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CT in appendicitis

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ABSTRACT
Appendicitis is the most common abdominal emergency occurring in 7%–12% of the population. The aim of this article was to pictorially present the spectrum of appendix and acute appendicitis appearances on computed tomography (CT). The various appearances on CT of the normal appendix are shown as well as the CT criteria for the differentiation of perforated and non-perforated appendicitis.

Key words: • *appendix* • *appendicitis* • *computed tomography*

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Appendicitis can be acute or chronic. Acute appendicitis is the most common surgical abdominal emergency in the western world occurring in 7%–12% of the general population (1). Prompt and accurate diagnosis reduces the morbidity and mortality of acute appendicitis. Due to its high sensitivity and specificity, computed tomography (CT) is becoming the preferred imaging modality for suspected acute appendicitis, particularly in adults (2). CT is more accurate in the diagnosis of acute appendicitis since it is less operator dependent than ultrasonography (US) (3). Therefore, the use of CT has been advocated so far in the minority of patients with acute appendicitis that present with atypical clinical features (4).

Although in most cases the diagnosis of acute appendicitis is usually clear on the basis of clinical features, there is a significant negative laparotomy rate. Therefore, some authorities now recommend CT for all patients with suspected acute appendicitis or for those with equivocal acute appendicitis. CT may also be helpful in the preoperative evaluation of patients undergoing laparoscopic appendectomy (4).

CT seems to be more sensitive (96% vs. 76%) and accurate (94% vs. 91%) than US in diagnosing acute appendicitis, whereas they are almost equal when it comes to specificity (89% vs. 91%). CT imaging tailored to evaluate acute appendicitis has proven to be particularly successful with a sensitivity of 100%, specificity of 95%, positive predictive value of 97%, negative predictive value of 100%, and accuracy of 98% (5, 6).

Multidetector-row CT (MDCT) currently has an important role in the diagnosis of acute appendicitis and its severity. Some authors suggest that they can diagnose acute appendicitis with an accuracy of 99%. It is also possible to reconstruct the entire form and position of appendices from successive CT findings because of high-resolution thin-slice MDCT images (7).

CT examination protocol

The patient is prepared with 800–1000 ml of oral contrast medium for bowel opacification 60–90 min prior to scanning. The scan is performed with the patient in the supine position, following an intravenous injection of 100–120 ml of iodinated contrast medium at a rate of 3 ml/s and a scan delay of approximately 60 s. The combination of oral and intravenous contrast medium provides the most information about the inflamed appendix and the surrounding tissues (5). It was reported that oral administration of up to 800 ml of contrast medium at least 1 h before CT scanning enables opacification of both the small bowel and the right colon in most patients (8).

CT appearances of the normal appendix

Although in the initial period after the development of CT the visualization of the normal appendix was poor, this changed with refinements in CT technology, standardization of the technique, and increasing experience (4). Compared with plain radiography, barium enema, and US, CT achieved both higher accuracy and greater consistency for appendiceal imaging (9). The identification of a normal appendix excludes appendicitis effectively and with a greater degree of confidence than does the lack of CT findings indicative of appendicitis (10). A normal appendix is visualized in 43%–58% of CT examinations of the abdomen. With 5-mm sections a normal appendix was identified in 75% of cases. Ingestion of contrast medium improves the detection rate and is recommended to enhance the appendiceal and cecal walls (4). Some authors reported a normal appendix on CT scans in 94% of patients with negative findings using rectal contrast material and additional decubitus series.

The normal appendix is usually not conspicuous and needs to be looked for diligently. It sometimes may be seen throughout its entirety as a tubular, linear, or curvilinear structure in a single CT section. More often, however, because of its convoluted course, the appendix appears in multiple contiguous sections and needs to be followed to its origin from the posteromedial wall of the cecum 2.5–3.0 cm below the ileocecal valve for confirmation (4). The position of the tip of the appendix varies and may be retrocecal (65%), pelvic (31%), paracolic (in the sulcus of the other side of the cecum), pre-ileal, post-ileal, promontory (pointing toward the sacral promontory), or subcecal. The appendix can even be located in the left lower quadrant if there is a visceral transposition. Congenital absence and duplication of the appendix have been reported, but are rare (2). The 3 most common positions are descending, pelvic, and retroperitoneal (in a fixed retroperitoneal position in 60% and mobile in 40% of cases) (4).

