Diagnosing Acute Appendicitis in Adults: Accuracy of Color Doppler Sonography and MDCT Compared with Surgery and Clinical Follow-Up

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OBJECTIVE. The objective of our study was to evaluate the accuracy of color Doppler sonography and contrast-enhanced MDCT in the diagnosis of acute appendicitis in adults and their utility as a triage tool in lower abdominal pain.

MATERIALS AND METHODS. We reviewed the medical records of 420 consecutive adult patients, 271 women and 149 men, 18 years old or older, referred from the emergency department to sonography examination for clinically suspected acute appendicitis between January 2003 and June 2006. Patients underwent sonography of the right upper abdomen and pelvis followed by graded compression and color Doppler sonography of the right lower quadrant. CT was performed in 132 patients due to inconclusive sonography findings or a discrepancy between the clinical diagnosis and the sonography diagnosis. Sonography and CT reports were compared with surgery or clinical follow-up as the reference standard. Statistical analyses were performed by Pearson's chi-square test and cross-tabulation software.

RESULTS. Sonography and CT correctly diagnosed acute appendicitis in 66 of 75 patients and in 38 of 39 patients, respectively, and correctly denied acute appendicitis in 312 of 326 and in 92 of 92 patients. Sonography was inconclusive in 17 of 418 cases and CT, in one of 132 cases. Sonography and CT allowed alternative diagnoses in 82 and 42 patients, respectively. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy for sonography were 74.2%, 97%, 88%, 93%, and 92%, respectively, and for CT, 100%, 98.9%, 97.4%, 100%, and 99%.

CONCLUSION. Sonography should be the first imaging technique in adult patients for the diagnosis of acute appendicitis and triage of acute abdominal pain. CT should be used as a complementary study for selected cases.

Keywords: abdominal imaging, appendicitis, color Doppler sonography, emergency radiology, MDCT

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Acute appendicitis, the most frequently suspected acute abdominal disorder in the emergency department and the most common indication for emergency abdominal surgery, is still a difficult diagnosis based on clinical and laboratory data. In adult patients, appendicitis-mimicking conditions of gastrointestinal, urologic, or gynecologic origin make the diagnosis even more difficult [1, 2]. Moreover, in pregnant women, both a missed diagnosis and an unnecessary laparotomy may carry serious complications and have adverse effects on fetal outcome [3]. The negative laparotomy rate when the diagnosis is based on only clinical and laboratory data ranges from 16% to 47%, with a mean of 26%. On the other hand, the perforation rate reaches 35% when surgery is delayed [4]. Imaging for the diagnosis of acute appendicitis lowered the negative laparotomy rate to 6–10% [5]. The death rate caused by acute appendicitis is now reported to be approximately 0.25% considering all age ranges [4, 6]. Consequently, imaging evaluation for suspected acute appendicitis in adult patients is increasingly requested.

The purpose of this study was to determine the role of imaging studies—color Doppler sonography and contrast-enhanced MDCT—in the diagnosis of acute appendicitis and their utility in the triage of lower abdominal pain in an adult population referred from the emergency department with clinical suspicion of acute appendicitis.

Materials and Methods

The institutional ethics review board approved the research protocol. The medical records of 420 consecutive adult patients referred from the emergency department to sonography examination, as the first imaging technique, between January

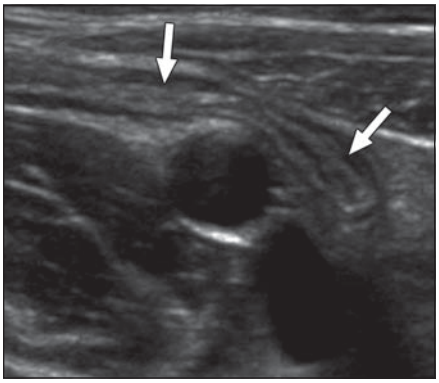


Fig. 1—Sonography of normal appendix in 18-year-old woman with lower abdominal pain. On longitudinal scan, tubular blind-ended structure with thin walls and less than 5 mm outer diameter (*arrows*) is seen in right lower quadrant, anterior to external iliac vessels.

