The nontraumatic acute abdomen is one of the most common presentations to the emergency room, with appendicitis being one of the most common causes of the acute abdomen. Up to 30% of patients suspected of having acute appendicitis will present with atypical signs and symptoms. There are many conditions that mimic acute appendicitis. The percentage of unnecessary appendectomies that result from a clinical false-positive diagnosis of appendicitis is reported to be 8% to 43%, with a mean of approximately 20%.

The use of computed tomography (CT) before planned surgery has decreased the negative appendectomy rate for patients with suspected acute appendicitis. Recognition of the typical and atypical CT signs of appendicitis is important to optimize the diagnosis yield of the examination. Visualization of an appendix with normal characteristics is the most important finding to exclude appendicitis.

Subjects and methods
A total of 113 patients with suspected acute appendicitis were referred for thin-section helical CT from the departments of surgery and emergency medicine. Patients ranged in age from 8 to 80 years (5 patients were younger than 15 years of age) and included 71 males and 42 females. CT diagnoses were recorded retrospectively. The studies were performed on an Advantage HI speed helical CT scanner (GE Medical Systems, Milwaukee, WI) using 3-, 5-, or 7-mm slice thickness. Some patients received oral enteric contrast. Intravenous contrast was administered to 29 of 57 (51%) of patients with acute appendicitis. Cases were reviewed for the following CT findings: maximum transverse diameter of the appendix, the “target” sign, calcified appendicolith, periappendiceal inflammation, appendiceal tip stranding, the “comet-tail” sign, the psoas sign, the “arrowhead sign,” the presence of appendiceal air (intraluminal, intramural, and periappendiceal), the position of the appendix (retrocecal or right hemipelvis and low abdomen), and the presence of free intraperitoneal fluid.

Final diagnoses were established based on pathologic findings of surgical specimens, clinical follow-up, or both. All cases of appendicitis were confirmed by surgical and pathologic findings. Negative diagnoses were confirmed surgically or through chart review until patient discharge. The variation and frequency of various CT signs of the inflamed appendix and characteristics of the normal appendix were noted.

Results
Among the 113 patients studied by preoperative helical CT, 57 patients had surgically and pathologically proven appendicitis. The other 56 patients did not have either surgical or clinical evidence of appendicitis at discharge.

The appendiceal lumen contained air or contrast in only 8.7% (5 of 57) of patients with acute appendicitis and in 75% (42 of 56) of patients without appendicitis (Figures 1 and 2). The maximum cross-sectional diameter of an inflamed appendix ranged from 8 to 22.5 mm. All of the 57 patients with appendicitis had an appendiceal diameter >0.6 cm, and 82% (47 of 57) had an appendiceal diameter >1 cm. Overlap in size between inflamed and normal appendices was noted although other signs of appendicitis were present in acute appendicitis.

The “target sign” is a hyperattenuated or intense contrast-enhancing thickened appendiceal wall. Intense contrast enhancement was defined as attenuation equal or greater than that of normal bowel wall. It was noted in 96% (27 of 29) of patients with acute appendicitis who underwent contrast-enhanced CT (Figures 3 and 4). An appendicolith is a focus of high attenuation that varies in size, shape, and number; they are usually seen within the proximal appendiceal...
CT OF ACUTE APPENDICITIS

FIGURE 1. A 39-year-old woman presented with unspecific abdominal pain. (A) Black arrow points to the cecum. White arrow shows the terminal ileum. (B) Arrow indicates the blinded end of an air-filled normal right hemipelvis appendix.

FIGURE 2. A 71-year-old woman with abdominal pain and proven appendicitis. (A) White arrow points to an air appendicolith. (B) White arrow indicates an enlarged appendix and periappendiceal stranding.

FIGURE 3. A 28-year-old woman presented with right lower quadrant pain; contrast-enhanced CT in a case of proven appendicitis. White arrow indicates a retrocecal appendix with thick and enhancing wall, the “target sign.”

FIGURE 4. A 20-year-old man with abdominal pain and proven appendicitis. White arrow indicates a retrocecal appendix with intense enhancing wall, the “target sign.”
lumen. One or more appendicolith was seen in 28% (16 of 57) of patients with appendicitis (Figure 5).

Periappendiceal fat stranding represents inflammation of the periappendiceal fat, mesenteric fat that surrounds the appendix. Spread of the appendiceal inflammation to surrounding mesenteric fat results in stranding of the right lower quadrant fat. Stranding of the mesenteric fat in the right lower quadrant was observed in 73% (42 of 57) of patients with acute appendicitis. When the appendix is borderline in size, this finding helps support the diagnosis of appendicitis (Figure 6). Appendiceal tip stranding was demonstrated in 68% (39 of 57) of patients. Inflammation may begin in the distal end of the appendix.

The psoas sign is defined as asymmetric obliteration of the fat immediately anterior to the right psoas muscle as compared with the left side. It was noted in 43% (25 of 57) of patients with acute appendicitis. Among patients with acute appendicitis, the psoas sign was noted in 43% (17 of 39) of lower abdominal and pelvic appendices and in 44% (8 of 18) of retrocecal appendices (Figures 7 through 9).

