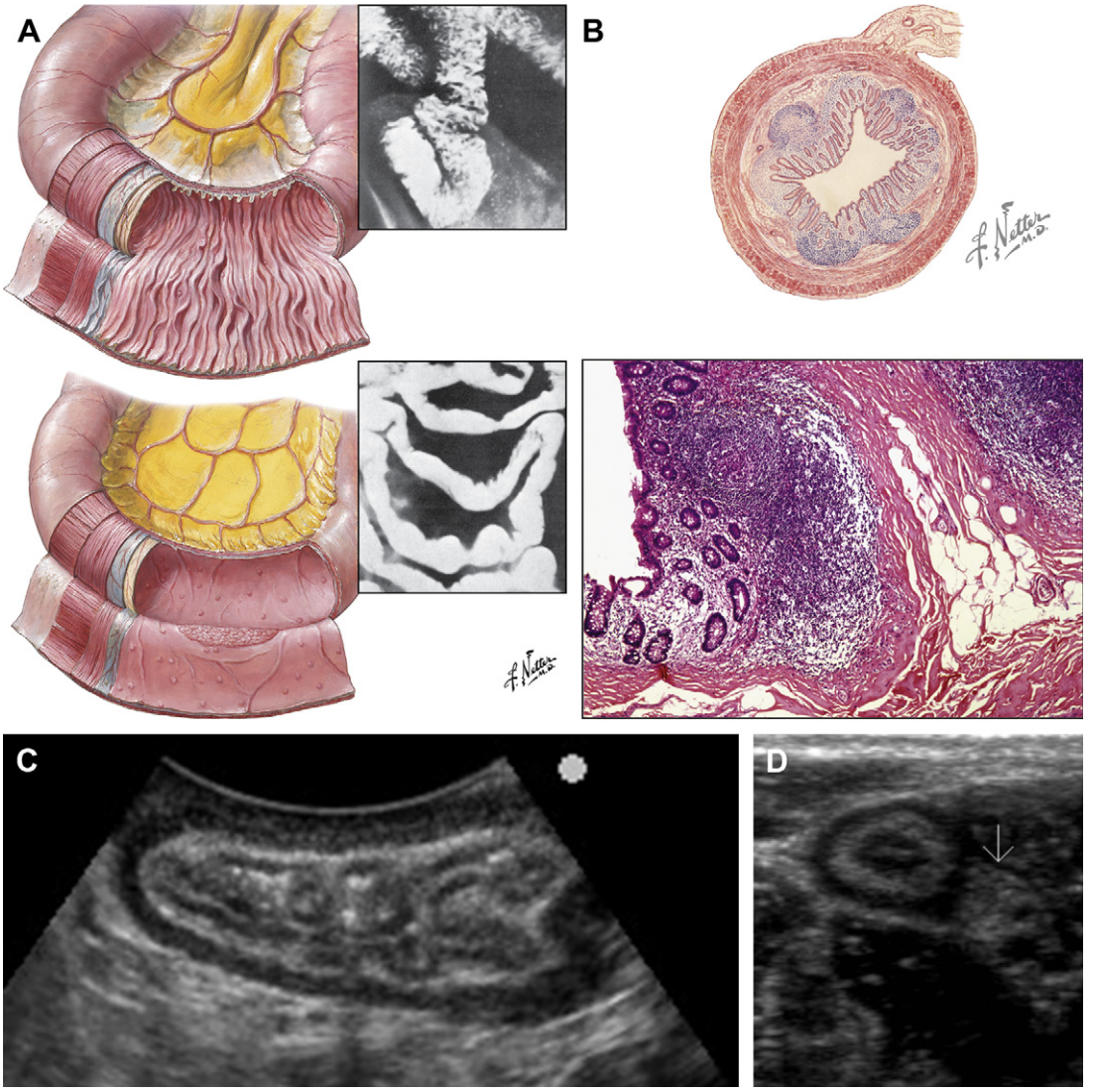

Fig. 1. (*A*) Netter diagram illustrating the layers of the bowel wall. (*upper panel*) Jejeunum with correlation on a barium study, (*lower panel*) ileum with correlation on a barium study. (*B*) Netter diagram illustrating the histologic arrangement of the bowel wall layers; shown both as a schematic (*upper illustration*) and on a histologic specimen (*lower illustration*). (*C*) US image of the normal stomach in cross section demonstrating the concentric echogenic and hypoechoic rings. (*D*) Abnormal appendix in cross section demonstrating the rings and adjacent mesoappendix (*white arrow*). ([*A, B*] Netter illustration from www.netterimages.com.)

right sacroiliac joint. This is the root of the small bowel mesentery. The superior mesenteric artery and superior mesenteric vein run between the 2 layers of peritoneum entering at the root. This posterior line of attachment is short but fans out to the free edge of the small bowel mesentery where the small bowel is located. The free edge of the small bowel mesentery is, therefore, essentially the length of the entire small bowel (approximately 6 m). This allows the small bowel to be mobile, making it difficult on US to be precise about location along the small bowel.

The cecum is the segment of large bowel inferior to the ileocecal valve. This valve is a landmark on US. The cecum does not have its own mesentery and has a variable attachment to the posterior abdominal wall. This accounts for the anatomic variability in position and mobility of the cecum observed in normal individuals (**Fig. 2**). This is an important point to understand when trying the find the cecum, terminal ileum, and appendix on US.

The appendix arises from the cecum posteromedial to the ileocecal valve and approximately 2.5 cm inferior. The length of the appendix is

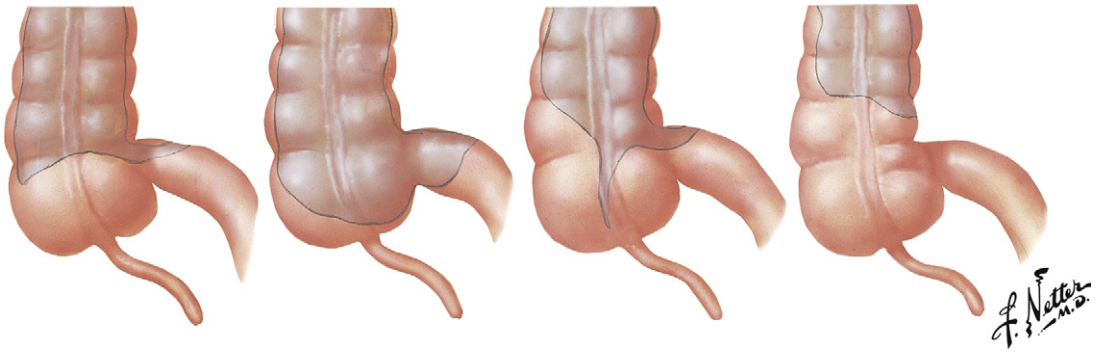

Fig. 2. Netter illustrations showing the variable posterior attachment of the cecum (*shaded area*). (Netter illustration from www.netterimages.com. © Elsevier, Inc. All rights reserved.)

variable (2–5 cm). Although the relationship of the origin of the appendix to the ileocecal valve is fixed, the tip of the appendix is variable. The origin of the appendix lacks a valve. This is a key feature in differentiating it from the terminal ileum on US (**Fig. 3**). The appendix has its own mesentery, called the mesoappendix. Like the small bowel, the appendix lies along the free edge of the mesoappendix; however, unlike the small bowel, the mesoappendix does not attach to the posterior abdominal wall but to the edge of the small bowel mesentery (**Fig. 4**).

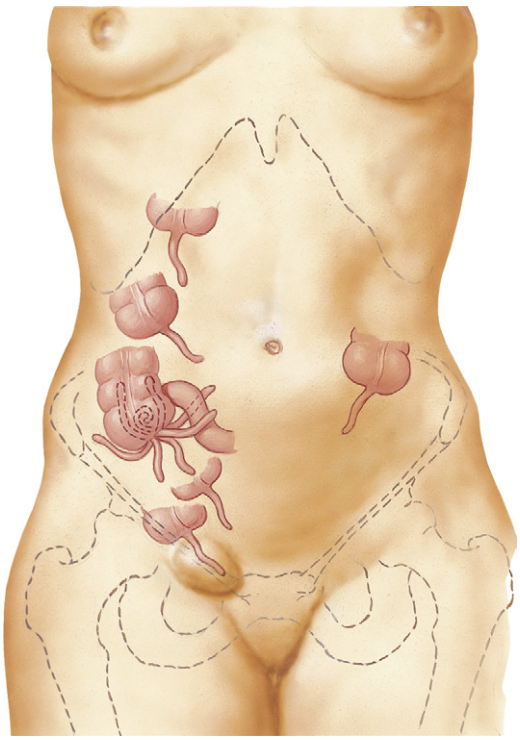

Fig. 3. Netter illustrations showing the variable position of both the appendix and the cecum. The constant relationship of the cecum, ileocecal valve, and appendix is important to understand when attempting to find these structures on US. (Netter illustration from www.netterimages.com. © Elsevier, Inc. All rights reserved.)

The right colon is covered by peritoneum anteriorly and laterally, which then attaches it to the posterior abdominal wall. The right colon is fixed in position and is considered a retroperitoneal organ. This arrangement is true for the left colon as well.

The transverse colon is suspended in its own mesentery, called the transverse mesocolon, which then attaches to the posterior abdominal wall similar to the small bowel mesentery. The posterior attachment or root is in a horizontal line beginning over the second portion of the duodenum extending above the pancreatic head and then along the inferior border of the pancreatic body and tail. The length of the transverse mesocolon is variable so that the transverse colon is also variable in position and can extend directly across the upper abdomen or can dip deep into the pelvis. The transverse mesocolon effectively divides the abdomen into a supracolic compartment and an infracolic compartment.

The sigmoid is also a suspended segment of bowel. Its mesentery can be thought of in 2 segments. The superior segment arises from the descending colon mesocolon and attaches along the medial side of the left iliac vessels. The inferior part has its root along the third sacral vertebra. This relationship causes the root of the sigmoid mesentery to attach to the pelvic sidewall in the configuration of an inverted V. Again this allows mobility so that the sigmoid can extend over to the right lower quadrant and cause right lower quadrant pain.

Finally the rectum is an extraperitoneal structure, fixed in location. Peritoneum covers the rectum along the mid and upper thirds of the anterior wall and around the upper third of the lateral walls (**Box 1**).