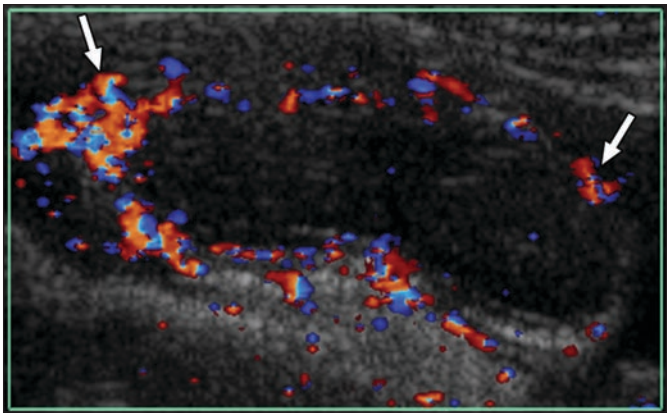


Fig. 2—28-year-old man with fever and right lower quadrant pain. Incompressible, blind-ended, fluid-filled tubular structure 6.6 mm in diameter with hyperemic walls (*arrows*), pathognomonic for acute appendicitis, is seen on color Doppler sonography.

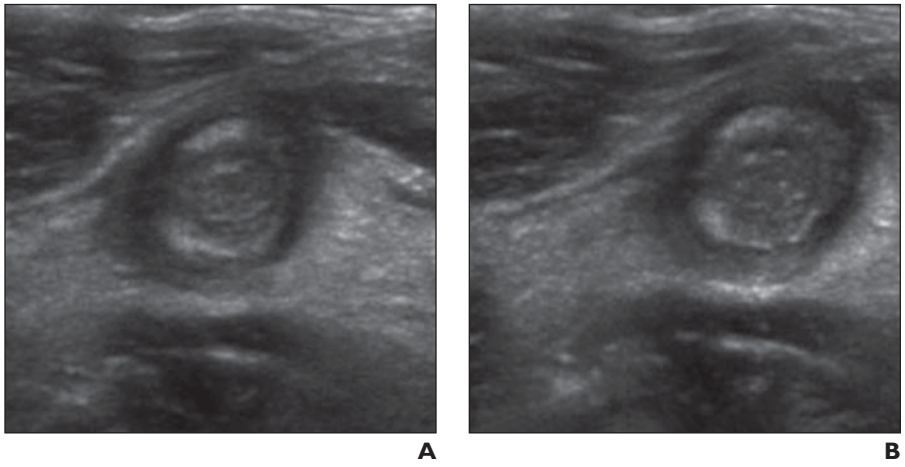


Fig. 3—32-year-old woman with right lower quadrant tenderness.
A and **B**, Axial sonography images obtained without compression (**A**) and during compression (**B**) show inflamed appendix with hypoechoic center, inner hyperechoic ring, and outer hypoechoic ring (target sign). Note hyperechoic surrounding area of inflamed mesentery fat (halo sign).

2003 and June 2006 for clinically suspected acute appendicitis were reviewed. The patient population included 271 (64.5%) women, 64 of whom were pregnant (23.6% of the women and 15.2% of the total population), and 149 (35.5%) men, who ranged in age from 18 to 73 years (mean age, 28.4 years). One hundred thirty-two patients underwent contrast-enhanced MDCT due to a discrepancy between the clinical diagnosis and the sonography diagnosis or to inconclusive sonography studies.

Clinical and laboratory findings, imaging diagnosis, and therapeutic procedure were recorded. Imaging test results were designated as positive, negative, or inconclusive. Alternative diseases diagnosed on imaging examinations were registered. Surgery or clinical follow-up was the gold standard for the evaluation of sonography and CT performance.

Color Doppler Sonography Examination

A routine sonography examination of the right upper abdomen and pelvis using a 3-5–MHz convex transducer (HDI 5000 and IU22, Philips Medical Systems) was initially performed to rule out alternative abnormalities related to the liver, gallbladder, pancreas, kidney or pelvic organs, and the presence of peritoneal fluid. Afterward, graded compression and color Doppler sonography of the right lower quadrant with special emphasis directed to the site of maximal tenderness was performed using a linear 5-12–MHz or 4-8–MHz transducer, according to body size.

On transverse scanning, the right colon was visualized and followed, the iliac vessels were identified, and scanning extended distally into the pelvis. The normal appendix appeared as a blind-ended, gut pattern, aperistaltic tubular structure originating from the base of the cecum with a wall thickness of 2 mm or less and diameter of 6 mm or less [7] (Fig. 1). The graded compression technique [8] allowed differentiation between an incompressible inflamed appendix and compressible and displaceable normal small-bowel loops. An incompressible, blind-ended, and fluid-filled tubular structure that was more than 6 mm in diameter with hyperemic walls was diagnostic of appendicitis (Fig. 2). The presence of an appendicolith, peritoneal fluid, or hyperechoic periappendicular fat (Fig. 3) was an additional positive finding. A right lower quadrant fluid collection without visualization of the inflamed appendix raised suspicion for perforated appendicitis and periappendicular abscess (Fig. 4). Lumbar manual compression was added to improve visualization of the inflamed appendix, especially when in a retrocecal position [9].