The “comet-tail” sign, defined as thickening of the right lateroconal fascia, was present in 26% (15 of 57) of patients with acute appendicitis. Right lateroconal fascia thickening was noted in 66% (12 of 18) of retrocecal and 7% (3 of 39) of low abdominal and pelvic appendices among patients with acute appendicitis (Figure 10).

Cecal signs of appendicitis, such as focal cecal apical thickening or the “arrowhead” sign, were under-evaluated because rectal administration of contrast was not used routinely in this study. The “arrowhead” sign occurs when cecal contrast material funnels symmetrically at the cecal apex to the point of appendiceal occlusion. In 2 patients, CT of the abdomen and pelvis with oral contrast was performed and the appendix was not visualized initially. Delayed images with additional oral contrast produced more distention of the cecum and subsequently the appendix was identified.

Free intraperitoneal fluid was present in 15% (9 of 57) of the patients with acute appendicitis. Inflamed appendices were seen in the lower abdomen and pelvis in 68% (39 of 57) of patients and were retrocecal in 31% (18 of 57) of patients (Figures 8 and 11 through 15). Intraluminal appendiceal air was seen in 8.7% (5 of 57) of patients with acute appendicitis. On the other hand, normal appendices demonstrated intraluminal appendiceal air in 75% (42 of 56) of patients without evidence of appendicitis (Figure 16).
FIGURE 7. A 35-year-old man with right lower quadrant pain, leukocytosis, and proven appendicitis. (A) Small arrow indicates a calcified appendicolith. Larger black and white arrows show asymmetric obliteration of the fat immediately anterior to the right psoas muscle as compared with left side; the psoas sign. (B) Small white arrows point to intramural air, a sign of microperforation. Large black and white arrows show asymmetric obliteration of the fat immediately anterior to the right psoas muscle as compared with left side, the psoas sign.

FIGURE 8. A 21-year-old man with abdominal pain, fever, and proven appendicitis. (A) White arrow shows a low-lying enlarged appendix in the pelvis without periappendiceal stranding. Averaging of intrapelvic organs and lack of periappendiceal stranding make the appendix difficult to find. (B) CT reconstruction images show a low-lying appendix in the pelvis.

FIGURE 9. A 29-year-old woman with abdominal pain and proven appendicitis. Black and white arrows indicate a psoas sign, asymmetric obliteration of the fat immediately anterior to the right psoas muscle as compared with the left.

Of the 56 patients without evidence of appendicitis, normal appendices were seen in the low abdomen and pelvis in 45 (80%) and were retrocecal in 11 (19%) (Figures 1, 16, and 17). The mean thickness of the normal appendix ranged from 6 and 10 mm. Of these 56 patients without acute appendicitis, an appendix with a diameter <0.6 cm was seen in 46% (26); a diameter >0.6 cm and <1 cm was noted in 51% (29); and a diameter >1 cm was seen in 1% (1).

Discussion
Presentation of many acute abdominal conditions overlap, and CT has been demonstrated to be a rapid and accurate tool in the diagnosis of many of these conditions. In order to confirm or exclude appendicitis on CT in a patient with clinical suspicion of appendicitis, finding the appendix is the initial step. Identification of anatomic landmarks (such as the cecum and terminal ileum), dynamic cine review, and reconstruction of CT...
FIGURE 10. A 40-year-old woman complaining of right lower quadrant pain. (A) White arrow points to a retrocecal appendix. (B) White arrow shows thickening of the right lateroconal fascia, the comet-tail sign.

FIGURE 11. A 23-year-old man complaining of abdominal pain with proven appendicitis. (A) White arrow points to a calcified appendicolith. (B) Black arrow shows a retrocecal appendix.

FIGURE 12. A 36-year-old woman with right lower quadrant pain and proven appendicitis. (A) White arrow shows an enlarged retrocecal appendix. (B) White arrow points to a thickened right lateroconal fascia, the comet-tail sign.

images on the monitor have been shown to be useful tools (Figure 1). Normal appendices are identified in 67% to 100% of adults without appendicitis on helical CT (Figure 16).

A normal appendix on CT is seen as a tubular structure, linear or curved with a blinded end arising from the postero-medial aspect of the cecum 1 to 2 cm below the ileocecal valve and measuring up to 10 mm in maximum diameter. Recognizing a normal appendix is the most important CT finding to exclude appendicitis (Figures 1 and 16).

Visualization of the appendix depends primarily on the amount of intraperitoneal fat and appendiceal position. Other factors that may help to recognize the appendix are the amount of ileocecal bowel opacification, intravenous contrast, and type and quality
FIGURE 13. A 22-year-old man with right lower quadrant pain and proven appendicitis. (A) Black arrow indicates an enlarged appendix in the right pelvis. (B) Black arrows point to the cecal appendiceal opening that appears to be obstructed by a hyperdense intraluminal structure.

FIGURE 14. A 27-year-old man with abdominal pain and proven appendicitis (A) White arrow points to a calcified appendicolith. (B) Black arrows show an enlarged appendix with periappendiceal stranding and enhancing walls.