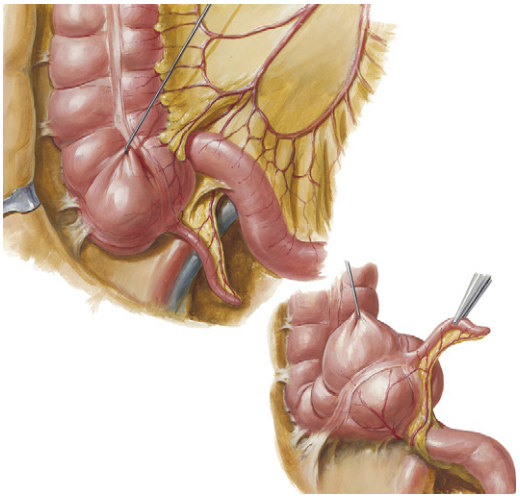

Fig. 4. Netter illustration showing the anatomy of the mesoappendix. (Netter illustration from www.netterimages.com. © Elsevier, Inc. All rights reserved.)

TECHNIQUE

Any US examination of the female pelvis should begin with noncompressive transabdominal scanning with a 3.5-MHz or 5-MHz curvilinear probe to gain a panoramic view of the pelvis. A higher frequency curvilinear probe can be advantageous in thinner patients. A distended bladder is helpful in evaluating the mid to distal sigmoid and the rectum transabdominally.[2] Examination of the bowel should then continue with a high-frequency linear probe. In thinner patients, a linear 12-MHz probe can produce exquisite images. Often alternating between multiple probes is necessary.

It is advantageous to have patients fast for at least 4 hours in subacute or chronic presentations, and often fasting is self-imposed in acute patients. Bowel gas is cited as a limitation of bowel US; however, in practice, diseased segments are often gasless. Graded compression and moving a patient into multiple positions can displace gas from the field of view.

Box 1
Fixation of the bowel by segment

Intraperitoneal and mobile	Small bowel Appendix Cecum Transverse colon Sigmoid colon
Extraperitoneal and fixed	Duodenum—second and third portions Right colon Left colon Rectum

The graded compression technique was first described by Puylaert in 1986 to evaluate the appendix.[3] It is now widely applied to sonography of the GI tract. The purpose of graded compression is 3-fold: to reduce the distance between the transducer and the bowel segment of interest; to displace bowel gas, improving visibility; and to minimize tenderness and discomfort. Graded compression consists of slowly and steadily compressing the bowel between the anterior abdominal wall and the posterior abdominal wall. In larger patients, performing additional compression by placing the left hand beneath a patient and pushing toward the transducer can improve visualization.[4] Positioning patients in the left lateral decubitus position helps identify a retrocecal appendix. Turning patients in multiple directions can be used in an effort to get air to move out of the field of view.

Bowel presets entered by manufacturers are now in general use and often include compound imaging. Harmonic imaging is useful when scanning the bowel due to the highly reflective nature of air. The use of more than one focal zone is also suggested.

The first task is to identify the anatomy of the GI tract. Often the sigmoid, left, transverse, and right colon are easy to identify with a transabdominal approach and can be scanned in a contiguous fashion, beginning in the sigmoid and moving up the descending colon, across the transverse (remembering its mobility), and down the right colon. Because the right and left colons are fixed, they are often a useful starting point when difficulty is encountered in following the large bowel. The anorectal region can be examined with a variety of techniques, including transperineal, transvaginal, and transrectal scanning.

The anatomy of the right lower quadrant, in particular the location of the cecum, ileocecal valve, and terminal ileum, can be challenging. The right colon is fixed to the posterior abdominal wall but the cecum may be variable in location. It can be found at McBurney point, the right upper quadrant, or deep in the pelvis, which is especially common in women. The cecum can be found at McBurney's point, the right upper quadrant or deep in the pelvis. A pelvic cecum is especially common in women. The ileocecal valve is identified by its fish mouth–like invagination into the lumen of the cecum, often made more prominent by surrounding fat. In female patients, if the cecum, terminal ileum, and appendix are not seen transabdominally, a transvaginal US must be performed.

Other than the terminal ileum and duodenum, the small bowel is difficult to precisely localize on US and generally topographic criteria are used: the jejunum in the left upper quadrant and the

ileum in the pelvis. As discussed previously, the small bowel mesentery allows great mobility so that topographic criteria are not always correct. small bowel mesentery allows great mobility and this is not always the case. The jejunum is characterized by many valvulae conniventes whereas the ileum has far fewer.

Hydrocolosonography is described in the literature mainly in the setting of inflammatory bowel disease.[5] It consists of administrating a water enema and buscopan after bowel preparation; however, this has not become part of routine clinical practice. Giving oral water at the time of the scan can greatly aid in visualization of the stomach and duodenum. Oral polyethylene glycol (PEG) has also been proposed for studying the small bowel with US. Like hydrocolosonography it has been described mostly in the setting of inflammatory bowel disease and has not become part of routine clinical practice.[6]

Although there is some variation in the literature, most investigators use a cutoff of 4 mm to identify a thickened bowel wall. Wall thickness is usually measured in the transverse plane from the inner echogenic line to the outer edge of the serosal surface. If a bowel segment is determined to be thickened then the layers must be carefully analyzed. If the bowel wall layers are preserved, a malignant process is considered unlikely.[7] Conversely, if the layers are destroyed, both malignancy and severe inflammation (common in Crohn's disease) are possible.

When the layers are thickened but preserved, determining which layer is the most involved can provide additional information. An epicenter of thickening that is the submucosal layer and which is circumferential and echogenic indicates an acute nonmalignant process intrinsic to that loop of bowel (**Fig. 5**A).[8] A thickened outer layer, especially if located on one side of the bowel only, is more likely secondary to an adjacent inflammatory process (see **Fig. 5**B). This finding is helpful in avoiding potential pitfalls, such as diagnosing cecal disease, when thickening is secondary to adjacent appendicitis.

US is a real-time technique and an assessment of peristalsis and of the compressibility of the bowel should also be made. The luminal content should also be evaluated: empty, fluid filled, stool filled, or air filled (in which case the posterior wall is obscured unless the air is displaced with compression or by turning the patient). The real-time advantage of US also allows localization of the point of maximum tenderness.

APPENDICITIS

Appendicitis is the most common cause for emergency surgery in the Western world.[9] It is known that preoperative imaging lowers the negative laparotomy rate and this is especially true for women.[10] A recent meta-analysis of the diagnostic performance of US versus CT revealed a sensitivity of 78% for US and 91% for CT with specificity of 83% for US and 90% for CT.[11]

There are a variety of management options in appendicitis, including laparotomy, laparoscopy, and conservative treatment with antibiotics plus or minus percutaneous drainage. In combination with the clinical presentation, surgeons require staging of appendicitis on imaging to make management decisions. The degree of periappendiceal inflammation; the degree of cecal or adjacent small bowel thickening; the presence of focal collections, free air, bowel obstruction, or ileus; and mesenteric seeding should be evaluated.

In order to identify the appendix, the graded compression technique should be used beginning

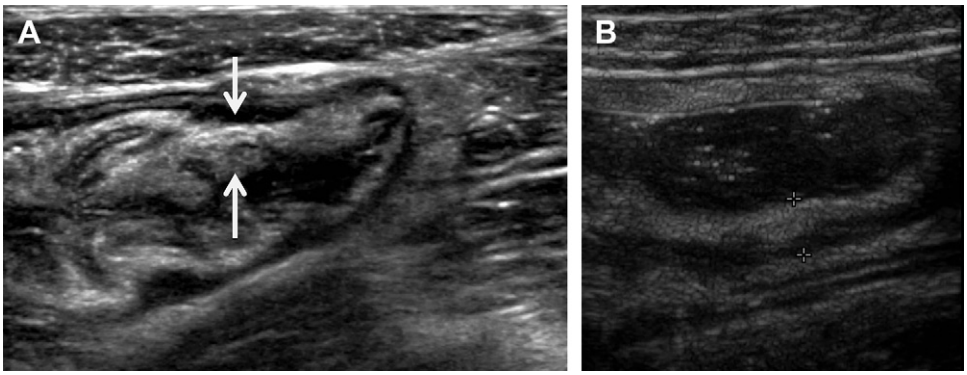

Fig. 5. (*A*) Marked thickening of the echogenic submucosal layer (*between arrows*) indicative of acute inflammation in this patient with infectious colitis. (*B*) Asymmetric thickening of the posterior wall (*between calipers*) of the cecum involving the outer layers more than the inner layers—in this patient, secondary thickening of the cecum is due to adjacent appendicitis.

in the right upper quadrant just below the liver (**Boxes 2** and **3**). Once the ileocecal valve and terminal ileum are identified, the appendix should be seen arising from the cecum without a valve. Because a retrocecal appendix is common, when the appendix is not seen, patients should be placed in a left lateral decubitus position (**Fig. 6**). All women should receive a transvaginal examination if the appendix is not seen from above. By identifying the ileocecal valve and the origin of the appendix separately, a common pitfall of mistaking the terminal ileum for the appendix or vice versa is avoided. Once the origin of the appendix is seen, then scanning commences along the entire length of appendix to prove it is blind ending, aperistaltic, and with gut signature. This avoids mistaking a loop of bowel as the appendix and other potential pitfalls, such as a dilated ureter, fallopian tube, or vessel (**Table 1**). It also ensures that inflammation limited to the tip, so-called tip appendicitis, is not overlooked.

Once an appendix is correctly localized, the next question is to determine if it is normal or abnormal.

One of the most established criteria for diagnosing appendicitis on US is an outer diameter under compression of 6 mm. This sign is more useful in excluding appendicitis; that is, an appendix measuring 6 mm or less is highly unlikely to be acutely inflamed. When an appendix measures more than 6 mm, additional signs should be used to rule in appendicitis.[12] The one exception to this is in cases of a perforated appendix that has deflated, producing a measurement less than 6 mm. The periappendiceal changes in these cases should prevent this pitfall. Another useful sign in ruling out appendicitis is demonstrating that the appendix is ovoid in cross section; care must be taken to ensure that this is the case along the entire length of the appendix.[13] When inflamed, the appendix is almost always round in cross section. This is in contrast to a loop of bowel, which maintains its ovoid cross section even when abnormal. If bowel wall thickening is noted in a segment with an ovoid cross section, an abnormal appendix is unlikely. If an appendix is compressible along its entire length, appendicitis is also reliably ruled out.[14]

Tenderness over the appendix is useful; however, this finding is not entirely specific for appendicitis (for example, when there is terminal ileitis) and can also be absent particularly in the elderly or very young and when a patient is on steroids or otherwise immunosuppressed.