Appendiceal sonography was performed in 10 minutes on average, after abdominal sonographic screening. The sonography report was positive, negative, or inconclusive for acute appendicitis. Alternative diagnoses, when achieved, were reported.

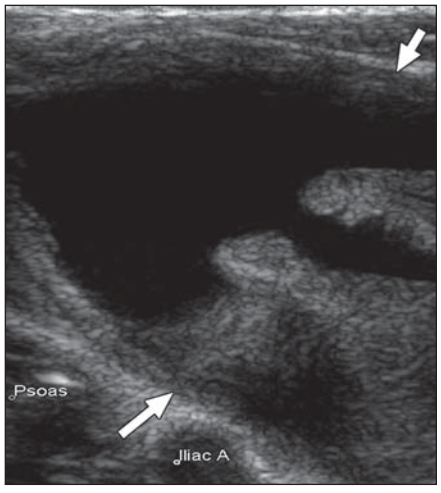


Fig. 4—23-year-old woman with fever and lower abdominal pain. Sonography image shows fluid collection with thick internal septum in right lower quadrant (*arrows*), which raised suspicion of periappendicular abscess and was confirmed on surgery. Inflamed appendix was not seen.

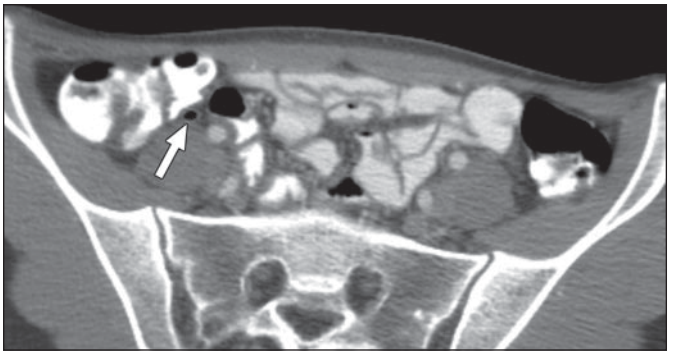


Fig. 5—18-year-old woman with lower abdominal pain (same patient as in Fig. 1). CT image shows normal appendix. Intraluminal air is seen in less-than-5-mm diameter appendix (*arrow*), surrounded by normal mesenteric fat.

Contrast-Enhanced MDCT Examination

CT of the lower abdomen and pelvis, from the xiphoid to the pubic symphysis, was performed after oral contrast administration and bolus injection of 80 mL of nonionic contrast medium (300 mg of iopamidol [Iopamiro, Bracco Diagnostics]). Examinations were performed on a 16-MDCT unit at 120 kVp and 100 mAs; a pitch of 1 was used. Axial reconstructions from the raw data, 3 mm thick, at 1.5-mm increments were obtained.

The normal appendix when visualized was reported. The diameter of the normal appendix ranged from 3 to 10 mm, depending on visualization of intraluminal contrast material or gas [10, 11] (Fig. 5). The diagnosis of appendicitis was based on the presence of a blind-ended tubular structure of more than 6 mm in diameter adjacent to the cecum without intraluminal air or contrast medium and the presence of additional positive findings, such as an appendicolith, cecal wall thickening, periappendicular fat stranding, or periappendicular fluid. An abscess in the right iliac fossa raised suspicion for perforated appendicitis. The CT report was positive, negative, or inconclusive for acute appendicitis. Alternative diagnoses, when achieved, were reported.

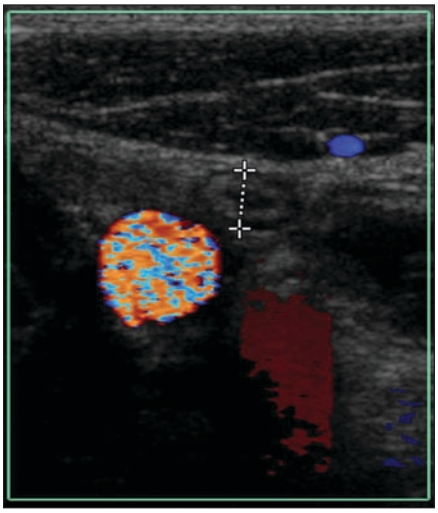


Fig. 6—20-year-old woman with periumbilical and lower right quadrant pain. Incompressible appendix, 4.2 mm in diameter (*cursors*), is seen on sonography. Iliac vessels are shown on color Doppler. Sonography report was inconclusive for acute appendicitis. Acute appendicitis was diagnosed on CT (not shown).

