Evaluation of Suspected Appendicitis in Children and Young Adults: Helical CT[1]

Carlos J. Sivit, MD
David L. Dudgeon, MD
Kimberly E. Applegate, MD
Valerie J. Borisa, BA
Sheila C. Berlin, MD
Stuart C. Morrison, MD
Melissa T. Myers, MD
Dayna M. Weinert, MD
Anthony Stallion, MD
Enrique R. Grisoni, MD

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[1] From the Departments of Radiology (C.J.S., K.E.A., V.J.B., S.C.B., S.C.M., M.T.M., D.M.W.) and Surgery (D.L.D., A.S., E.R.G.), Rainbow Babies and Children's Hospital of the University Hospitals of Cleveland and Case Western Reserve School of Medicine, 11100 Euclid Ave, Cleveland, OH 44106-5056. Received August 11, 1999; revision requested September 17; final revision received December 7; accepted December 13. **Address correspondence to** C.J.S. (e-mail: *sivit@uhrad.com*).

Author contributions:
Guarantor of integrity of entire study, C.J.S.; study concepts and design, C.J.S.; definition of intellectual content, C.J.S.; literature research, C.J.S.; clinical studies, C.J.S., S.C.B., K.E.A., M.T.M., A.S., E.R.G., S.C.M., D.M.W., D.L.D.; data acquisition, C.J.S., S.C.B., K.E.A., M.T.M., S.C.M., V.J.B., D.M.W.; data analysis, C.J.S.; manuscript preparation, C.J.S.; manuscript editing and review, C.J.S., S.C.B., K.E.A., M.T.M., A.S., E.R.G., S.C.M., D.M.W., D.L.D.

PURPOSE: To evaluate the accuracy of helical computed tomography (CT) for the diagnosis of appendicitis in children and to assess the utility of CT in establishing alternative diagnoses.

MATERIALS AND METHODS: The medical records of 154 children (median age, 12 years; age range, 1–20 years) who were suspected to have appendicitis and who underwent CT were reviewed. The gastrointestinal tract was opacified in 151 of 154 patients: Only orally administered contrast material was used in 126 patients; only rectally administered contrast material, in 21 patients; and both oral and rectal contrast material, in four patients. CT findings were correlated with surgical and histopathologic findings or with clinical follow-up findings.

RESULTS: Sixty-four CT scans were interpreted as positive for appendicitis and included 58 true-positive and six false-positive scans. Ninety scans were interpreted as negative and included 87 true-negative and three false-negative scans. CT had a sensitivity of 95% and a specificity of 94% for the diagnosis of appendicitis. In addition, in 32 (34%) of 93 patients without appendicitis, an alternative diagnosis was established on the basis of CT findings.

CONCLUSION: Helical CT is useful in a pediatric population to diagnose or exclude appendicitis and to establish an alternative diagnosis.

Acute appendicitis is the most common condition that requires abdominal surgery in children (1). An accurate diagnosis based on clinical criteria is more difficult to make in children (2,3). Thus, approximately one-third of children with appendicitis have an uncertain preoperative diagnosis (4). The uncertainty in diagnosis may lead to a delay in surgery or to unnecessary laparotomy. The principal imaging technique for evaluating patients suspected to have appendicitis has been graded-compression ultrasonography (US) (4–13). There have been numerous recent reports on the use of helical computed tomography (CT) for the diagnosis of appendicitis in adults (14–19). However, to our knowledge, there has been only one prior series in which investigators addressed the utility of CT in the evaluation of appendicitis in a pediatric population (20). The purpose of our study was to evaluate the accuracy of helical CT for the diagnosis of appendicitis in children and in young adults and to assess the utility of CT in establishing alternative diagnoses.