Box 2
Signs to rule out appendicitis

Diameter less than 6 mm

Compressible along its entire length

Ovoid in cross section along its entire length

Box 3
Signs to rule in appendicitis

Single wall thickness greater than 3 mm

Noncompressible

Presence of Doppler signal

Loss or irregularity of the submucosal layer

Focal tenderness

Once an appendix is found to measure more than 6 mm and noncompressible, a careful assessment of the appendicular wall and content must be performed. If the diameter of the appendix is greater than 6 mm, it is suggested that measuring individual wall thickness as greater than 3 mm can increase confidence that the appendix is inflamed. This is helpful in situations when a normal appendix measures more than 6 mm because of inspisated fecal content. In many cases of appendicitis, however, the wall is thinned rather than thickened, meaning that 3 mm is useful to rule in inflammation but not to rule it out. Another helpful tool in avoiding this potential false-positive result is to examine the content. A noncompressible appendix filled with fluid is concerning. In contrast, inspisated fecal content is echogenic and noncompressive. The integrity of the submucosal layer should then be evaluated. Loss of the submucosal layer is seen in gangrenous appendicitis (**Fig. 7**). Presence of Doppler signal is useful in ruling in the diagnosis of appendicitis and increasing confidence; however, absence does not rule it out. Absent Doppler signal can be seen in an inflamed appendix, especially with gangrene (**Fig. 8**).[15,16] The presence of a focal defect in the wall, especially at the tip, should be looked for as an indication of perforation (**Fig. 9**).

The periappendiceal area must then be examined. The degree of secondary thickening of the terminal ileum and cecum should be ascertained. Periappendiceal inflamed fat should be assessed, seen as mass-like, noncompressible, echogenic fat with or without Doppler signal. When inflamed fat is limited to the mesoappendix, it is seen as a triangular-shaped echogenic mass adjacent to the mesenteric side of the appendix (see **Fig. 1**D). When the inflammation extends beyond the mesoappendix, the inflamed fat can become extensive, particularly as the omentum moves in to wall off the process. The presence of a focal

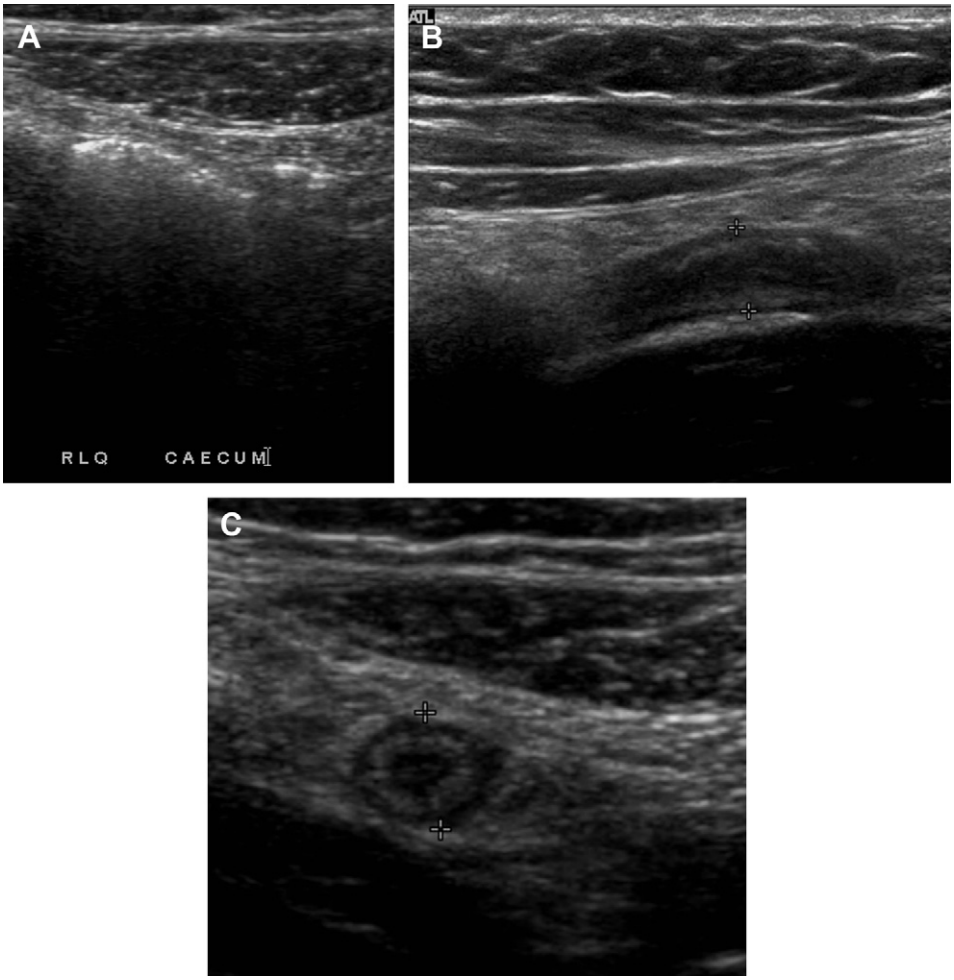

Fig. 6. (*A*) Patient scanned supine—appendix not seen, a potential false-negative on US. (*B*, *C*) Same patient scanned in the left lateral decubitus position demonstrates an inflamed retrocecal appendix.

collection should be ruled out. A collection less than 4 cm may respond to antibiotics plus or minus image-guided aspiration. A collection greater than 4 cm likely requires percutaneous drainage.

When evaluating patients with appendicitis, two special circumstances can arise. The first is the indeterminate appendix on CT. This is typically an appendix that measures greater than 6 mm in the absence of periappendiceal inflammatory or focal cecal changes. A normal appendix on CT can measure from 2 to 11 mm.[17] One common clinical scenario is a patient sent to CT to rule out renal colic with no renal stone seen and an equivocal appendix. The first option is to administer intravenous contrast to evaluate appendiceal enhancement; however, my preference is evaluate the appendix with a focused US. This allows localization of the point of tenderness and an assessment of the compressibility of the appendix. If normal, the same appendix that measures greater than 6 mm on CT may compress to less than 6 mm on US (**Fig. 10**).

The second scenario that can arise is the indeterminate appendix on US. Typically this is an appendix that measures 6 mm or 7 mm and is noncompressible. Single wall thickness also is borderline. Doppler signal is absent and tenderness is equivocal. In these cases, it can be difficult to know if the noncompressibility is due to normal content or normal lymphoid tissue. A helpful strategy in these cases, in direct discussion with the referring surgeon, is to follow patients clinically and with a repeat US in 24 hours.

One final point to make regarding appendicitis is in cases when obstruction is not caused by an appendicolith or lymphoid hyperplasia but rather by tumor. A careful evaluation of the base of the appendix on US should avoid the pitfall of missing an obstructing cecal or appendiceal mass. Care should be taken

Table 1
Pitfalls of appendiceal ultrasound

False-Negative Ultrasound	Solution
Unusual position of the appendix	1. Clearly identify the ileocecal valve first 2. Perform transvaginal US in all women if appendix is not seen transabdominally 3. Perform a coronal scan to look for a retrocecal appendix 4. Put the patient in the left lateral decubitus position to look for a retrocecal appendix
Incomplete visualization	1. Ensure demonstration of the blind end
False-Positive Ultrasound	**Solution**
Mistake a normal appendix for abnormal	1. Short-term follow-up US in discussion with the surgeon for equivocal results on both US and clinical examination 2. When the appendix measures more than 6 mm, also measure the individual wall thickness and evaluate the content 3. Use of Doppler to help rule in appendicitis
Mistake the terminal ileum for the appendix	1. Be rigorous about identifying the ileocecal valve and the blind end of the appendix 2. Terminal ileum is ovoid in cross section, not round, and usually demonstrates peristalsis
Mistake secondary enlargement of the appendix for primary appendicitis • Crohn's disease • Cecal carcinoma or mass • Perforated peptic ulcer disease • Cecal diverticulitis	1. Recognition of the underlying cause 2. Think of an obstructing lesion when the appendix measures greater than 1.5 cm diameter

especially when the diameter of the appendix is more than 15 mm because this has been shown associated with neoplastic obstruction.[18,19]

TERMINAL ILIEITIS

Infectious causes of terminal ilieitis, including *Yersinia*, *Campylobacter*, *Salmonella*, and *Shigella*, can cause a clinical presentation identical to that of appendicitis. The role of US in these cases is to diagnose thickening of the terminal ileum and to identify a normal appendix so that surgery is avoided. Bowel wall thickening of the terminal ileum is the predominant feature centered on the inner bowel wall layers. Thickening may also involve the cecum and can extend to involve the entire right colon. The ileocecal valve can be prominent and there is usually mesenteric adenopathy (**Fig. 11**).

INFLAMMATORY BOWEL DISEASE

Inflammatory bowel disease consists of 2 entities, ulcerative colitis (UC) of the large bowel and Crohn's disease. Both can present acutely as a first presentation or with flares and complications of the disease. They are not immune to presenting with a ruptured ovarian cyst, appendicitis, or other bowel pathology and, therefore, a thorough US evaluation must be performed. These patients are often young, requiring many investigations over the course of their disease, and US is ideal to avoid cumulative radiation exposure. Endoscopy is the cornerstone of evaluating inflammatory bowel disease; however, it provides only luminal and mucosal information. US, CT, and MR imaging directly image the bowel wall and the perienteric region. Of these, US is the most cost-effective, the most readily available, and the most suited to repeated examination. It is the only examination at present to offer practical real-time imaging.

