Although the incidence of appendicitis appears to be declining slightly in the Western world, it nonetheless remains the most common cause of acute abdominal pain requiring surgery.\textsuperscript{1,2} In the United States each year, \textasciitilde250,000 patients undergo appendectomies for presumed appendicitis.\textsuperscript{1,2} The differential diagnosis of acute appendicitis is extremely broad, and appendicitis often mimics the presentation of many other gastrointestinal, genitourinary, or gynecologic abnormalities. Historically, clinical misdiagnosis is common; \textasciitilde20\% of patients presumed to have appendicitis undergo a nontherapeutic laparotomy with removal of a normal appendix. The rate of negative appendectomy is even higher in women of reproductive age, in whom 30 to 40\% of surgeries yield normal appendices.\textsuperscript{3,4}

Surgeons have traditionally relied almost entirely on the patient’s history and physical examination to determine the need for surgery.\textsuperscript{1–13} However, during the past decade imaging studies have played an increasingly important role in the diagnostic evaluation of patients with possible appendicitis.\textsuperscript{8,9} Several large clinical series have documented a high degree of sensitivity and specificity for computed tomography (CT) and sonography in the evaluation of patients with right lower quadrant pain and possible acute appendicitis.\textsuperscript{8,9} The accurate noninvasive imaging of acute appendicitis now makes obsolete the complete reliance upon the patient’s history and physical examination to determine the need for surgery.

### Differential Diagnosis

In patients with acute right lower quadrant pain, appendicitis is only one of a large number of gastrointestinal, genitourinary, and gynecologic disorders. Common clinical mimics of acute appendicitis include mesenteric adenitis (Fig. 12–1), ureteral calculi, right-sided diverticulitis, acute gynecologic disorders, and viral gastroenteritis. In his classic monograph on the early diagnosis of the acute ab-

**Figure 12–1** Mesenteric adenitis. Note multiple enlarged mesenteric lymph nodes (N) on sagittal sonogram of right lower quadrant in a patient with a normal appendix (not shown).

**Figure 12–2** Pelvic inflammatory disease. Transverse sonogram of right lower quadrant demonstrates dilated and tortuous fallopian tube (arrow) containing intraluminal low-level echoes representing pus.
domen, Sir Zachary Cope listed 34 different disorders that may clinically mimic acute appendicitis. This list has greatly expanded in the past several decades, with advances in medical knowledge and newer disease entities, such as acquired immunodeficiency syndrome (AIDS), associated with immunosuppressive states. One factor contributing to the overall complexity of acute right lower quadrant pain as a clinical problem is that the differential diagnosis ranges from benign self-limited disorders (e.g., mesenteric adenitis or viral gastroenteritis) to lesions that carry significant morbidity if not treated promptly, including bowel obstruction, perforation, infarction, or abscesses of various etiologies.

In women of reproductive age, it is often difficult to clinically differentiate appendicitis from acute gynecologic disorders. Pelvic inflammatory disease (Fig. 12–2), degenerating myomas (Fig. 12–3), ovarian torsion, and ruptured or hemorrhagic functional cysts may all mimic the clinical presentation of acute appendicitis at times. In patients over 50 years of age, perforated cecal neoplasm should also be considered in the differential diagnosis.

**Clinical Presentation**

The “classic history” for acute appendicitis is the onset of diffuse abdominal or midepigastric pain that after a period of time localizes to the right lower quadrant. Pain is frequently accompanied by anorexia and at times nausea and vomiting. Of note is the fact that this classic history is present in only 55% of patients with acute appendicitis. The most characteristic physical finding is guarding and rebound tenderness over the McBurney point in the right iliac fossa. The early diagnosis of acute appendicitis is often difficult in pediatric patients due to problems in obtaining an adequate history. Some elderly or immunocompromised patients may have relatively minimal pain with acute appendicitis.

The location of the appendiceal tip is highly variable and may be a major factor in contributing to the patient’s symptoms and localization of pain. Flank pain may be the most striking finding in a patient with a retrocecal appendix that extends along the right lateral flank. In patients with a pelvic appendix, suprapubic tenderness or deep pelvic pain may be the most predominant clinical symptom. In female patients this may closely mimic symptoms of salpingitis, ovarian torsion, or other acute gynecologic abnormalities. Endovaginal sonography may be quite useful to demonstrate pelvic appendicitis in women (Fig. 12–4).