Average length of the appendix is 9 cm (range, 4–25 cm). The diameter of the appendix outer wall does not exceed 6 mm and the lumen may contain fluid, fecal material, air, or contrast medium. It is very important to determine the maximum thickness of the normal appendix with CT in order to diagnose acute appendicitis and to rule out other etiologies of acute abdominal pain (3). An appendicolith may be present within the lumen of the appendix in asymptomatic patients. The wall of the appendix is well depicted by the surrounding fat and is thin, measuring less than 1 mm in thickness (2). The normal appendix may be collapsed. Ileocolic vessels may be mistaken for the appendix if their branching is not readily visualized. Gerota's fascia may have a similar appearance, but is readily differentiated by its continuity with the lateral conal fascia (4).

Surgeons and clinicians often ask whether the normal appendix was identified, as this increases their confidence in the negative predictive value of a negative CT report (10). Non-enhanced limited CT is not operator dependent and does not require the same level of extensive experience that is needed for accurate US results (11).

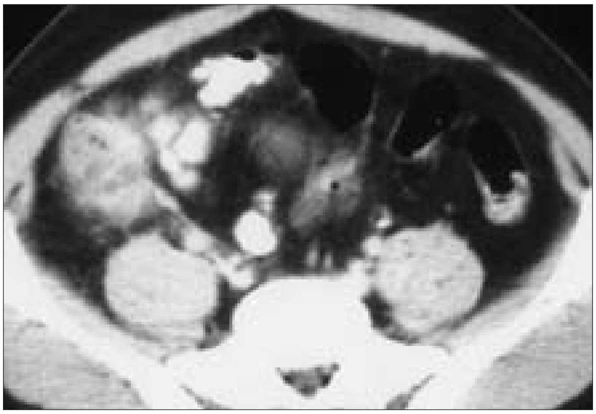

Figure 1. On axial CT image of an acute appendicitis case, periappendiceal soft tissue mass, with a variable degree of enhancement representing a phlegmon is evident.

CT appearances of appendicitis

The appearance of appendicitis on CT depends on the extent and severity of inflammation, and the presence or absence of complications (4). Inflammation of the appendix results from obstruction of its lumen from fecaliths, foreign bodies, lymphoid hyperplasia, parasites, or tumors (primary or metastatic) (2).

A prompt and accurate diagnosis of acute appendicitis significantly decreases morbidity and mortality. Although in most cases clinical symptoms and signs may strongly suggest a diagnosis of acute appendicitis, the clinical presentation is atypical in 20% of cases, while in another 20% the condition is misdiagnosed. The clinical features in children are often atypical, with generalized rather than localized abdominal pain, whereas in the elderly there is a wider range of differential diagnosis than in the younger population because of the frequency of age-related diseases such as diverticulitis. The diagnosis may also be delayed in the elderly as they complain less of pain than younger patients do and clinical signs are less pronounced. There is also an increased risk of misdiagnosis in young females because gynecological diseases can mimic acute appendicitis (2). Women suspected of having appendicitis benefit mostly from preoperative CT or US, and they have significantly lower negative appendectomy rate than women who do not undergo preoperative imaging (12). For some female patients clinicians order pelvic US to be performed within 24 h of a CT study.

The diagnosis of acute appendicitis is usually based on clinical symptoms and laboratory tests; however, one third of patients with acute appendicitis show atypical clinical symptoms and physical findings. In this group of patients radiological imaging can play an important clinical role.