FIGURE 15. A 20-year-old woman with low abdominal pain and proven appendicitis. White arrows indicate a low-lying appendix in the pelvis and no evidence of periappendiceal stranding.

FIGURE 16. A 57-year-old woman with nonspecific abdominal pain. White arrow indicates a normal air-filled appendix.

of the CT examination\(^{10,11}\) (Figure 1). Large amounts of intra-abdominal fat have been shown to provide excellent contrast to delineate the appendix and to facilitate identification of periappendiceal fat stranding. A low-lying appendix in the pelvis may be difficult to identify and differentiate from the adjacent intrapelvic organs (Figures 8 and 15). False-negative examinations in patients with appendices that lie low in the pelvis have been described.\(^{12}\) A lack of inflammatory changes in the periappendiceal region may further contribute to misinterpretation.\(^{12}\) Distention of the bowel lumen by enteric contrast highlights the anatomic landmarks, the cecum, and
FIGURE 17. A 45-year-old woman with abdominal pain. CT demonstrates a normal contrast-filled subhepatic appendix.

FIGURE 18. A 29-year-old man with right lower quadrant pain and proven appendicitis. White arrows point to an enlarged appendix with periappendiceal stranding.

FIGURE 19. A 47-year-old man with abdominal pain and leukocytosis. Open arrow shows an enlarged appendix with periappendiceal stranding. Black and white arrows indicate asymmetric obliteration of the fat immediately anterior to the right psoas muscle as compared with the left side.

FIGURE 20. A 46-year-old patient with abdominal pain and proven appendicitis. Small white arrow shows a right pelvic appendix with an intensely enhancing wall and periappendiceal stranding. Large black arrows indicate asymmetric obliteration of the fat immediately anterior to the right psoas muscle as compared with the left side, the psoas sign.

terminal ileum and permits easier recognition of the appendix. Utilization of rectal contrast distends the cecum more effectively than does oral contrast, and cecal signs of appendicitis, such as focal cecal apical thickening or the arrowhead sign, can be seen. An unfilled small bowel loop may be confused with an enlarged appendix, but this confusion is less likely with adequate oral contrast opacification of the small bowel.

The CT characteristics of appendicitis may vary according to the position of the appendix, the amount of intra-abdominal fat, and evolution of the disease over time. An enlarged appendix with periappendiceal stranding is a strong indicator of appendicitis. In this study, CT demonstrated periappendiceal inflammation in 73% of patients with acute appendicitis but up to a 98% incidence has been reported in other series.11 (Figures 6 and 18).

When an enlarged appendix is noted, evaluation for periappendiceal fat stranding is needed to ensure the proper diagnosis (Figures 6 and 18).

Patterns of inflammation may vary depending on the appendix position. Right lateroconal fascia thickening is seen more commonly with an inflamed retrocecal appendix (Figure 10) than with a right pelvic appendix. A positive psoas sign is seen as often in retrocecal as in right hemipelvis and low abdominal appendicitis (Figures 7, 9, and 19). The target sign (the enhancing, high-attenuation, thickened wall of an inflamed appendix) is best demonstrated after intravenous contrast (IV) administration. Intravenous contrast may have a role in distinguishing between early appendicitis and a normal appendix (Figures 3, 4, and 20).

Intraperitoneal fat is the intrinsic contrast medium for nonenhanced CT examinations. Identifying inflamma-
tory changes in slender patients with little periappendiceal and pericecal fat may be difficult; therefore, false-negative interpretations have been reported in pediatric patients and young women.14

An appendicolith has a high specificity for the diagnosis of acute appendicitis (Figures 5, 11, 21, and 22). The initial event in acute appendicitis is likely the appendicolith obstruction of the appendiceal lumen.15,16 The obstructed lumen leads to increased intraluminal pressures, causing venous congestion, arterial compromise, and tissue ischemia. Subsequently, there is epithelial mucosal barrier interruption, bacterial invasion, and transmural appendiceal wall inflammation.17 Finally, appendiceal wall infarction and perforation occur, which allows the inflammatory process to extend to the periappendiceal mesenteric fat, parietal peritoneum, and adjacent structures.17

Intraluminal appendiceal air is a finding on CT in both normal and inflamed appendices. However, intraluminal air is seen more commonly in normal appendices than in inflamed appendices. The appendix is connected to the cecum, a gas-filled viscus, and air probably regurgitates from the cecum into the nonobstructed appendiceal lumen.13 Intraluminal air can be seen in early appendicitis but is an uncommon finding in the late stages of the disease; appendiceal luminal air is probably resorbed after obstruction.15 Intramural, extraluminal or periappendiceal air is more characteristic of advanced inflammation and indicates a perforated appendix15 (Figure 7).

Summary

Intraluminal gas and an appendiceal diameter measuring up to 10 mm on CT are common findings of a normal appendix. Recognition of a normal appendix is required to exclude appendicitis. An enlarged appendix with periappendiceal inflammation is the most common finding of acute appendicitis. Fat stranding may present in different patterns depending on location of the appendix.

REFERENCES