**Diagnostic Evaluation**

Laboratory values in appendicitis are highly variable and often nonspecific. Although leukocytosis with left shift is common, up to one third of adult patients with acute appendicitis have a normal leukocyte count. Elderly patients, in particular, are known to have relatively normal laboratory values with acute appendicitis. A high fever with leukocytosis is characteristic of, but not always present with, a periappendiceal abscess.

Although it seems reasonable that patients with clear-cut clinical evidence of acute appendicitis be managed surgically without preoperative imaging, patients with
atypical presentations and patients who are poor surgical candidates can benefit from preoperative imaging. Due to the extensive differential diagnoses in women of childbearing age, including numerous gynecologic entities for right lower quadrant pain, these patients benefit most from preoperative imaging. Bendek et al showed that the negative appendectomy rate was significantly lower (8% vs 28%) in women who underwent preoperative sonography versus those who had no preoperative imaging. Other studies have also documented a reduction in the negative appendectomy rate with preoperative imaging.

**Ultrasound**

**Imaging**

Graded compression sonography is based on the principle that when pressure is applied to a normal bowel loop with a transducer, it will readily compress. Any inflammatory or neoplastic process infiltrating the bowel wall alters its compliance, making it relatively noncompressible. Whenever possible, it is important to use the highest-resolution linear array transducer that affords adequate penetration to visualize the key anatomical landmarks of the psoas muscle and external iliac artery and vein. The study should be considered nondiagnostic if these normal structures cannot be visualized. In general, a 6 to 8 MHz linear or curved array transducer is adequate for most pediatric and adult patients. Endovaginal sonography is a valuable tool in female patients of reproductive age to evaluate the adnexal areas and detect pelvic appendicitis.

At the outset of the examination, the patient is asked to point with a single finger to the site of maximal pain or tenderness. This maneuver is often helpful in identifying a potentially aberrantly located appendix. Sonographic imaging is then initiated in the transverse plane using light pressure to first identify the abdominal wall musculature and the right colon. The right colon is the largest structure in the right flank with the typical sonographic bowel signature (echogenic submucosal layer) that has no peristalsis. The right colon is then followed caudally to its termination as a cecal tip. Pressure is gradually applied to the cecal tip to express all the gas and fecal contents from its lumen and enhance visualization of the noncompressible appendix. It is very important to vary the acoustic window to obtain the optimal view to demonstrate the appendix. Sometimes, as in the setting of a deep pelvic appendix, a full urinary bladder can be used as an acoustic window to visualize an otherwise inaccessible appendix. This technique, however, obviates graded compression. In the situation of a retrocecal appendix, placing the patient in a left lateral decubitus position may aid visualization by displacing the cecum and terminal ileum medially. With the

![Figure 12-5](image1)

*Figure 12-5* Early acute appendicitis. Enlarged noncompressible appendix (APP) is noted anterior to external iliac artery (A) and iliopsoas muscle (M).

![Figure 12-6](image2)

*Figure 12-6* Normal appendix visualized by sonography. Appendix (APP) is identified in its long axis with maximal diameter of 5 mm.

![Figure 12-7](image3)

*Figure 12-7* Acute nonperforated appendicitis. Note enlarged appendix (A). Echogenic submucosa is still preserved (arrow), indicating lack of perforation.
patient in this position, scanning the right flank can sometimes be helpful by reducing the transducer–target distance. Finally, in women of childbearing age, transvaginal sonography can play an important role in the visualization of a pelvic appendix or in the identification of alternative diagnoses. In one study of sonographically detected appendicitis, transabdominal sonography detected 76% of cases, whereas transvaginal sonography added 24%.\(^\text{18}\)

Although other published reports have suggested that the normal appendix can be visualized in a high percentage of patients (Fig. 12–6), the point is somewhat controversial.\(^\text{19}\) At our own institution, we are able to image the normal appendix in only –15 to 20% of patients. In general, the normal appendix measures 5 mm or less in maximal anteroposterior diameter and is readily compressible.\(^\text{20}\) Often there is a small amount of echogenic residual fecal debris and gas within the normal appendix.