MATERIALS AND METHODS

We queried our institution's pediatric radiology imaging database of information from June 1996 to April 1999 for pediatric patients who had right-lower-quadrant pain, who were suspected to have appendicitis, and who were evaluated with CT. One hundred fifty-four patients formed the basis for the study. Eighty-six patients were female and 68 were male. The median age was 12 years (age range, 1–20 years). Twenty-six (17%) patients were 5 years of age or younger, 22 (14%) patients were 6–9 years of age, 63 (41%) patients were 10–14 years of age, 40 (26%) patients were 15–17 years of age, and three (2%) patients were 18 years of age or older. The decision to perform CT evaluation in a patient suspected to have appendicitis was based on the clinical judgment of the referring pediatric surgeon or of the emergency department physician and usually was related to a clinical manifestation that was thought to be

Figure 1. Appendicitis. Transverse CT scan through the lower part of the abdomen after the administration of intravenous and rectal contrast material in a 9-year-old boy with acute right-lower-quadrant pain demonstrates an enlarged (8-mm-maximal diameter) appendix (arrow) that is associated with stranding of the surrounding mesenteric fat.

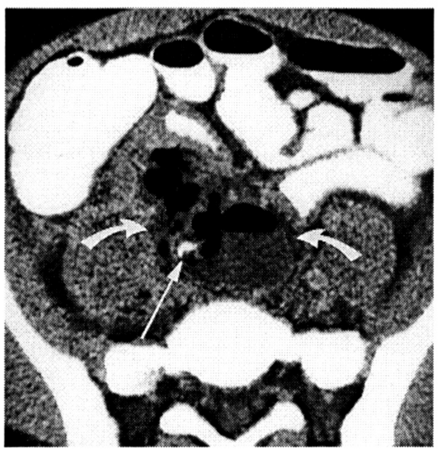


Figure 2. Perforated appendicitis. Transverse CT scan through the upper part of the pelvis after the administration of intravenous and oral contrast material in an 8-year-old girl with acute right-lower-quadrant pain demonstrates a complex collection (curved arrows) of low-attenuating fluid and air. Note the punctate area of high attenuation (straight arrow) within the collection, which represents an appendicolith. At surgery, a perforated appendix and a periappendiceal abscess were noted.

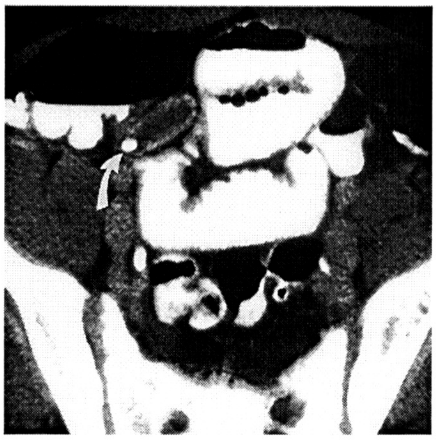


Figure 3. Enlarged appendix with an appendicolith. Transverse CT scan through the upper part of the pelvis after the administration of intravenous and rectal contrast material in a 15-year-old boy with acute right-lower-quadrant pain demonstrates an enlarged, fluid-filled appendix, which measures 8.5 mm in maximal diameter and contains an appendicolith (arrow).

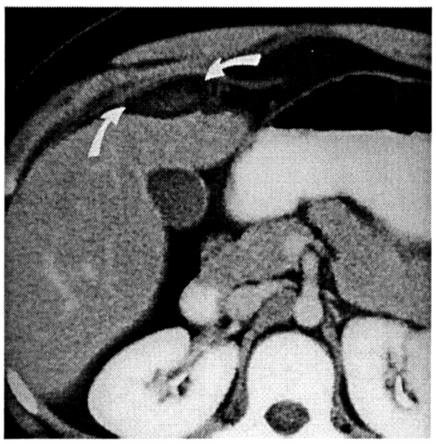


Figure 4. Segmental omental infarction. Transverse CT scan through the upper part of the abdomen after the administration of intravenous and oral contrast material in an 11-year-old girl with fever, leukocytosis, and acute right-lower-quadrant and midabdominal pain demonstrates an oval mass in the omental fat anterior to the liver, with associated inflammatory stranding (arrows) indicative of segmental omental infarction.

equivocal for acute appendicitis. Patients with clinically unequivocal cases of appendicitis underwent immediate laparotomy. During the study period, 193 patients underwent laparotomy for suspected appendicitis without undergoing CT.