Radiologist Responsible

Sonography examinations were performed from 8:00 am to 4:00 pm by a sonography technician; the appendiceal sonography examination and any abnormality seen on the upper abdominal examination were always confirmed by a sonography examination performed by a sonography-dedicated or body imaging senior radiologist. From 4:00 pm to 8:00 am, the examinations were performed by a resident in radiology with at least 6 months' training, and the report was revised by the senior radiologist on-call through a home-installed PACS connection or personally the next day.

Reference Standard

The reference standard was surgery or conservative treatment. Imaging tests and therapy—observation before discharge from the hospital, hospitalization for appendectomy, or hospitalization for treatment of alternative diseases—were performed within 12 hours of patient arrival to the emergency department. Diagnostic performances of sonography and CT were compared with the reference standard for each patient.

Statistical Analysis

True-positive cases were those with a positive imaging diagnosis for acute appendicitis confirmed on surgery and pathologic reports, and false-positive cases were those with a positive imaging diagnosis but negative pathologic specimen. The true-negative cases were composed of patients with a negative imaging diagnosis who were discharged from the hospital or treated for an alternative diagnosis, and the false-negative cases were those with a negative imaging diagnosis but acute appendicitis diagnosed on pathologic specimen.

The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of the imaging diagnoses were calculated. Statistical analyses were performed using Pearson's chi-square test and SPSS software (version 14, SPSS) for Windows (Microsoft).

Results

Surgery was performed in 102 patients either for a positive imaging diagnosis of acute appendicitis (97 patients) or for an alternative diagnosis (five patients). Acute appendicitis was confirmed on pathologic specimen in 95 patients: 84 were phlegmonous appendicitis; seven, necrotic; and four, perforated with a periappendicular abscess. The appendix was normal in two patients (1.9% of white appendectomies). The alternative diagnoses were confirmed in all five patients. A total of 24.4% (102/418) of the patients underwent surgery, 93% with a confirmed pathologic diagnosis of appendicitis and 5% with a proven alternative diagnosis.

Three hundred sixteen patients with a negative imaging diagnosis of acute appendicitis were either discharged from the emergency department with a diagnosis of nonspecific abdominal pains or hospitalized for clinical observation or medical treatment of an alternative disease and had an uneventful outcome. Patients discharged from the emergency department with a negative diagnosis of appendicitis were followed up at the outpatient clinic for an average of 2 weeks. Two of the 420 patients were excluded from the study because the sonography reports were lost.

Diagnostic Performance of Color Doppler Sonography

Among 420 color Doppler sonography examinations performed for clinical suspicion of acute appendicitis, 75 (18%) were positive for acute appendicitis, 326 (77.6%) were negative, and 17 (4%) were indeterminate; for the remaining two examinations, the reports were not found. The sources of inconclusive studies included an incompressible appendix with a normal diameter (Fig. 6), a right lower quadrant phlegmon or abscess without a visible appendix (Fig. 4), retrocecal position of an inflamed appendix (Fig. 7), cecal edema or terminal ileum thickening, distal or tip appendicitis with a normal proximal appendix, obesity, and pain-limiting compression.

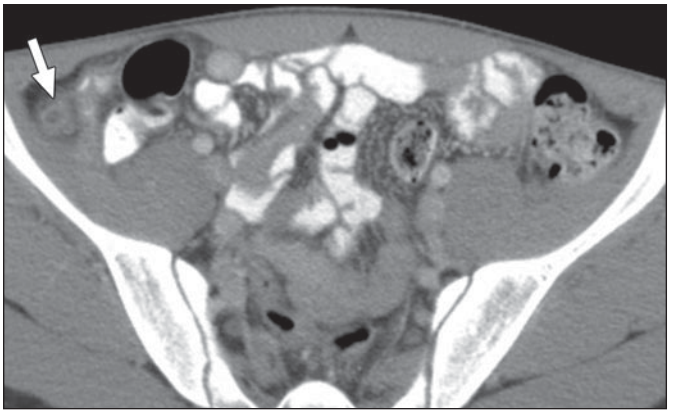


Fig. 7—40-year-old man with right lower abdominal pain. Retrocecal inflamed appendix (*arrow*) and surrounding blurred fat were seen on MDCT but were missed on sonography examination (not shown).

Statistical analysis was performed for a population of 401 patients after excluding the 17 indeterminate cases and the two cases without an available sonography report. Among the 75 patients with positive findings for acute appendicitis, surgery was performed in 68, confirming the diagnosis in 66 (66/75 true-positive). In two cases the diagnosis was denied on the pathologic specimen, and seven patients with appendicitis diagnosed by the resident on duty did not undergo surgery based on negative CT results (Fig. 8) required by the senior staff after reviewing the sonography examination, with an uneventful clinical outcome (9/75 false-positive cases).