CROHN'S DISEASE

Crohn's disease involves the colon alone (30%), the small bowel alone (20%), or both large and small bowel (50%).[20] Although MR imaging and CT enterography and enteroclysis have the highest diagnostic accuracy for the detection of intestinal involvement and extraintestinal complications of Cohn disease, they are not always readily available nor are they well suited to serial examination.[21] US has been shown useful especially in ileal disease (approximately 50% of patients have ileal disease usually over the distal 15–25 cm) but is operator-dependent and requires significant expertise.[22] US is often the initial examination of choice in acute presentations. A meta-analysis of the role of US in diagnosing

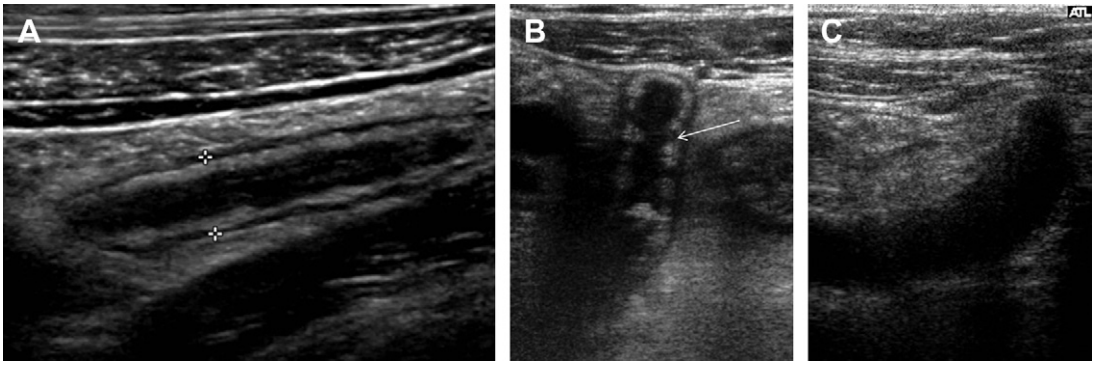

Fig. 7. (*A*) An abnormal appendix measuring 8 mm in diameter (*between calipers*) with an intact submucosal layer. (*B*) An abnormal appendix measuring 10 mm in diameter with an irregular submucosal layer (*arrow*). (*C*) An abnormal appendix measuring 11 mm in diameter with complete loss of the submucosal layer.

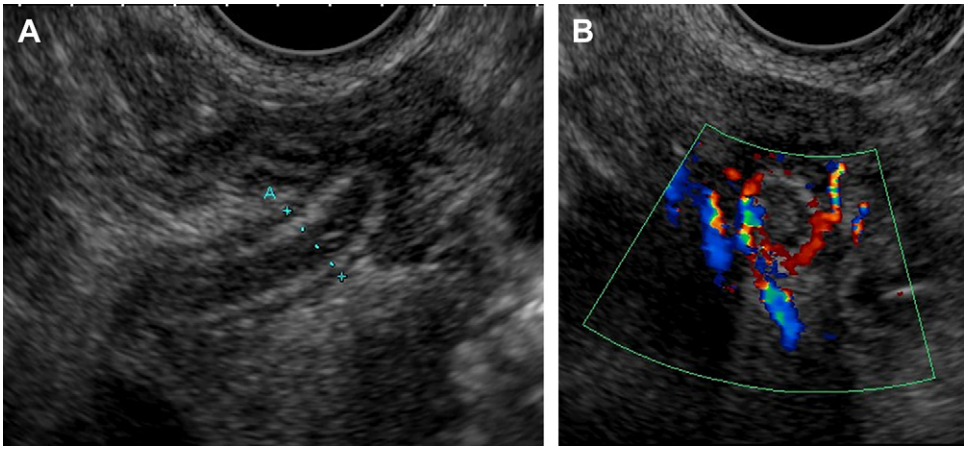

Fig. 8. (*A*) Abnormal appendix identified only transvaginally, measuring 8 mm. (*B*) Presence of increased Doppler signal supporting the diagnosis of appendicitis.

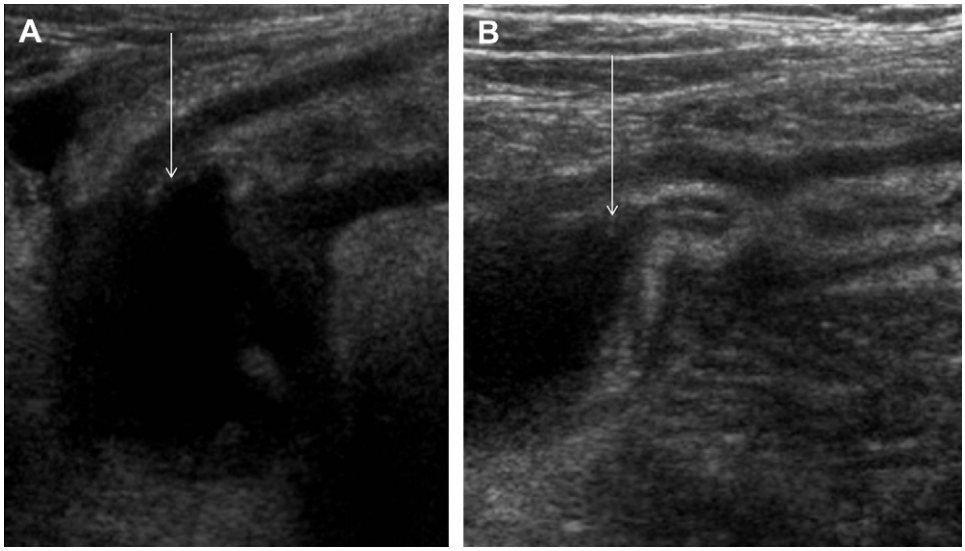

Fig. 9. (*A, B*) Two separate patients with perforated appendicitis and a focal wall defect at the tip of the appendix (*arrows*).

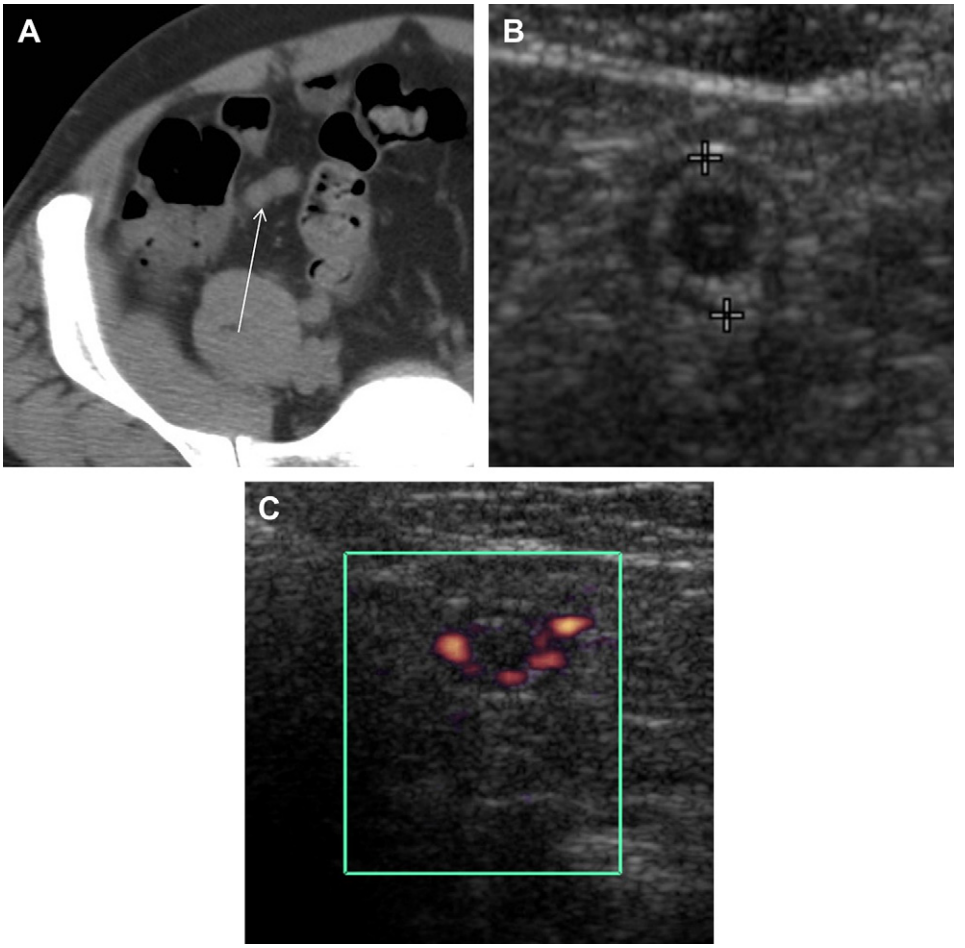

Fig. 10. (*A*) Prominent appendix on CT with no periappendiceal inflammatory change (*arrow*). (*B*) Same appendix on US (*between calipers*), round in cross section, measuring 8 mm, and noncompressible. (*C*) Presence of Doppler signal further confirming appendicitis.

Crohn's disease found a sensitivity of 75% and a specificity of 97% when a bowel wall thickness cutoff of 4 mm was used.[23] US has been shown to be a useful first diagnostic test in patients clinically suspected of having Crohn's disease before proceeding to further more invasive tests.[24–26] It plays a key role in follow-up of patients with known disease, to assess location and extent, and to detect abscesses and strictures. It also can be used in assessment of postoperative recurrence (**Box 4**).[27,28]

Roles 1 and 2: Patients with Acute Right Lower Quadrant Pain or the Initial Evaluation in Suspected Crohn's Disease

The hallmark of Crohn's disease is bowel wall thickening, usually at least moderate, 5 mm to 14 mm.[22] Bowel wall thickening is nonspecific, however, and occurs in other infectious, inflammatory, and neoplastic conditions. The suspicion of Crohn's disease as a cause is raised, therefore, when the disease is ileocecal in location, is segmental with skip lesions, and in the presence of perienteric findings, such as fistula and abscess. False-negative US occurs when early disease involves the mucosa only, thereby not producing bowel wall thickening. Stratification of the bowel wall is preserved early on in the disease process. As the disease becomes more severe and transmural, the layers become ill defined, finally becoming partially or completely destroyed. In addition the bowel segment is usually stiff and demonstrates reduced or absent peristalsis. Angulation of the bowel may also be appreciated.