All CT was performed with a model PQ 5000 helical scanner (Picker International, Cleveland, Ohio). Helical scanning was performed from the diaphragm to the pubic symphysis in all patients per our routine procedure. One hundred forty-five patients received intravenously administered contrast medium. Intravenous contrast medium (iothalamate meglumine [Conray 43; Mallinckrodt, St Louis, Mo] or iohexol [Omnipaque 240; Sanofi Winthrop, New York, NY]) was administered at 3 mL/kg of body weight (maximum dose, 120 mL) by using a power injector (CT 9000 ADV; Liebel-Flarsheim, Cincinnati, Ohio). Opacification of the gastrointestinal tract was achieved through the oral or rectal administration of 3% diatrizoate meglumine solution (Gastrografin; Bristol-Meyers Squibb, Wallingford, Conn) in 151 patients. The volume of the oral and/or rectal contrast material administered was based on the patient's age and ranged from 240 mL in a patient 1 year of age to 1,000 mL in patients older than 10 years of age. Rectal contrast material was administered through a small rubber rectal catheter. One hundred twenty-six patients received only oral contrast material, 21 received only rectal contrast material, and four received both oral and rectal contrast material. The route of gastrointestinal tract contrast medium administration (oral vs rectal) for each study was selected by the attending radiologist who monitored the procedure (C.J.S., K.E.A., S.C.B., M.T.M., S.C.M., or D.M.W.).

Collimation and image reconstruction through the upper part of the abdomen was 4–10 mm on the basis of patient age (<18 months, 4-mm collimation; 18 months through 5 years, 8-mm collimation; and >5 years, 10-mm collimation). Variable collimation and image reconstruction were used through the lower part of the abdomen and through the pelvis. In 102 patients, the collimation and image reconstruction through the lower part of the abdomen and through the pelvis were 8–10 mm, depending on patient age, while in 52 patients, 4-mm collimation and 4-mm image reconstruction were used in scanning the lower part of the abdomen and the pelvis, with origination approximately 3 cm above the cecal tip, as identified on the initial CT digital radiograph (scout view).

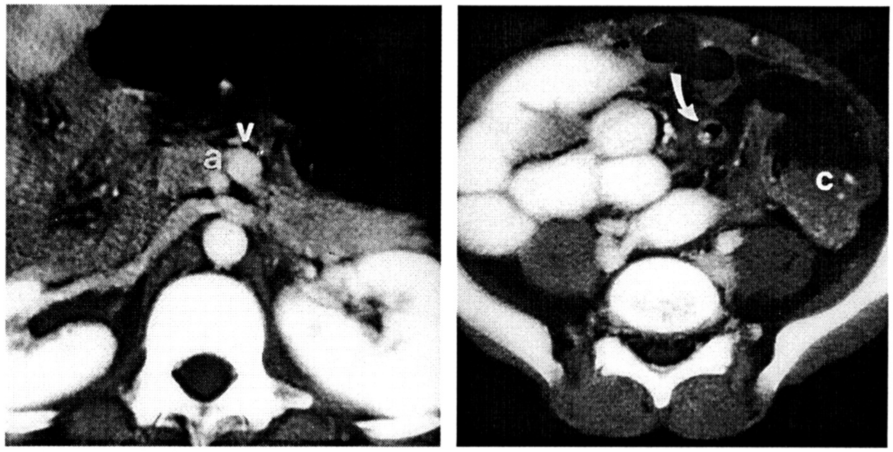
All CT was supervised, and scans were interpreted immediately by one of six pediatric radiologists (C.J.S., K.E.A., S.C.B., M.T.M., S.C.M., or D.M.W.). CT scans were interpreted as either positive or negative for appendicitis, and the findings were made known to the patients' caregivers. The interpretations were both the official study result and the official radiology report for each case. Appendicitis was diagnosed if the appendix did not fill completely with contrast material or air; if it exceeded 6 mm in cross-sectional diameter (14); or if an appendicolith, adjacent extraluminal air, or a complex fluid collection or mass was noted. The decision for surgical intervention was at the discretion of the pediatric surgeon (A.S., D.L.D., or E.R.G.).

We reviewed the radiology reports and correlated them with the final diagnoses,

Alternative Diagnoses Established at CT in Children and Young Adults Suspected to Have Appendicitis

Diagnosis	No. of Patients (N = 32)
Mesenteric lymphadenopathy	12
Ovarian cyst	6
Acute pyelonephritis	4
Neutropenic typhlitis	3
Segmental omental infarction	2
Gallstones	2*
Tubo-ovarian abscess	1*
Infected urachal remnant	1
Ureteral calculi	1
Foreign body	1

* One patient had gallstones and a tubo-ovarian abscess.



a. b.