Among the 326 patients with negative sonographic findings for acute appendicitis, five underwent surgery for an alternative diagnosis, and 298 were treated conservatively (303/326 true-negatives) and 23 patients underwent appendectomy based on positive clinical and CT diagnoses confirmed on pathology (23/326 false-negatives). Retrocecal appendicitis, correctly diagnosed on CT, was an important source of missing diagnoses on sonography reports (Fig. 7). The adjuvant use of a posterior manual compression technique to the single graded compression examination improved visualization of the normal appendix in five cases and the diagnosis of retrocecal appendicitis in 18 patients.

The sensitivity, specificity, PPV, NPV, and accuracy of Doppler sonography for the diagnosis of acute appendicitis in this population of adult patients were 74.2%, 97%, 88%, 93%, and 92%, respectively. In 82 patients with a negative sonography examination for acute appendicitis, an alternative diagnosis was reported, such as mesenteric lymphadenitis, cholecystitis, hydronephrosis, and several gynecologic disorders; these diagnoses were confirmed by clinical follow-up, other diagnostic modalities, or surgery (Table 1). An inconclusive diagnosis was reported in 17 cases. Among those 17 patients, 13 underwent CT. Nine of the 17 cases were classified as definitively not having appendicitis and eight as definitively acute appendicitis.

Diagnostic Performance of Color Doppler Sonography Performed by Residents Versus Senior Radiologists

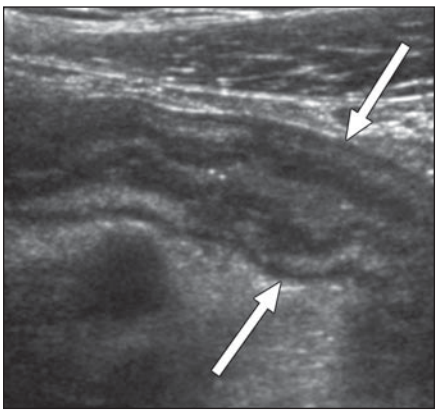
For 398 sonography examinations, we could discriminate between radiology resident ($n = 187$) and senior radiologist ($n = 211$) operators. The sensitivity of the sonography examinations performed by residents was 63.8% compared with 85% by senior radiologists ($p < 0.001$) and the specificity, 96.4% versus 97.7%, respectively.

Diagnostic Performance of Color Doppler Sonography According to Population Sex

Color Doppler sonography showed a sensitivity of 81.8% for men and 61.8% for the whole female population including pregnant women ($p < 0.001$) and a specificity of 97.7% for men and 96.9% for women. The specificity rose to 97.6% and the PPV to 91.7% for the population of men and nonpregnant women, who comprised 84% of the patients. Among the 64 pregnant patients (15.2% of the population) referred to color Doppler sonography, findings of three examinations were positive, 59 negative, and one indeterminate for acute appendicitis. The remaining patient was excluded because the sonography report was missing. We did not perform CT in this group of pregnant patients. Based on clinical judgment, two pregnant patients with positive results and all the patients with negative results for appendicitis were kept on conservative treatment without any adverse outcome. One patient underwent surgery, with a negative pathologic report (false-positive color Doppler sonography examination).

Diagnostic Performance of CT

CT was performed in 132 patients (31.4% of the population). CT studies followed a positive ($n = 20$), negative ($n = 99$), or indeterminate ($n = 13$) sonography examination. CT findings were positive for acute appendicitis in 39 patients (29.5%), negative in 92 (69.7%), and indeterminate in one (0.8%). Regarding the 39 patients with positive CT



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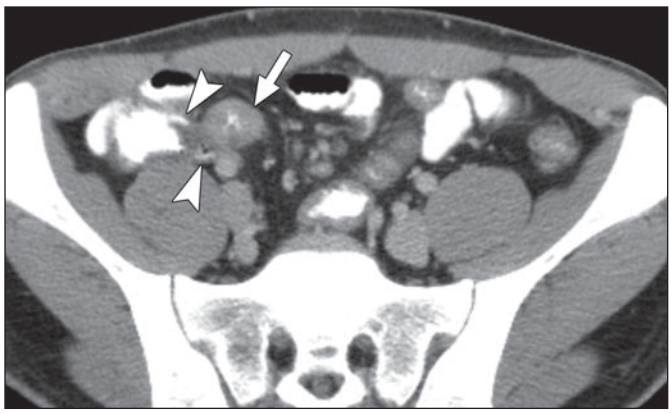

B

Fig. 8—26-year-old woman with fever and abdominal pains.
A, Sonography image shows incompressible thickened wall structure in lower right quadrant (*arrows*), diagnosed by resident on duty as acute appendicitis.
B, CT image shows pathologic terminal ileum (*arrow*) compatible with terminal ileitis. Normal appendix (*arrowheads*) is seen.

findings for acute appendicitis, sonography was positive in 13 (33%), negative in 20 (51%), and indeterminate in six (15%). Regarding the 92 patients with negative CT findings for acute appendicitis, sonography was negative in 79 (85.9%), positive in six (6.5%), and indeterminate in seven (7.6%).