The inflamed appendix shows a variable degree of distension, has a diameter measuring 6–40 mm, and wall thickness of 1–3 mm. The wall is usually asymmetrically thickened and enhances with intravenous contrast medium (13). As the disease progresses a periappendiceal inflammatory mass called phlegmon may develop (Fig. 1). Thickening and enhancement with intravenous contrast medium may also be observed in the adjacent wall of the cecum or ileum if they are involved in the inflammatory process (Fig. 2). Progression of the inflammatory process may lead to the findings ranging from a sealed abscess to widespread intra-

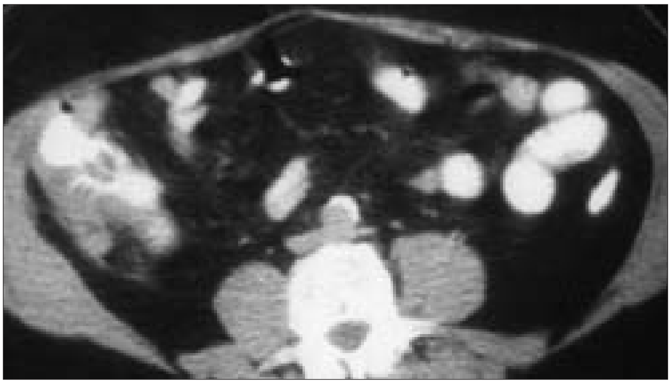

Figure 2. Axial CT image shows the inflammatory changes thickening the cecal wall and involving the peri-cecal fat due to appendicitis.

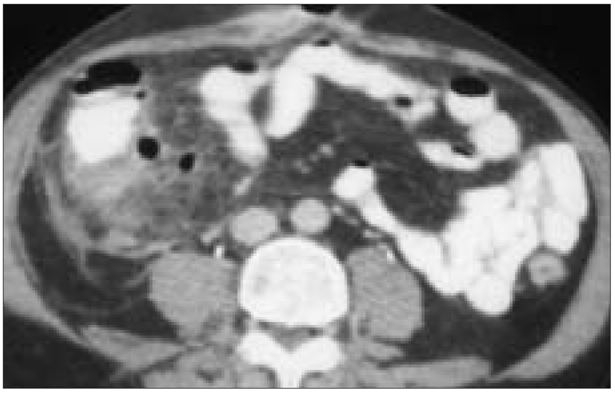

Figure 3. On axial CT image, an area of ill-defined and variable enhancement with pockets of extraluminal gas is present due to an appendiceal abscess. Note that there is thickening of the peri-cecal fascia.

Figure 4. Axial CT image shows dilated appendix lumen filled with fluid, with thickened and enhanced walls, following the administration of intravenous contrast medium. Note the presence of an adjacent fluid collection.

Figure 5. Appendiceal abscess in the process of being drained under CT guidance.

abdominal inflammatory seeding with multiple abscesses. An abscess with a well-defined border usually indicates chronicity and the presence of air bubbles or air fluid levels inside indicates the presence of gas-forming organisms or communication of the abscess with the bowel (Fig. 3). If the periappendiceal fat is involved in the inflammatory process then it shows an increased haziness, streaky densities, and/or fluid collection (Fig. 4). In 30% of appendicitis cases the arrowhead sign is present and it has 100% specificity. It describes focal thickening of the cecal wall around the root of the appendix, which funnels toward the point of obstruction of the appendiceal lumen (14).

There are 5 specific CT findings for perforated appendicitis: abscess, phlegmon, extraluminal air, extraluminal appendicolith, and focal defect in the enhanced wall of the appendix. Among these findings with 100% specificity, a focal defect in the enhanced appendiceal wall has the highest sensitivity. Many surgeons now avoid a surgical approach once perforation has occurred because of perioperative complications. Instead, they choose conservative medical treatment or percutaneous CT drainage (Fig. 5), with or without interval appendectomy (15–18).

Perforation without abscess formation, peri-appendicitis (serosal inflammation of the appendix due to disease outside the appendix), or inflammation limited to the mucosa or submucosa of the appendix makes the diagnosis of appendicitis on CT difficult. Microscopically some of the small blood vessels in the submucosa show fibrinoid necrosis with neutrophilic infiltrations in acute appendicitis in Henoch-Shonlein purpura cases (19).

The advantage of using intravenous contrast material is that it allows assessment of appendiceal wall enhancement, differentiation of pelvic blood vessels from a retrocecal appendix, and identification of other pathologic conditions (8). The ability of CT to depict periappendiceal pathologies, which may alter the management plan, is of primary importance to clinicians (20).