Figure 5. Midgut malrotation and appendicitis. **(a)** Transverse CT scan through the upper part of the abdomen after the administration of intravenous and oral contrast material in a 10-year-old boy with acute abdominal pain demonstrates reversal of the mesenteric artery (*a*) and vein (*v*), which is indicative of midgut malrotation. **(b)** Transverse CT scan through the lower part of the abdomen in the same child demonstrates an enlarged appendix (arrow) of 9-mm maximal diameter in the left lower quadrant, with periappendiceal inflammatory changes. Note the location of the cecum (*C*) in the left lower quadrant.

which were established by means of surgical and histopathologic evaluation in 69 patients and by means of clinical follow-up in the remaining 85 patients. We calculated sensitivity, specificity, accuracy, positive predictive value, and negative predictive value for the CT diagnosis of appendicitis.

RESULTS

Sixty-one (40%) of 154 patients were proved to have appendicitis at appendectomy and at histopathologic examination. Eight (5%) of 154 patients had appendicitis excluded at appendectomy and at histopathologic examination; four of these eight patients underwent laparotomy secondary to suspicion of a condition other than appendicitis, which included a segmental omental infarction in one, an infected urachal remnant in one, a foreign body in one, and neutropenic typhlitis with perforation in one. Appendicitis was excluded in the remaining 85 (55%) patients on the basis of clinical follow-up findings.

There were 58 true-positive diagnoses of appendicitis at CT. An enlarged appendix was visualized in 29 of these (Fig 1). In 29 additional patients, the appendix was not visualized, but a complex mass or fluid collection was noted in the lower part of the abdomen or in the pelvis; this was indicative of a phlegmon or an abscess (Fig 2). An appendicolith was noted at CT in 11 of these 58 patients: within an enlarged appendix in six patients (Fig 3), and within a complex mass in five patients (Fig 2).

There were six patients with false-positive diagnoses of appendicitis at CT. The appendix was visualized in three of these patients, and the maximal diameter of the appendix was 6.5–7.0 mm. One of these patients underwent laparotomy, which revealed a normal appendix and no histopathologic diagnosis. The other two patients had resolution of their symptoms and were discharged without undergoing laparotomy. Two additional patients had pelvic fluid collections that were thought initially to be periappendiceal abscesses but that had resolved at follow-up CT within 36 hours of the initial study; these patients did not undergo laparotomy. Thus, four of these patients had resolution of their symptoms and were discharged without undergoing surgery. There were no specific histopathologic diagnoses in these four patients. One additional patient had a complex mass in the right side of the pelvis that was believed to be a periappendiceal abscess. At surgery, a tubo-ovarian abscess was noted.

There were 87 patients with true-negative diagnoses at CT. In 32 (37%) of these patients, an alternative diagnosis was established on the basis of CT findings (Fig 4) (Table). The most common alternative diagnosis was mesenteric lymphadenopathy, in 12 patients.

There were three false-negative diagnoses at CT in patients with surgically proved appendicitis. One of these patients had midgut malrotation diagnosed at CT and underwent laparotomy, at which time appendicitis also was noted. In retrospect, an enlarged appendix in the left lower quadrant was visible on the CT scan (Fig 5). The appendix was not visualized at CT in the other two patients with surgically proved appendicitis.

Statistical analysis indicated a sensitivity of CT for the diagnosis of appendicitis of 95% (58 of 61 patients), a specificity of 94% (87 of 93 patients), and an accuracy of 94% (145 of 154 patients). The positive predictive value of CT for the diagnosis of appendicitis was 91% (58 of 64 patients), and the negative predictive value was 97% (87 of 90 patients).

DISCUSSION

The role of helical CT in the diagnosis of appendicitis has been well reported in adults, but its use in children has not been addressed specifically (14–19). Although investigators in two prior studies (21,22) retrospectively reviewed CT findings in a small number of children with surgically proved appendicitis, to our knowledge there is only one prior report (20) in which investigators evaluated the diagnostic accuracy of helical CT for appendicitis in children.