Although mucosal disease is the territory of endoscopists, careful evaluation on US can reveal deep ulcers and intramural linear fissures (they may or may not contain gas) in the muscularis mucosa and submucosal layers (**Fig. 12**). Postinflammatory

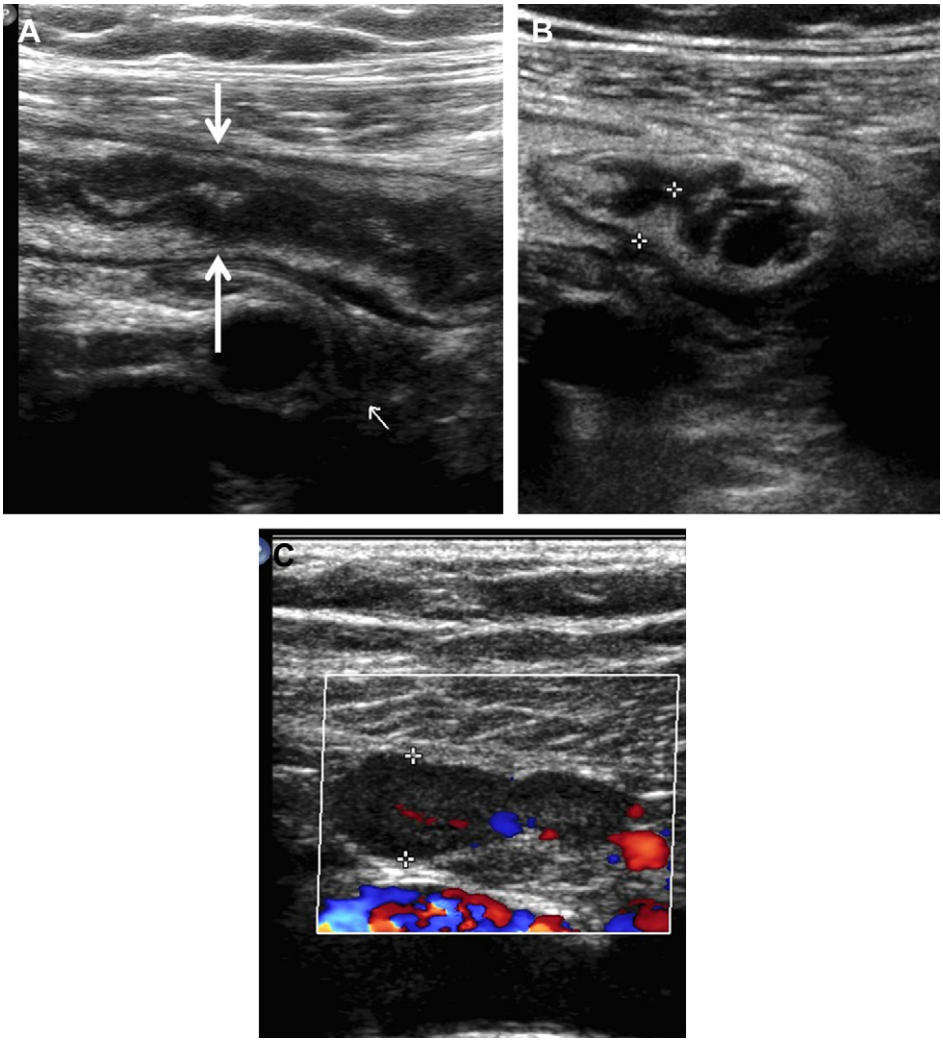

Fig. 11. (*A*) *Yersinia* causing concentric thickening of the terminal ileum (*between thick white arrows*) with preservation of the bowel wall layers. Note the normal appendix (*small white arrow*) posterior to the terminal ileum. (*B*) Wall thickening measuring 5 mm (*between calipers*). (*C*) Mesenteric nodes (*between calipers*).

Box 4
Current roles for ultrasound in Crohn's disease

1. Evaluation of acute patients with right lower quadrant pain
2. Initial evaluation of patients with clinically suspected Crohn's disease
3. Defining anatomic location and extent of disease
4. Detection of complications
5. Follow-up of patients postresection and post–medical therapy

Fig. 12. Initial presentation of Crohn's disease; there is preservation of the bowel wall stratification but the presence of a deep ulcer is seen as a focal disruption of the echogenic submucosal layer (*white arrow*). (*Courtesy of* Dr Josee Sarrazin.)

pseudopolyps are seen as mural nodules, particularly when there is fluid in the bowel lumen.

As with appendicitis, perienteric findings should also be evaluated. The so-called creeping fat of Crohn's disease is seen as mass-like, noncompressible adjacent fat often with linear hypoechoic bands running through it. It is most prominent on the mesenteric side. When chronic it can become heterogeneous or even hypoechoic.[22] It causes loop separation classically described on barium studies but which can also be appreciated on US.

Mesenteric nodes are often seen in Crohn's disease. They usually are hypoechoic, are ovoid in configuration, and measure greater than 5 mm in short axis. They can become conglomerate.

Role 3: Assessing the Location and Extent of Disease

One of the most important factors affecting the accuracy of US in Crohn's disease is the location of disease, with high sensitivity reported for the terminal ileum and left colon and lower sensitivity for the rectum and upper small bowel.[24]

When Crohn's disease is suspected on US, because of its skip nature, a survey of the bowel should be performed as described previously. Although the ileum is the most common site of disease and one of the easier to localize on US, other sites are discovered if a methodical approach is used. The rectum can be seen with a transvaginal or transperineal scan in women (**Fig. 13**A, B). The duodenum is a blind spot unless specifically looked for.

Role 4: Detection of Complications

Among patients with Crohn's disease, 17% to 82% experience at least one fistula.[27] They are particularly common in the terminal ileum and in the anus. Fistula can occur between the affected segment and adjacent segments of bowel (enteroenteric), to the abdominal wall (enterocutaneous), to the bladder (vesicoenteric), to the vagina, and to the retroperitoneum. They can also blind end in the mesentery. Fistula can occur between the inflamed segment of bowel and an adjacent segment of bowel (enteroenteric), the abdominal wall (enterocutaneous), the bladder (enterovesicle), the vagina or the retroperitoneum. They are often vascular on Doppler and may or may not contain air (**Fig. 14**). Using manual compression can sometimes help move air through the fistula, further confirming its presence on US. US

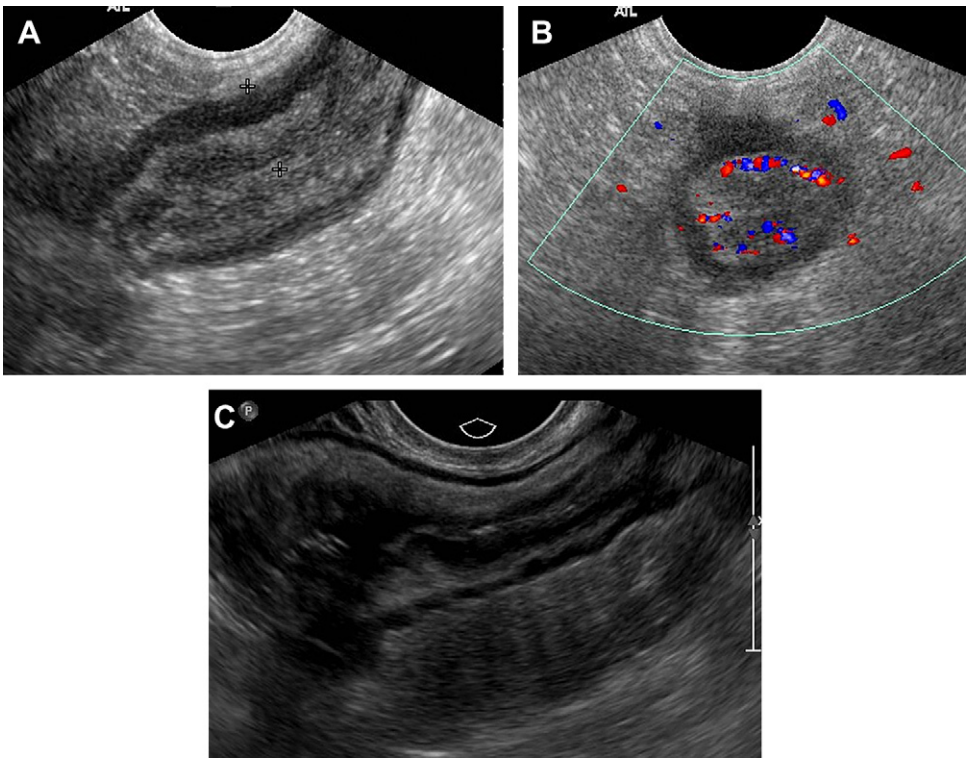

Fig. 13. (*A*) Crohn's disease of the rectum seen transvaginally in the sagittal plane. (*B*) Crohn's disease of the rectum, axial view. (*C*) Crohn's disease of the small bowel—not the terminal ileum—seen only on a transvaginal scan. Note the bowel wall thickening, particularly of the submucosal layer.

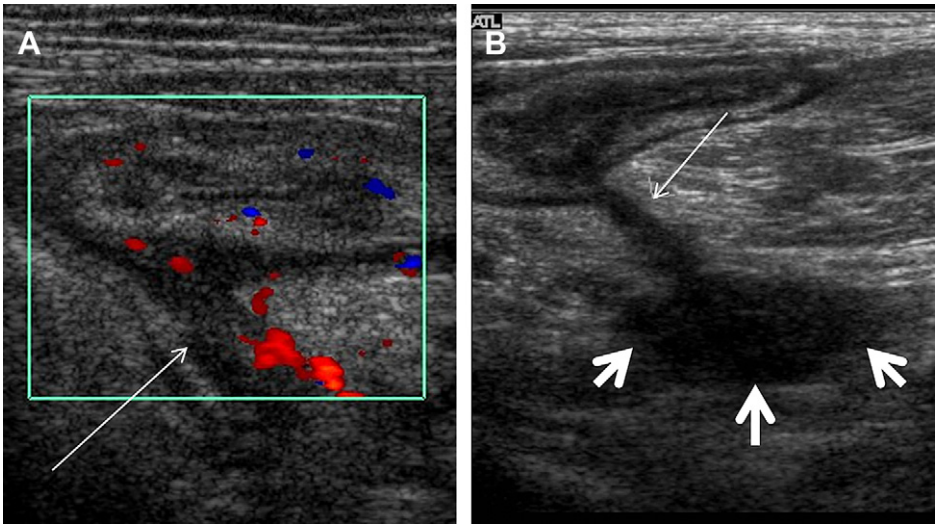

Fig. 14. Two separate patients with fistula secondary to Crohn's disease seen as hypoechoic linear tracts extending beyond the bowel wall into the adjacent tissues. (*A*) A vascular hypoechoic tract (*arrow*). (*B*) A fistula (*long arrow*) leading to a focal abscess (*short arrows*).

is reported in a systematic review to have a 74% sensitivity and a 95% specificity in the diagnosis of Crohn's fistulas.[29]

Abscesses are often the result of a fistula and seen in 12% to 30% of patients.[27] They are commonly found along the mesenteric side, often occurring in the psoas muscle, paracolic gutter, or mesentery of the terminal ileum (see **Fig. 14**B). They are defined as focal collections of fluid often with an irregular wall. They may contain air and debris. By convention they are larger than 2 cm in diameter to differentiate from a blind-ending fistula.[30] US is reported in a systematic review to have an 84% sensitivity and a 93% specificity in the diagnosis of Crohn's abscess.[29]

Strictures occur in up to 21% of people with ileal disease[27] and often require surgery. US has been shown to detect strictures with high accuracy[30–32] as a thickened, stiff loop of affected bowel with a narrow lumen and upstream distended (greater than 3 cm) either fluid-filled or echogenic content-filled bowel.[31] There often is upstream hyperperistalsis. US is reported in a systematic review as having 79% sensitivity and a 92% specificity in the diagnosis of Crohn's stricture.[29]

Role 5: Postsurgical Recurrence

Surgery in the setting of Crohn's disease is used when patients have failed medical management or who have developed complications, such as fistula or stricture. Unfortunately recurrence rates are high. Within 3 years at endoscopy up to 85% to 100% develop recurrence and 34% to 86% if only symptomatic recurrence is considered. US has been shown to correlate with endoscopy in the detection of postsurgical recurrence (**Fig. 15**).