Although most cases of acute appendicitis can be diagnosed correctly with a meticulously obtained history and physical examination, 22%–33% of patients do not present with typical signs,

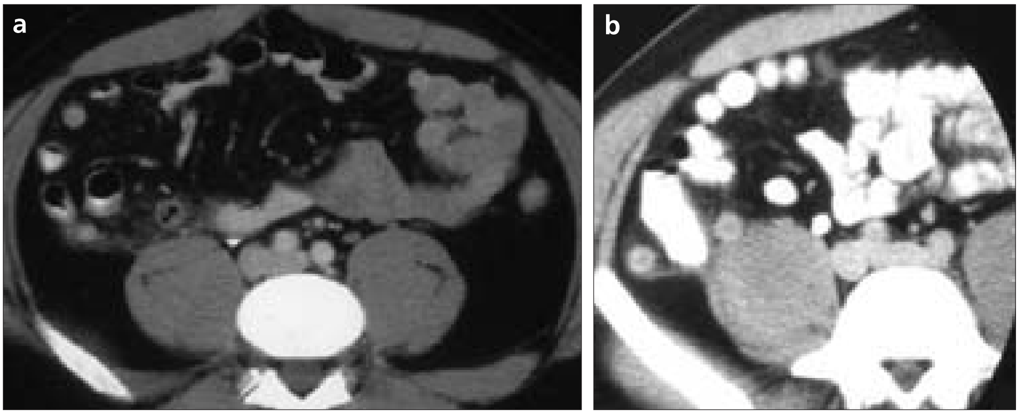

Figure 6. a, b. Axial CT images of two different cases showing a thickened appendix wall with homogenous enhancement after intravenous contrast medium administration.

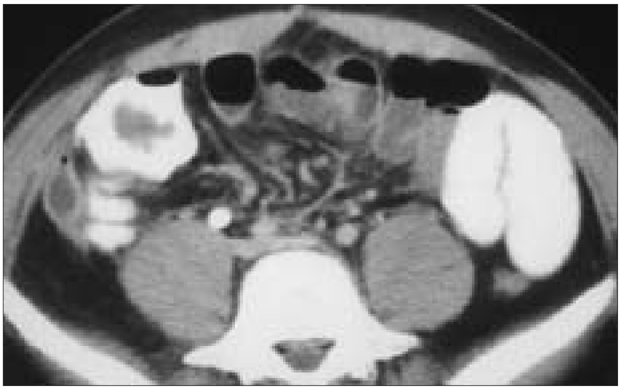

Figure 7. On axial CT image, the dilated lumen of the appendix is filled with fluid and shows thickened and enhanced walls after intravenous contrast medium administration.

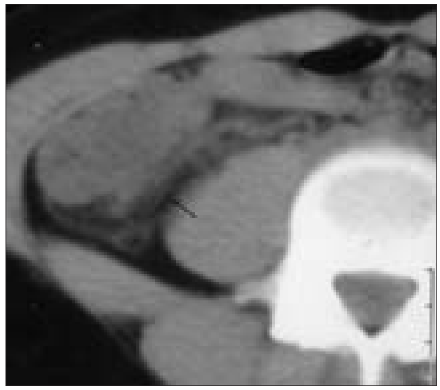

Figure 8. Axial CT image without oral or intravenous contrast medium administration in acute appendicitis. Note the dirty fat sign.

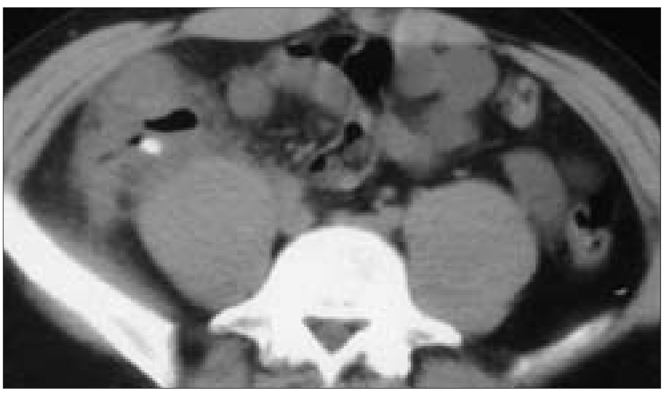

Figure 9. Unenhanced CT image demonstrating an appendicolith and an inflammatory process surrounding the appendiceal lumen.

symptoms, and accurate diagnosis (20). CT has been shown to be accurate in the diagnosis of acute appendicitis. Negative appendectomy rates were as high as 30% in the pre-CT era. Its use has decreased the negative laparotomy rate to 4%–7% (11, 21). With the progressive increase in the use of CT has also come a decrease in negative appendectomy rate to 2% (22).