It could be speculated that the paucity of body fat in younger children may result in increased difficulty in the diagnosis of appendicitis compared with that in adults because of the inability to readily distinguish the appendix from adjacent structures. However, a majority of the patients examined in the present series were older. The median age of the patients examined with CT in the present series was 12 years, and more than two-thirds of the patients were 10 years of age or older. Indeed, we believe that the investigators in the present study achieved a high diagnostic accuracy for appendicitis in children and young adults, which included a sensitivity of 95% (58 of 61 patients) and a specificity of 94% (87 of 93 patients). There were only three false-negative results and six false-positive results in the 154 patients examined. These results were achieved even though CT was performed with a variety of techniques and the scans were interpreted by six pediatric radiologists. This indicates that a high diagnostic accuracy for appendicitis can be achieved with helical CT in a pediatric clinical practice.

The use of helical CT for the diagnosis of appendicitis in children and in young adults raises concern with regard to exposure to ionizing radiation. The principal imaging technique for examining children suspected to have appendicitis has been graded-compression US (4–13). However, there has been a wide range in the reported sensitivities and specificities of US for the diagnosis of appendicitis because of the large degree of operator dependency inherent in the use of this modality (4,6–13). Although the ranges of sensitivity and specificity reported at US and CT show some overlap, there is a greater range in the reported reliability of US. Furthermore, the results of several prior comparison studies (20,16) show that CT has a higher diagnostic accuracy than US for the diagnosis of appendicitis in children and adults. Therefore, the concern regarding the potential overuse of ionizing radiation in children suspected to have appendicitis may be better addressed by placing more emphasis on the use of clinical variables for stratifying the risk of disease and by allowing more selective use of imaging (23). Those patients who can be identified on the basis of physical examination findings or of laboratory findings as having a very low or a very high risk of disease should not require cross-sectional imaging (23). The selective use of CT may be more helpful than US in assisting medical decision making because the diagnostic accuracy of CT is higher than that of US (20,16).

The use of focused appendiceal CT without intravenous contrast medium and limited to the lower part of the abdomen and to the pelvis has been advocated for the evaluation of suspected appendicitis in adults (14,15). In the present series, the entire abdomen and pelvis were scanned routinely by using intravenous contrast medium. The principal reason for this approach is that although appendicitis was the principal diagnosis being considered, it has been shown that other acute conditions may have a clinical manifestation similar to that of appendicitis (4,24). An alternative diagnosis was established at CT in 32 (34%) of 93 patients in the current series who did not have appendicitis. The location of the abnormality was in the upper part of the abdomen in nine of these patients.

Another important issue that should not be overlooked when evaluating the positive effect of CT as the primary imaging modality in children and in young adults suspected to have appendicitis regards the value of normal CT findings. Normal CT findings may be used to prevent unnecessary hospital admission or surgical exploration by evaluating the abdomen and the pelvis comprehensively. Therefore, the authors think that it is useful to scan the entire abdomen and the pelvis even if the primary concern is appendicitis.

A limitation of the present study was that the scanning protocol was not standardized in all patients in the study group. At the beginning of the study period, a standard collimation of 4–10 mm chosen on the basis of the patient's age was used throughout the abdomen and the pelvis. In addition, oral contrast medium was used to opacify the gastrointestinal tract. The scanning protocol was altered during the 35-month study period to include the use of thin collimation through the lower part of the abdomen and pelvis and the use of rectal rather than oral contrast medium for gastrointestinal tract opacification. These changes were made to expedite CT and to enhance the opacification of the colon and of the distal small intestine. However, even after the introduction of the new scanning protocol, in some patients, oral rather than rectal contrast material was used either because of neutropenic precautions or because of patient refusal of a rectal catheter.

The high diagnostic accuracy of CT in spite of the varied scanning protocol emphasizes the effectiveness of this examination in a clinical setting in which one expects practice variations. However, it should be noted that only one false-positive CT finding and no false-negative findings occurred when the scanning protocol included the use of both thin collimation through the lower abdomen and the pelvis and rectal contrast material.

In conclusion, helical CT is useful for the diagnosis of appendicitis in children and in young adults. The diagnostic accuracy of CT in the present study was similar to values that have been reported in adults and in one prior study in children. In addition, CT helped to establish an alternative diagnosis in one-third of the patients who did not have appendicitis.

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