Disease Activity

Being able to assess disease activity is important in management and prognosis of Crohn's disease. The most widely used method is the clinical Crohn's disease activity index; however, this method has limitations. Lower endoscopy is the method of choice for determining activity in the colon and terminal ileum; however, it is invasive and does not evaluate the remainder of the small bowel. US offers 3 potential techniques for assessing activity. Color Doppler of the superior mesenteric artery[33,34] and Doppler vessel density in the intestine per square centimeter have both been shown to correlate with disease activity but have not entered routine practice.[34–36] Contrast-enhanced US is currently being investigated and may offer increased sensitivity and specificity in terms of assessing disease activity.[35] Gray-scale findings of wall thickness and echo pattern have not proved useful in predicting disease activity. Because the treatment of an inflammatory stricture is medical and a fibrotic stricture surgical, it would be helpful if imaging could distinguish the two. In addition, as newer and more expensive medical therapies are discovered, an objective imaging method to assess disease activity in response to therapy would be useful. This would require serial examinations for which US or contrast-enhanced US are well suited.

Crohn's disease and pregnancy deserve special mention. If disease is in remission at the time of conception, approximately one-third of patients

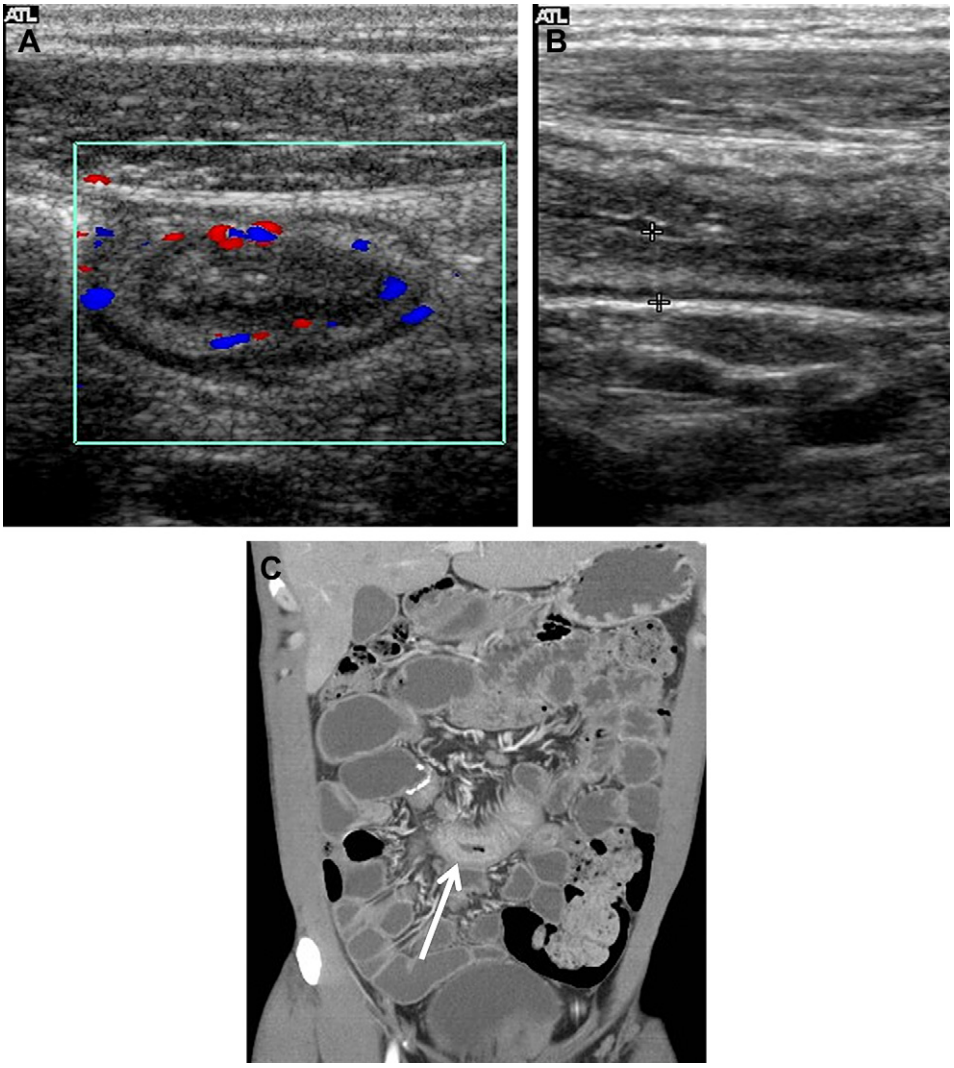

Fig. 15. Recurrence at the neoterminal ileum. (*A*) Cross section of the neoterminal ileum demonstrating bowel wall thickening measuring 7 mm and Doppler signal consistent with inflammation. (*B*) Longitudinal view of the neoterminal ileum; note preservation of bowel wall layers with bowel wall thickening (*between calipers*). (*C*) CT enterogram confirming findings of recurrence at the neoterminal ileum (*arrow*).

will relapse and, therefore, may require imaging. If disease is active during conception, two-thirds of patients will have persistent disease and of this population two-thirds will deteriorate.[36] These numbers, in addition to the safety of US during pregnancy, underscore the necessity for skilled bowel ultrasonographers.

ULCERATIVE COLITIS

UC, in contrast to Crohn's disease, is a condition limited to the colon, occurring continuously from the rectum without skip lesions. Because this disease is colonic and confined to the mucosa, it is particularly well suited to endoscopic evaluation. US plays much less of a role in UC than it does in Crohn's disease. Although the disease is confined to the mucosa, it can cause thickening of all the layers, especially the submucosa, resulting in bowel wall thickening often up to 5 mm to 10 mm. The muscularis layer, however, is usually normal or only mildly thickened and in general the stratification of the wall is preserved. The deep ulcers of Crohn's disease are not seen in UC. Perienteric findings are typically absent. Pericolonic edema and fluid is uncommon in UC. With chronic disease, there is loss of haustration leading to the lead pipe colon, which is also recognizable on US. Pseudopolyps can be seen as echogenic nodules protruding into the lumen

especially when the affected segment contains fluid. Overall it is difficult to reliably distinguish Crohn's colitis from UC and the best predictors are location and presence of perigut disease.[28]

Distinguishing UC from other infectious etiologies is generally not possible on US. Pseudomembranous colitis, however, often causes an accordion sign seen as an exaggeration of the haustra by severe submucosal edema, a sign not generally seen in UC (**Fig. 16**). The thickening is striking, with an effaced lumen, and the outer muscular layer is thin. It is often associated with ascites.[37] In addition the history of recent antibiotic use is helpful.

DIVERTICULITIS

Diverticular disease is a common entity in the Western world; it is estimated that one-third of people over age 40 harbor the disease and that 10% to 25% of people with diverticulosis have at least one episode of acute diverticulitis as a result.[38] As with many conditions discussed in this article, the clinical presentation is nonspecific. Classically patients present with left lower quadrant pain, elevated white count, and fever. Fever and white count, however, are not sensitive, even in the presence of an abscess,[39] underscoring the need for imaging to make a correct diagnosis and to guide management.

There are few studies comparing modalities for diagnosis of diverticulitis and many of them were published before the year 2000; however, US has been shown to have a sensitivity of 85% and a specificity of 84%[40] and CT 91% and 77%, respectively.[31] Because US is often the first test especially in premenopausal women radiologists and ultrasonographers have to be familiar with the findings of diverticulitis on US. A reasonable algorithm in patients with clinically suspected diverticulitis might be to start with US in young patients in the absence of peritoneal findings. CT could then be performed in the patients who are either inconclusive on US or are found to have large abscesses for consideration of percutaneous drainage.

On US, the diagnosis of diverticulitis is made when there is bowel wall thickening at the site of tenderness measuring more than 4 mm from the inner echogenic interface to the outer edge of the echogenic serosal layer in the presence of an inflamed diverticulum. A diverticulum is a focal outpouching arising from the colonic wall associated with a focal disruption of the bowel layers at its neck. The tic may be hypoechoic, hyperechoic, or hyperechoic with a hypoechoic rim. Content may or may not cause acoustic shadowing (**Fig. 17**). Inflammation is heralded by echogenic noncompressible surrounding fat. Perienteric features should be evaluated, including the presence or absence of extraluminal foci of air, focal fluid collections/abscess, fistula, and adjacent free fluid.

Although diverticulitis is most often a left-sided disease, right-sided diverticulitis is also well recognized. These tics are often congenital true diverticula, meaning that they contain all bowel wall layers. This fact may explain why right-sided diverticulitis is not associated with the complications of abscess, perforation, and fistula seen in left-sided disease. Patients are often younger and clinically can present as identical to appendicitis. It is critical on US to identify the offending tic at the epicenter of inflammation and maximal wall thickening and to document a normal appendix because this disease is treated conservatively. If right-sided diverticulitis is inadvertently sent to

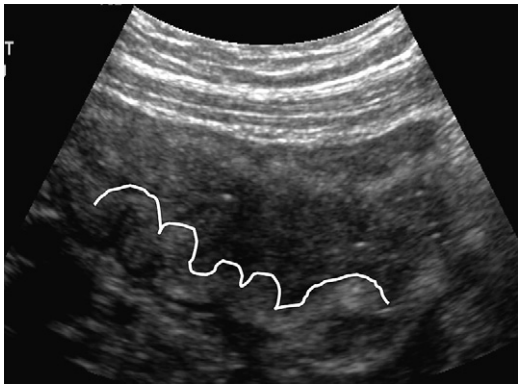

Fig. 16. Accordion sign (tracing) of pseudomembranous colitis, unusual for UC.