**Diagnostic Criteria for Sonographic Diagnosis of Appendicitis**

The appendix can be confidently identified when a non-peristaltic, blind-ending, tubular structure is seen arising from the base of the cecum. The diagnosis of acute appendicitis can be established with confidence if a non-compressible appendix with a maximal outer diameter of 7 mm or greater is identified\(^\text{20}\) (Fig. 12–7). An appendix that measures in the range of 5 to 6 mm should be considered equivocal.\(^\text{21}\) These patients may be observed clinically because there is no risk of morbidity from perforation. Some of these patients will not prove to have appendicitis and, therefore, a trial period of observation is clearly warranted. Short-interval follow-up imaging of these patients during the observation period may reveal positive findings in those patients with early developing appendicitis.\(^\text{21}\) Patients with right lower quadrant pain and a visualized appendicolith are often taken to surgery, even with a borderline-sized appendix, due to concern for the potential morbidity of perforation in such patients.

For the most part, the diagnosis of acute appendicitis is based on gray-scale imaging findings. In equivocal cases, hyperemia of the inflamed appendix demonstrated by color Doppler sonography may be helpful in establishing the diagnosis, with reported sensitivities and specificities of 50 to 88% and 96 to 100%, respectively\(^\text{22–24}\) (Fig. 12–8). Microbubble contrast agents used in conjunction with power and spectral Doppler imaging have recently been reported to improve the sensitivity of this finding.\(^\text{25}\) However, false-negatives can result from gangrenous appendices with necrosis of appendiceal vessels. It is important to use low volume flow settings to visualize the small intramural appendiceal blood vessels. Other potential uses of color Doppler sonography are in evaluation of focally thickened bowel wall segments or other entities that may simulate appendicitis. These include inflammatory bowel disease (Fig. 12–9), thrombosis of the ovarian vein (Fig. 12–10), degenerating myomas, and other focal gastrointestinal abnormalities (Fig. 12–11).

Several other ancillary findings that support the diagnosis of acute appendicitis can be helpful. An appendicolith may be seen as an associated echogenic shadowing focus (Fig. 12–12), and its identification in the setting of other findings of appendicitis strengthens the sonographic diagnosis. Hyperechoic periappendiceal fat representing inflamed mesentery or omentum is a frequent finding in the presence of appendicitis with high specificity but low sensitivity.\(^\text{26}\) Although in our experience this is often an early sign of appendicitis, at least one study suggests that this finding may be an indicator of more advanced disease.\(^\text{27}\)

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**Figure 12–8** Hyperemia in early appendicitis. (A) Power Doppler sonogram demonstrates enlarged increased mural flow (arrow) within a minimally enlarged appendix (A), borderline in size. (B) The more advanced stage of appendicitis; note marked mural flow in appendix (arrow).
Limitations of Sonographic Diagnosis of Appendicitis

The entire length of the appendix must be visualized to its termination as a blind tip to avoid incorrect diagnoses. Unless the tip is identified, one cannot conclude that the structure in question truly represents the appendix because a segment of distal ileum may be misinterpreted as a dilated appendix. Ileum, however, does not arise from the cecal base, is not blind-ending, and often demonstrates peristalsis. Additionally, when the distal tip is not visualized, one cannot conclude that the appendix is normal because the inflammatory process of appendicitis may be entirely confined to the distal appendix. On rare occasions, a mildly dilated fallopian tube may be misconstrued as the appendix. Secondary thickening of the ap-
appendix may be due to extrinsic periappendiceal inflammatory processes such as tubo-ovarian abscesses or Crohn’s disease (Fig. 12–9). The diagnosis of a periappendiceal abscess can only be established with confidence if there is an associated appendicolith or if the abscess is in continuity with mural necrosis of the appendix (Fig. 12–13). A rare pitfall is that inspissated stool in the right colon may cause acoustic shadowing and can be misconstrued as an appendicolith.

Spontaneous resolution of acute appendicitis may be observed in a small subset of patients (abortive appendicitis).30 These patients may have imaging criteria for acute appendicitis in the absence of abdominal pain. This underscores the importance of always interpreting the imaging abnormalities in light of the clinical setting.