For statistical analysis, 131 CT examinations were included. Among the 39 patients with positive findings for acute appendicitis, the diagnosis was confirmed in 38 (38/39 true-positive). None of the 92 patients with negative findings for acute appendicitis underwent appendectomy, and all had an uneventful follow-up (92/92 true-negatives). An alternative diagnosis was reported in 42 patients with a negative CT examination for acute appendicitis and was confirmed by clinical follow-up, other diagnostic modalities, or surgery (Table 1). The sensitivity, specificity, PPV, NPV, and accuracy of CT for the diagnosis of acute appendicitis in this adult population was 100%, 98.9%, 97.4%, 100%, and 99%, respectively.

TABLE 1: Alternative Appendicitis-Mimicking Diagnosis in 92 CT and 326 Sonography Studies with Negative Results for Acute Appendicitis

Diagnosis	Sonography	CT
Gynecologic		
Ovarian cyst, corpus luteum	18	9
Tuboovarian abscess	1	3
Ectopic pregnancy	1	
Urologic		
Kidney hydronephrosis	8	
Kidney stones	3	2
Ureteral stone	1	3
Pyelonephritis		1
Lobar nephronia	1	
Gastroenterologic		
Mesenteric adenitis	35	11
Intussusception		1
Terminal ileitis	10	5
Diverticulitis	2	3
Epiploic appendagitis		3
Typhlitis		1
Cholecystitis	2	
Total	82	42

Diagnostic Performance of Clinical and Laboratory Data

Periumbilical or right lower quadrant abdominal pain was the only finding present in 100% of the patients with clinically suspected acute appendicitis. Fever was present in 7.6% and leukocytosis ($> 11.0 \times 10^9$/L WBC) in 46.6% of patients. Patients with leukocytosis had a 46% probability of having appendicitis compared with 18.9% when the WBC count was normal.

Discussion

Acute appendicitis, the most common acute abdominal disorder suspected in the emergency department and the most common indication for emergency abdominal surgery, is still a difficult diagnosis, mainly in adult patients and pregnant women. In our study, laboratory test results were of limited value in predicting appendicitis.

In the elderly population, the clinical diagnosis of appendicitis is even more difficult than in young and middle-aged adults because of a frequently atypical presentation and a delay in seeking medical assistance, with a higher rate of perforation, postoperative complications, and mortality [1]. Consequently, imaging evaluation for suspected acute appendicitis in adult patients is increasingly requested.

Diagnostic imaging can confirm or deny the clinical suspicion of acute appendicitis and detect alternative appendicitis-mimicking disorders allowing selection of the correct therapeutic approach. We detected an alternative diagnosis of gastrointestinal, urologic, or gynecologic source that was confirmed on surgery or clinical follow-up in 82 of the 326 color Doppler sonography examinations and in 42 of the 92 MDCT studies negative for appendicitis, which spared the patients from a white appendectomy—that is, the resection of a normal appendix without signs of inflammation—and allowed triage for the correct therapeutic approach. As can be seen in Table 1, we had 14 alternative diagnoses on sonography examinations placed in the upper abdomen: eight kidney hydronephrosis, three kidney stones, one lobar nephronia, and two acute cholecystitis, justifying the time and expense of the upper abdominal examination.

The current emergency department policy in our university tertiary care center is to refer adult patients with clinical suspicion of appendicitis to undergo imaging studies, starting with color Doppler sonography. MDCT is therefore performed according to clinical judgment or in the face of inconclusive findings on color Doppler sonography. When compared with surgery or clinical follow-up as the reference standard in our retrospective study, the specificity, NPV, and accuracy of color Doppler sonography and MDCT were not significantly different: 97%, 93%, and 92% for color Doppler sonography and 98.9%, 100%, and 99% for MDCT, respectively. In contrast, the sensitivity of color Doppler sonography was moderate for the whole population (74.2%), rising to 81.8% for the men, compared with the sensitivity of MDCT (100%). The PPV of color Doppler sonography was 88% for the whole population, compared with 97.4% for MDCT, rising to 91.7% when pregnant women were excluded. This may be explained by the increased rate of obese patients among women and the technically difficult sonography examination in pregnant women.