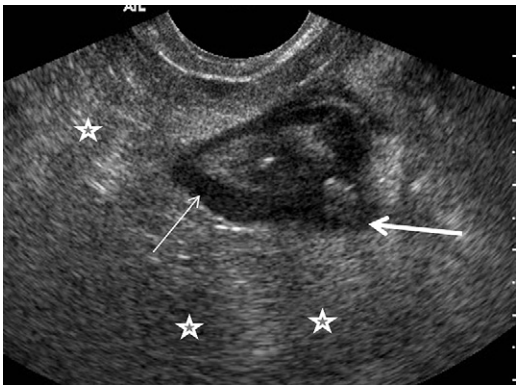

Fig. 17. Transvaginal scan of acute diverticulitis. Note the preferential thickening of the hypoechoic muscular layer rather than the submucosal layer (*thin arrow*). The diverticulum is seen as a focal outpouching projecting beyond the bowel wall, in this case with echogenic nonshadowing content and a hypoechoic rim (*thick arrow*). Surrounding echogenic fat and focal tenderness are consistent with inflammation (*stars*).

the operating room it can result in a right hemicolectomy because the diverticulum is obscured by inflammation and the intraoperative impression is that of a mass rather than diverticulitis (**Fig. 18**).

COLITIS VERSUS TUMOR

GI tumors can present acutely, especially when complicated by perforation. In general, differentiation of acute inflammation, such as diverticulitis from malignancy, can be difficult both clinically and on imaging. It is recommended, therefore, that a first attack of diverticulitis be followed up after the acute presentation with either barium enema or colonoscopy. There are features on US, however, which can be helpful, in particular preservation of the bowel wall layers. Tumor is usually over a shorter segment than inflammation and is bulky with asymmetric involvement. Stratification is lost. Typically perigut features are absent when there is no associated perforation (**Figs. 19** and **20**).[7] If bowel wall layers are lost, with no pericolonic inflammation and in the presence of adjacent nodes, malignancy should be considered. If bowel wall layers are preserved and there is pericolonic inflammatory change, colitis or diverticulitis is more likely.[41]

ISCHEMIA

Multidetector CT is the initial modality of choice in suspected bowel ischemia. On US, ischemia is segmental and generally over a longer length, bowel wall stratification may or may not be preserved, and Doppler signal may be reduced or absent. Absent arterial flow has been associated with a poor outcome.[42] Pericolonic fat changes have been associated with transmural necrosis.[43] Although ischemia is not an indication for US, two situations may arise in which familiarity with US features can aid in arriving at a proper diagnosis.

The first situation is when bowel thickening is seen on CT with no specific features of ischemia and when a differential diagnosis of ischemia versus inflammatory is entertained. Although on US, the degree of bowel wall thickening is not useful, if there is little or absent Doppler signal and no arterial tracings, ischemia is suggested. Readily visible Doppler signal supports inflammation.[44] It is important to ensure that parameters are optimized for sensitivity, including an appropriate filter for low-volume flow, low-velocity scale, wide gate width, and maximal gain (**Fig. 21**).

The second situation is when a patient is referred to US for nonspecific abdominal pain and clinically ischemia has not been suspected. Because the symptoms of ischemia are nonspecific, this is not that unlikely a scenario. In these patients, bowel wall thickening is recognized first, often aided by localizing the point of maximum tenderness with probe pressure. Application of Doppler can then suggest the diagnosis of ischemia, leading to further evaluation with CT (**Fig. 22**).

More recently, contrast US has been investigated in the evaluation of bowel ischemia with positive results but its role in clinical practice is not yet established.[45]

SMALL BOWEL OBSTRUCTION

As with ischemia, multidetector CT is the test of choice in small bowel obstruction. Particularly in

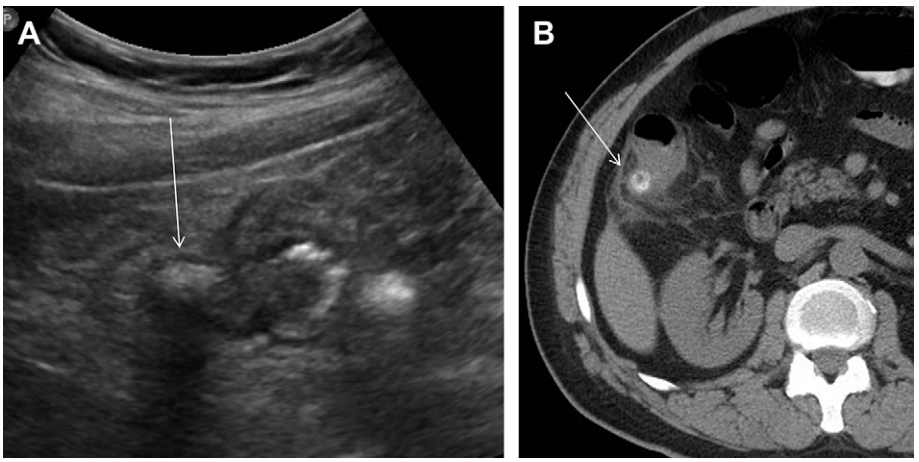

Fig. 18. (*A*) Young male patient presenting to US to rule out appendicitis. Note focal wall thickening at the neck of a diverticulum (*arrow*) and surrounding echogenic fat. Appendix was seen separately and was normal. (*B*) Confirmation on CT (*arrow*).

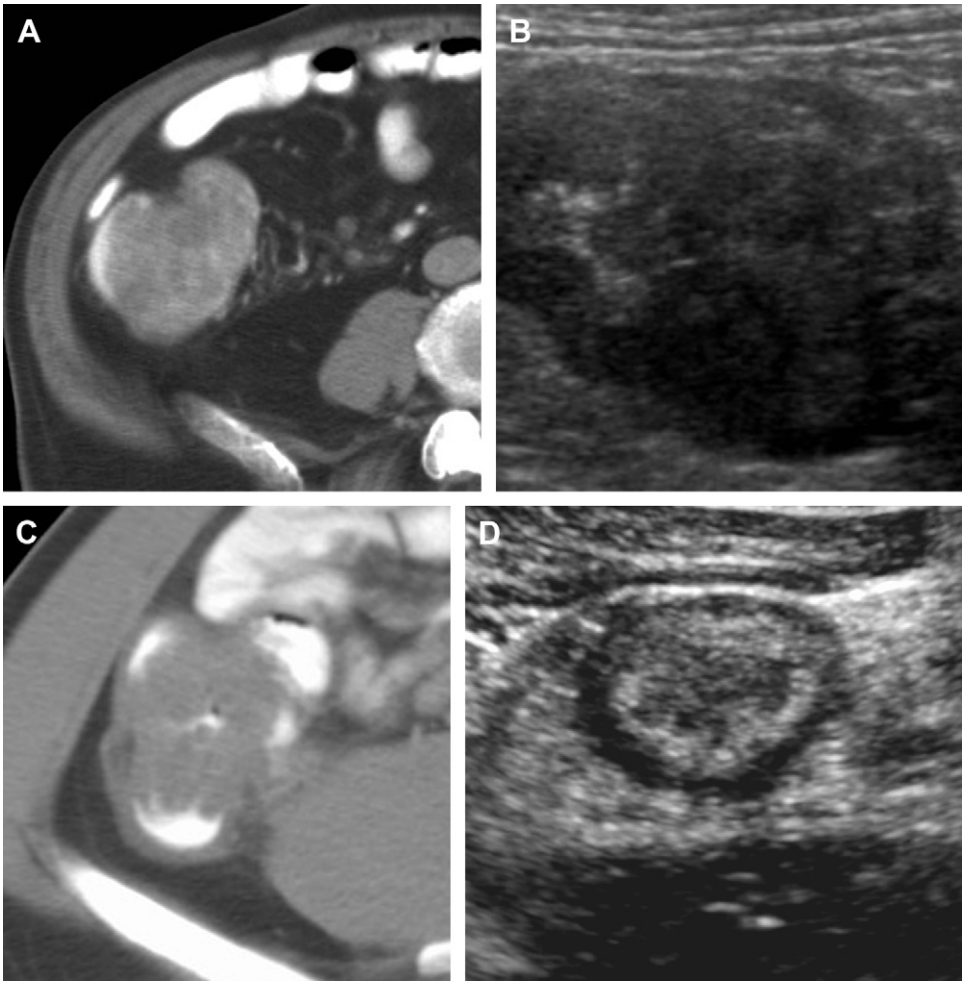

Fig. 19. (*A*) Focal nonspecific thickening on CT involving the right colon in a patient with right lower quadrant pain. (*B*) Same patient on US demonstrating typical features of malignancy, including loss of bowel wall layers and eccentric and bulky short segment thickening. Right colonic adenocarcinoma at scope. (*C*) Separate patient with right lower quadrant pain and nonspecific focal thickening of the right colon on CT. (*D*) Same patient with preservation of bowel wall layers confirming inflammation rather than malignancy.

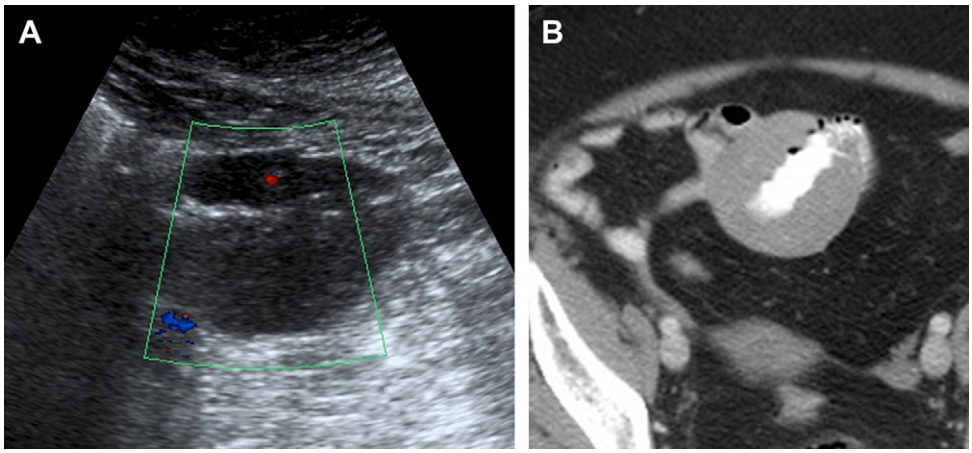

Fig. 20. (*A*) Patient with right lower quadrant pain; short segment of hypoechoic eccentric bowel wall thickening with loss of stratification. (*B*) Same patient at CT. Lymphoma at surgery.