CT classification of appendicitis

Based on CT findings, acute appendicitis may be classified into 4 categories of increasing severity:

Category 1: Simple appendicitis in which findings are limited to the appendix, and the lumen of the appendix may be distended with a thick and enhancing wall (Figs. 6, 7).

Category 2: Appendicitis with periappendiceal inflammatory changes. In this case, the fat surrounding the appendix and/or cecum appears enhanced (Figs. 4, 8, 9).

Category 3: Appendicitis with appendiceal phlegmon or abscess (Figs. 1, 3, 5, 10).

Category 4: Appendicitis with distal inflammatory changes. This is the most severe type, indicating perforation of the appendix with dissemination of the inflammatory process.

Chronic appendicitis

Chronic appendicitis is rare and may be seen in cystic fibrosis where mucoid material occupies the lumen of the appendix. It is also seen with recurrent episodes of acute appendicitis or when the appendix has been incompletely removed (8). Continuous symptom duration of more than 3 weeks (chronic appendicitis) or previous episodes of similar symptoms (recurrent appendicitis) occur in 6% and 13% of patients with appendicitis referred for CT, respectively. Recurrent and chronic appendicitis are indistinguishable from acute appendicitis on

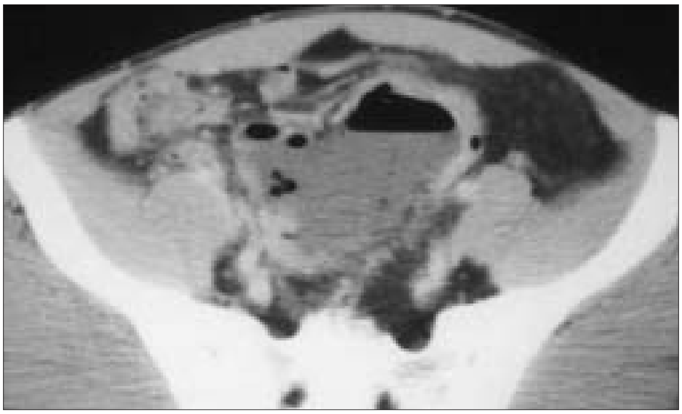

Figure 10. Axial CT image shows air-fluid level due to an abscess in an appendicitis case.

Figure 11. Axial CT image shows asymmetrical mural thickening of the cecum in a case of cecal cancer, resembling an inflammatory mass.

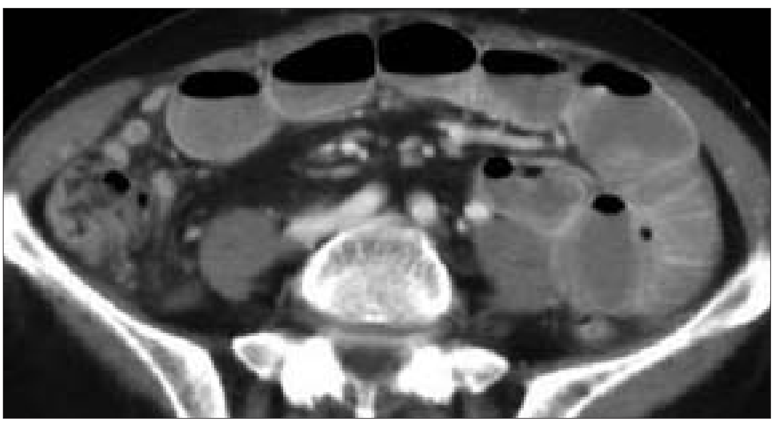

Figure 12. Axial CT image shows distended ileum loops in a case of Crohn's disease and peri-cecal inflammatory changes.