The rate of an inconclusive diagnosis was significantly higher for color Doppler sonography (4%) than for MDCT (0.8%). In contrast to sonography, CT allowed visualization of the normal appendix in most of the cases, allowing a confident negative diagnosis. In some cases, CT was better for staging the extent of disease, such as in perforation, abscess, phlegmon, or fistula, and for management planning.

Color Doppler sonography performance was more accurate during day hours due to the experience of senior radiologists performing the examinations. The sensitivity of color Doppler sonography when performed by residents during off-hours was 63.8% compared with 85% when performed by senior radiologists ($p < 0.001$), although the specificity was not significantly different—96.4% and 97.7%, respectively. The lower sensitivity of sonography examinations done by on-duty residents confirms the known sonography operator dependency. It would have been ideal for a senior radiologist to perform sonography examinations on a 24-hour basis, but this is not practical. We believe that residents who have completed a 6-month training period are able to cope with the sonography examination while the senior radiologist is available for consultation.

In contrast, MDCT performance was not influenced by operator experience because the study is not dynamic and may be reviewed on the PACS system at a senior radiologist's home. In a prospective study, the diagnostic performances of sonography and CT for acute appendicitis or an alternative diagnosis were not significantly different, regardless of the radiologist's experience or the patient's body mass index (BMI), although more inconclusive examinations were obtained with sonography [5].

In a study performed in a community hospital, sonography performance was similar for body-dedicated radiologists compared with general radiologists with a sensitivity of 83%, specificity of 95%, PPV of 86%, NPV of 94%, and accuracy of 92% [12]. According to a review on the accuracy of sonography and CT for detecting acute appendicitis in adults and adolescents, CT is probably more accurate than sonography in that age group, although, in their opinion, the true diagnostic accuracy of these tests remains to be estimated [13]. Daly et al. [14] reported an equivocal CT interpretation in 12% of patients suspected of having appendicitis. After reassessing appendiceal size and the presence of fat stranding, fluid, or an appendicolith, those investigators found appendicitis in approximately 30% of the patients with equivocal CT findings and concluded that appendicitis should be considered in appropriately symptomatic patients. Bendeck et al. [15] reported a sensitivity of 93% for CT and 77% for sonography and a PPV of greater than 92% for both imaging examinations irrespective of patient age or sex. Other authors have reported a sensitivity of sonography ranging from 80% to 93% and a specificity of between 94% and 100% for the diagnosis of acute appendicitis [16–18]. Color Doppler sonography has been found to be sensitive in the diagnosis of early acute appendicitis when the appendix is equivocal in size (5–7 mm in maximal outer diameter) [19].

In our experience, the presence of an incompressible appendix that was larger than 6 mm in diameter with hyperemic walls on color Doppler sonography was the main sonographic positive sign (100% of positive cases). In fact, the diagnosis was based on transducer compression and gray-scale imaging. Color Doppler imaging was a complementary feature, allowing confirmation of appendicitis by showing hyperemia in the inflamed appendiceal wall. To identify the inflamed appendix in cases we were unable to diagnose using graded compression with a high-frequency linear transducer, we added posterior manual compression and used a lower-frequency linear transducer. This strategy allowed most of the diagnoses of retrocecal appendicitis to be achieved. This operator-dependent technique also improved visualization of the appendix in another study [20].

Hyperechoic periappendicular fat is a sign of severe appendicitis with spreading of the inflammatory process into the omentum and adjacent mesenteric fat (Fig. 3). This sign was correlated with a gangrenous appendicitis in all of the cases in a previous study [21]. Our study group was composed of consecutive patients referred to sonography from the emergency department to rule out appendicitis and triage lower abdominal pain. The low rate of positive examinations for acute appendicitis on sonography was not surprising considering the fact that some patients with a high clinical suspicion of acute appendicitis were sent to the operating room without undergoing imaging, at least in the first years of the study period, and considering the high number of women in our population. Women complain more frequently of lower abdominal pains than men because of symptoms of gynecologic or obstetric origin and are, therefore, referred more frequently to sonography examinations to rule out appendicitis. The high number of negative examinations may be related to an "overuse" of color Doppler sonography, particularly in young women and in pregnant patients, thus leading to a bias in patient selection by the emergency department staff.

In the selected group of pregnant patients with nondiagnostic sonographic findings and a high clinical suspicion of appendicitis, MRI has been suggested as an alternative to CT [3]. Bendeck et al. [15] found that the negative appendectomy rate was significantly lower for adult women who underwent preoperative CT or sonography (7% and 8% negative rates, respectively) than for those who underwent no preoperative imaging (28% negative rate), making routine preoperative imaging evaluation in women suspected of having acute appendicitis a recommended policy.