Benefits of Sonography in Diagnosing Appendicitis

Despite the fact that appendiceal sonography may be technically challenging, it has several clear imaging advantages.31–34 Sonography is readily available, inexpensive to perform, and has no ionizing radiation. Unlike CT, it is a real-time, interactive study. Sonographic findings are relatively easy to correlate with the patient’s anatomical site of maximal pain and tenderness. In addition, sonography can display bowel peristalsis and identify the discrete anatomical layers of the bowel wall, such as the echogenic submucosa. In the past several years, there have been substantial improvements in color Doppler sensitivity to enable visualization of blood flow to bowel without the use of contrast agents.35,36 Hyperemia, which is characteristic of acute inflammation, can thus be differentiated from ischemic disorders that cause decreased flow to the bowel. As with CT, sonography can effectively survey the remainder of the abdomen and pelvis if the appendix is normal.37 With the use of endovaginal probes, sonography excels at diagnosing gynecologic disorders. Sonography may also be useful in identifying mesenteric adenitis, inflammatory bowel disease, pyosalpinx, small bowel obstruction (Fig. 12–14), and ovarian torsion.37

Numerous reports have established the sensitivity of sonography in the range of 76 to 89%.20,21,34 Sonography is an operator-dependent technique that requires a dedicated sonologist willing to spend the time and effort to master the graded compression technique. Some institutions have much greater experience with CT diagnosis of appendicitis and have relegated sonography to a second-line imaging study.

Comparison of Ultrasonography and Computed Tomography for Diagnosing Appendicitis

In addition to graded compression sonography, a variety of CT techniques have been developed that are extremely valuable in the evaluation of patients with suspected appendicitis.38–41 The differences in CT methodology relate to whether there is administration of oral, intravenous, or rectal contrast. In patients with ample intraperitoneal fat, unenhanced CT (no oral and no intravenous contrast) is an accurate technique.39,40 It is important to note, however, that patient selection is key to the success of noncontrast CT for appendicitis. One significant limitation of noncontrast scans is that, in very thin patients with appendiceal perforation, it may be difficult to distinguish liquefied pus from indurated soft tissue inflammation. Intravenous contrast is thus routinely administered in such studies at many institutions and is particularly useful in patients

Figure 12–13 Perforated appendicitis. Transverse scan of inflamed appendix demonstrates focal loss of submucosal layer (arrow) and adjacent hypoechoic abscess (A).

Figure 12–14 Abortive appendicitis. Mildly dilated appendix (6.5 mm) (arrow) is demonstrated, consistent with appendicitis. Patient’s pain resolved spontaneously and no surgery was performed.
Sonography and CT play an increasingly important role in reducing the number of negative surgical explorations for acute appendicitis. Although at times technically challenging, sonography has several distinct advantages in imaging patients with right lower quadrant pain. At our institution sonography is the method of choice for imaging pediatric patients, women of reproductive age, and thin male patients. CT is complementary to sonography and excels in imaging patients who are poor candidates for sonography; namely, obese patients or patients with appendiceal perforation.

**Summary**

Sonography and CT play an increasingly important role in reducing the number of negative surgical explorations for acute appendicitis. Although at times technically challenging, sonography has several distinct advantages in imaging patients with right lower quadrant pain. At our institution sonography is the method of choice for imaging pediatric patients, women of reproductive age, and thin male patients. CT is complementary to sonography and excels in imaging patients who are poor candidates for sonography; namely, obese patients or patients with appendiceal perforation.

**References**

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AQ1 Au: legend for fig. 12–5 mentions iliopectoas, not psoas. Pls reconcile
AQ2 Au: this term, inflammatory bowel disease, not used in fig. legend. OK?
AQ3 Au: Please check fig ref. Legend mentions perforated appendicitis, not mural necrosis.
AQ4 Au: legend mentions small bowel obstruction, not app perf. Please chq.
AQ5 Au: I found this reference with the same title and authors but the journal, year, volume, and page numbers were different than your original. I updated this reference to match PubMed, okay?
AQ7 Au: Ref 45, please add city of publisher
AQ8 Au: Fig 12–5, A and M not shown on my copy. Please check
AQ9 Au: Fig 12–6, is the arrow pointing to the APP or something else? Please clarify/mention arrow in legend.
AQ10 Au: Fig 12–12, does APP stand for appendix? Please note in legend.