CT. Stump appendicitis is a rare variation of recurrent appendiceal disease, which occurs after appendectomy with simple ligation and without appendiceal stump investigation. The residual appendiceal stump acts as a small appendix or diverticulum that can become obstructed and inflamed. CT shows peri-cecal fat stranding and focal thickening of the cecal apex (23).

Distal appendicitis

Most cases of appendicitis begin with luminal obstruction of the appendiceal orifice; however, as many as 8% of patients with appendicitis that undergo appendiceal CT have at least 3 cm of a normal proximal appendix with the appendicitis confined to the distal appendix. CT features to distinguish distal from full-length appendicitis include an absence of change in the cecal apex and a transition point between a proximal normal and a distal inflamed appendix (23).

Appendicitis in children

Acute appendicitis may be missed at initial clinical examination in 28%–57% of children aged 12 years and younger, and in nearly 100% of children under the age of 2 years. Diagnostic imaging has an ever-increasing role in the prompt and accurate diagnosis of acute appendicitis in the pediatric population (24). Current reports in the pediatric medical emergency and surgery literature advocate imaging, particularly CT, as the gold standard for diagnosing appendicitis (25). Researchers found that 60.5% of children had equivocal clinical findings and 14.7% had negative appendectomies, and when an imaging protocol was used 4.1% of cases had negative appendectomies. After implementation of an imaging protocol using US and CT, the perforation and negative appendectomy rates decrease (26). In a recent article (27), it was suggested that patients with appendicolith should have an interval appendectomy.

Differential diagnosis

A number of pathological conditions may mimic appendicitis on CT imaging. These include right-sided diverticulitis, complicated cecal carcinoma (Fig. 11), Crohn's colitis (Fig. 12), mesenteric inflammation, complicated ovarian cysts, endometriosis, ectopic pregnancy, local lymphadenopathy, and fibro-fatty proliferation (28). Most of them may be difficult to differentiate from acute appendicitis. Alternative diagnoses identified on CT scans with a normal appendix may also include right tubo-ovarian abscess, epiploic appendagitis (Fig. 13), biliary colic, or urinary tract infection (9). Perforated duodenal ulcer, superior mesenteric venous thrombosis, small bowel ischemia, and abdominal wall hernia are some abdominal pathologic entities that require surgery and which present with right lower abdominal pain (29).

Carcinoid tumors of the appendix, in most cases, are found incidentally during appendectomies, especially in young females, and are usually smaller than 1 cm, which is the reason for that there are no metastases. These tumors are thought to be the

Figure 13. Axial CT image shows increased attenuation of mesocolic fat in a case of epiploic appendagitis. The location of acute epiploic appendagitis is most commonly adjacent to the sigmoid colon, whereas acute omental infarction is typically located in the right lower quadrant and often is mistaken for acute appendicitis.

most common type of appendiceal neoplasms (30). Some authors suggest that a standardized CT protocol for patients who present with right lower quadrant pain that includes imaging of the abdomen and pelvis with routine oral and intravenous contrast material provides an accurate diagnosis, even without the preselection of patients who are more likely to have appendicitis. If CT can be postponed until bowel preparation is feasible, it can then be performed with a higher diagnostic yield (31).

Limitations of CT

CT has been shown to be an excellent diagnostic technique for patients with acute abdominal pain and may have a major effect on the treatment of these patients. Exposure to radiation limits the use of CT imaging during pregnancy and for young women and children (32). Preliminary findings indicate that it is feasible to optimize the CT dose used to evaluate appendicitis in children by using phantom-based computer simulations (33).

Conclusion

CT can demonstrate the normal appendix as well as the many ways that appendicitis can appear (4). Both abdominal and pelvic CT examinations are necessary to increase sensitivity and identify the many possible causes of right lower quandrant pain in patients with clinically suspected appendicitis (29). CT is considered to be the initial diagnostic tool of choice for confirming suspected appendicitis in adult patients with a normal or obese body habitus (34). CT has better sensitivity and specificity than US, but we need to evaluate the value of CT's improved diagnostic performance versus its cost and availability (35, 36). It is a safe, reliable, and accurate modality for the diagnosis of acute appendicitis, especially in patients with equivocal presentation.

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