In our experience, routine referral of adult patients with clinical suspicion of acute appendicitis to color Doppler sonography and selected referral to CT, according to color Doppler sonography results and clinical judgment, improved diagnostic accuracy and therapeutic management. This policy reduced the negative appendectomy rate to 1.9% and the delay in achieving a correct alternative diagnosis or an appropriate discharge. Several studies comparing the performance of sonography and CT in the diagnosis of appendicitis have obtained a better sensitivity, a slightly better specificity, and a higher rate of alternative diagnoses with CT than with sonography [22–24].

Appendiceal sonography in our study population was performed in 10 minutes, on average, after abdominal sonographic screening. Sonography was significantly less time-consuming than the average 90 minutes needed for oral contrast medium to reach the cecum, contrast medium injection, scanning, and raw data reconstruction on CT examination. Some pitfalls and limitations lower the diagnostic performance of color Doppler sonography in clinically suspected acute appendicitis, such as obesity, unusual location of the appendix, tip appendicitis [25], right lower quadrant abscess without visualization of the appendix, inspissated feces in a dilated and poorly compressible appendix [26], and edematous incompressible terminal ileum or cecum. BMI data would have been very useful to analyze our incorrect sonography diagnoses. Unfortunately, this study is retrospective, and these data were acquired for only a few patients, not allowing a statistical analysis. In general, very obese patients are sent directly to CT from the emergency department because of the known limitation in sonography penetration, a fact that may have biased patient selection.

Patients discharged from the emergency department with a negative diagnosis of appendicitis were followed up at the outpatient clinic for an average of 2 weeks. We cannot deny the possibility of mild appendicitis that resolved on its own in patients with negative sonography findings. As in any noninvasive study, the favorable outcome of the patient confirms the accuracy of the diagnosis. An unusual location of the appendix, retrocecal, subhepatic, and even in the left lower quadrant, may be solved by examining the place of maximal tenderness or by placing a hand under the lumbar region and elevating the cecal origin of the appendix [9]. Tip appendicitis, described as the involvement of the distal appendix in the inflammation process with sparing of most of the proximal part, may be diagnosed by following the appendix in its whole length until the blind end is detected [25]. After perforation, the appendix may be undetectable and a collection at the right lower quadrant may appear as the only pathologic finding [26]. By identifying the normal appendix, CT may allow differentiation between periappendicular abscess and other sources of collections at the right lower quadrant, such as perforated diverticulitis or tuboovarian abscess. Although infrequent, stump appendicitis after appendectomy may be easily missed [27, 28].

The possible adverse outcomes as an effect of an imaging examination's performance, such as a higher rate of perforation due to treatment delay, has been analyzed. Investigators found that perforation rate or in-hospital delay

was not statistically significant compared with the benefits of lowering the negative appendectomy rate or reaching an alternative diagnosis [29]. In our experience and in other recently published studies [5, 30], sonography performed as a primary diagnostic tool followed by CT in only selected cases conforms to the correct diagnostic policy. A longer learning curve for the sonography diagnosis of appendicitis combined with the need for high-quality sonography equipment available must be considered. The higher diagnostic performances of CT need to be evaluated against the disadvantages of its lower availability, higher cost, and radiation exposure, a significantly important consideration not only in young females but also in young males.

In our institution, sonography of the abdomen and pelvis costs $60, whereas CT costs $150. Protocols for reducing radiation on CT in our institution include reduction of the field of view to the lower abdomen and pelvis and the application of radiation modulation technology, which automatically adjusts the radiation dose to the thickness of the studied area. Because of the relatively high false-negative rate, sonography should not be used to exclude acute appendicitis in patients with a high clinical suspicion based on classical signs and symptoms, and CT examination is warranted in these selected cases.

Although CT has a higher sensitivity than sonography in diagnosing appendicitis, we choose the strategy of performing sonography first because it may reach a definitive diagnosis in most of the patients and may triage acute abdominal pain. The final decision to perform CT is always according to good clinical judgment. At the time of the study, we recommended this strategy, but some surgeons were still reluctant to send patients to sonography as the first examination, which is why some patients in our institution were sent directly to CT. After analyzing the data, we established this strategy as the guidelines to be followed.

We conclude that color Doppler sonography examination should be the first imaging examination for the diagnosis of acute appendicitis in adult patients, whereas CT should follow the sonography examination in selected cases. Lack of radiation exposure, especially significant in a population of mostly young patients, higher availability, and lower cost are the main reasons for trying sonography first. By performing an upper and lower abdominal examination, color Doppler sonography is an accurate method for the triage of adult patients with acute abdominal pains. Alternative appendicitis-mimicking sonography diagnoses allow a correct reorientation of management and prevention of a nontherapeutic appendectomy.

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