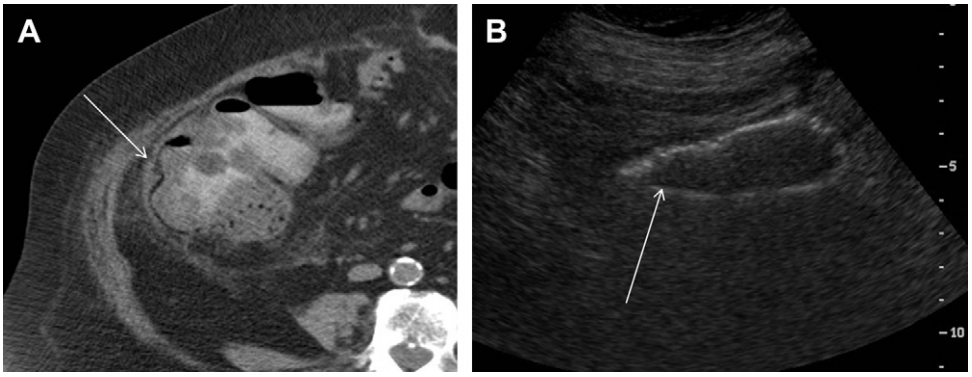

Fig. 21. (*A*) CT scan demonstrated wall thickening of the right colon. Pneumatosis was questioned (*arrow*). Lactate normal. (*B*) US clearly confirmed the presence of pneumatosis (*arrow*) and also showed no Doppler signal (not shown), favoring ischemia over inflammation.

patients who are poor historians or when a language barrier is present, patients can present to US. The inherent fluid-filled nature of obstructed loops makes them well suited to US evaluation. By recognizing and systematically following the dilated loops, the point of obstruction and often the cause is found on US. Obstruction is suspected when the small bowel measures more than 3.0 cm over a length of more than 10 cm and contains increased content. Hyperperistalsis is seen and the valvulae conniventes are obvious. In contrast, ileus usually demonstrates dilated small bowel with reduced peristalsis and the colon may also be dilated.[46]

EPIPLOIC APPENDAGITIS

Epiploic appendages are fatty tags 1 cm to 2 cm thick and 2 cm to 5 cm long that hang from the antimesenteric border of the colon in two longitudinal rows along the tenia. They are most numerous in the sigmoid and cecum.[47] These appendages can twist or the central vein can thrombose, leading to acute pain. Typical patients are younger than those presenting with diverticulitis. Clinically this can mimic the presentation of either diverticulitis or appendicitis. Usually patients can precisely localize the point of their pain, often with 1 finger. Typically associated symptoms, such as diarrhea and nausea, are absent and laboratory findings are normal. Fever is variable. Because the clinical presentation overlaps significantly with epiploic appendagitis and diverticulitis, this becomes a radiologic diagnosis and is an important one to make because treatment is conservative not surgical.

On US, epiploic appendagitis is seen as an ovoid fatty mass adjacent to the colon and immediately beneath the abdominal wall that is tender and noncompressible (**Fig. 23**). The center can

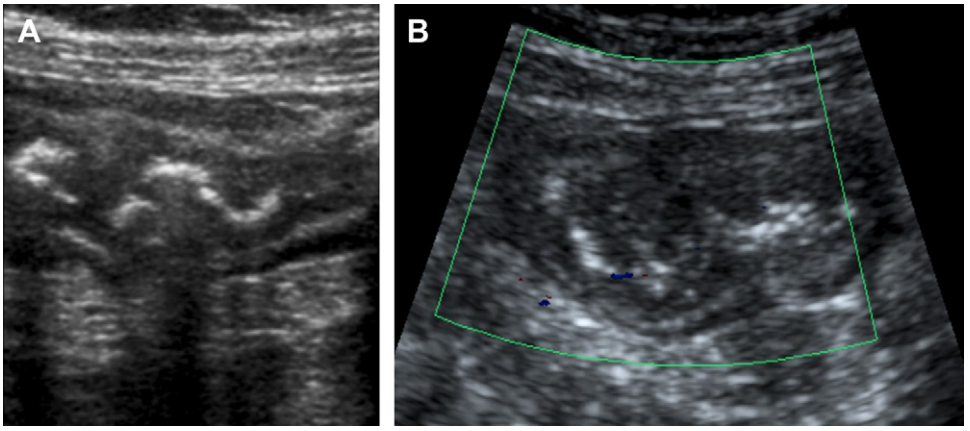

Fig. 22. (*A*) An elderly man sent to US for nonspecific abdominal pain post total knee replacement; thickening of the right colon was associated with tenderness. (*B*) No Doppler signal obtained despite maximizing parameters concerning for ischemia rather than inflammation. CT scan performed. Ischemia confirmed at surgery.

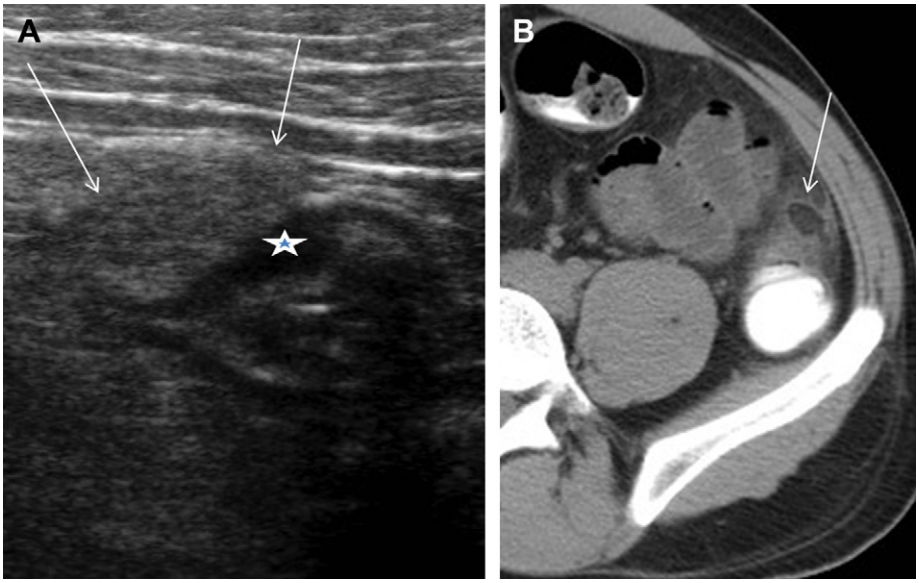

Fig. 23. (*A*) Epiploic appendagitis—a fatty tender mass (*arrows*) adjacent to the left colon. Note the focal eccentric thickening of the outer layer of the left colon (*star*) indicating an adjacent inflammatory process rather than disease of the left colon itself. (*B*) Confirmed on CT (*arrow*).

be hypoechoic secondary to hemorrhage and there is often a thin hypoechoic rim (**Fig. 24**). There may be associated focal thickening of the adjacent colonic wall but the colonic wall should not be circumferentially thickened. The mass moves with the colon on respiration and can often also be fixed to the adjacent peritoneum. Doppler signal is typically absent (in contrast to diverticulitis).[47] On the right, a normal appendix must be documented, and on the left, a careful search should be made for an underlying inflamed diverticulum.

OMENTAL INFARCTION

Omental infarction is far less common than epiploic appendagitis. It usually occurs on the right side and can present as similar to appendicitis. As with epiploic appendagitis, management is conservative. The normal appendix must be

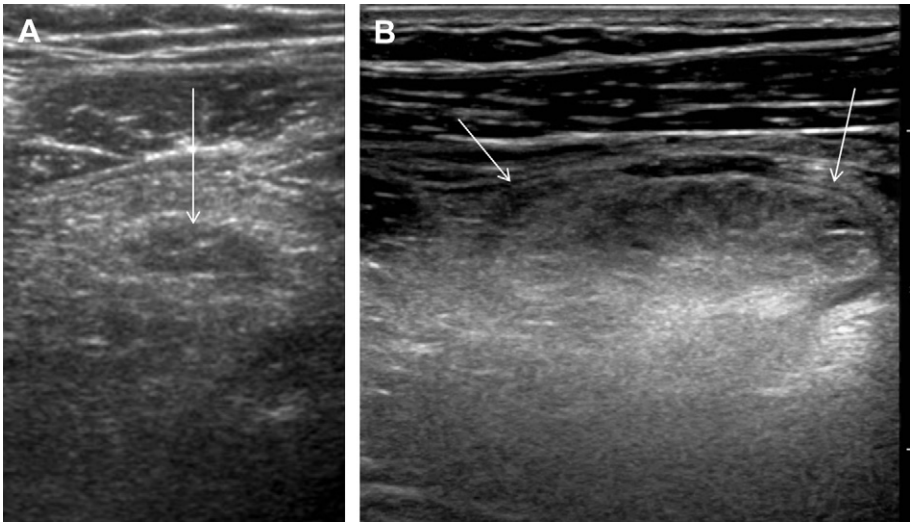

Fig. 24. (*A*) Epiploic appendagitis on US demonstrating a hypoechoic center (*arrow*). (*B*) Another patient with epiploic appendagitis demonstrating a fatty mass with a hypoechoic rim (*arrows*). (*Courtesy of* Dr Laurent Milot.)

demonstrated. Omental infarction also presents as a hyperechoic noncompressible fatty mass; however, it is usually larger than epiploic appendagitis. It is located anterior to the right colon and is often adherent to the peritoneum.[48,49]

SUMMARY

In summary, US of the bowel requires significant expertise but is extremely useful, especially in premenopausal women presenting to the US department with pelvic pain. Gynecologic and GI causes of pelvic pain can cause similar clinical presentations. When a gynecologic cause for a patient's pain is not found, the GI tract should be evaluated. Knowledge of the anatomy of the bowel wall and the GI tract is required. A methodical approach must be used. US is known to be accurate in the diagnosis of appendicitis, diverticulitis, and inflammatory bowel disease. Familiarity with the features of small bowel obstruction and intestinal ischemia prevent misdiagnosis and allow proper use of further imaging.

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