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Appendicitis is a serious diagnosis with the potential for catastrophic outcomes in any age group, but especially in the young child. Although the clinician may have this diagnosis in the differential for select patient populations, this article highlights the clinical scenarios when the clinician should consider the diagnosis in a child. The utility, advantages, and disadvantages of available testing modalities also are reviewed to aid the clinician in making informed choices with the hope of reducing the incidence of appendiceal perforation.

— The Editor

Appendicitis in the Young Child: Making the Right Diagnosis

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Introduction

The young child who presents with vomiting with or without abdominal pain is often a challenge for the emergency medicine physician. These children often have vague symptoms, a challenging physical examination, and an extensive differential diagnosis that includes diseases varying from a simple otitis media to catastrophic necrotic bowel secondary to malrotation with midgut volvulus.

Careful attention to the patient's history and physical examination may assist the clinician in focusing the diagnostic testing. Obtaining a thorough history may require information from several caretakers, dietary information, and the time course of the pain. A detailed physical examination — including a child's genitalia to look for possible hernias— cannot be overemphasized. Serial physical examinations over time also may be helpful to determine the location and progression of the pain.

For children who have the potential for a serious problem, utilization of consulting services (e.g., radiologists and surgeons), or an appropriate specialist is very important and can be extremely helpful in developing a logical individualized approach to the evaluation of the young child with abdominal pain or vomiting.

Statement of Financial Disclosure

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The clinician cannot forget the importance of communication with the caregivers regarding clinical concerns, difficulties in establishing a diagnosis, and limitations of testing during the evaluation to gain not only their trust, but also as a tool to enlist their help in identifying any further information or symptom progression or resolution. If a young child with abdominal pain or vomiting is discharged, indications for a repeat evaluation should be clearly outlined verbally and in written form.

This article will focus on the presentation and diagnosis of appendicitis in the young child. The article will emphasize clinical factors to be considered, appropriate involvement of colleagues in pediatric surgery and radiology, and the discriminate utilization of diagnostic testing to facilitate an early diagnosis of appendicitis in the pediatric patient.

Incidence

Although appendicitis is reportedly the most common atraumatic surgical abdominal disorder in the child older than 2 years, the diagnosis of appendicitis is uncommon in the child younger than 2 years.[1] Less than 2% of children treated for appendicitis are younger than 2 years, and only 0.4% of children are younger than 1 year.[2] The peak age for appendicitis in children is 10-12 years.[3] In a review of the 28-year experience of a single pediatric surgeon working at an academic children's hospital, only 27 children younger than 3 years were diagnosed with appendicitis.[4]

Neonatal appendicitis is indeed a rare surgical condition. In their review of neonatal appendicitis, Karaman and colleagues reported a total of 141 cases of neonatal appendicitis in the English-language literature during the period of 1901-2000.[5] Although a decreasing mortality rate was reported, the authors found perforation rates of 73% between 1901-1975, 70% between 1976-1984, and 82% between 1985-2000.

Complications of Delayed Diagnosis

Although appendicitis is an uncommon diagnosis in children younger than 2 years, the majority are diagnosed only after perforation has occurred. One study found that children younger than 1 year diagnosed with appendicitis had a 100% perforation rate, and children 1-2 years of age had a 93% perforation rate.[6] Another study had an overall perforation rate of 47%. For children younger than 4 years there was a 100% perforation rate; 4- to 5-year-old children had a perforation rate of 55%; 12- to 13-year-old children had an appendiceal perforation rate of 42%; and children between 14-16 years had a perforation rate of 13%.[7] The Pediatric Health Information System database from 30 freestanding children's hospitals served as the source of review of 3,393 cases of children diagnosed with appendicitis.[8] In the 351 patients age 0-4 years, the average rupture rate was much higher (65.8% vs 32.7%) than in the 3,042 children age 5-7 years.

The effect of appendiceal perforation is significant, both to the patient and the clinician. According to the Physician Insurers Association of America database during a 16-year period (1985 – 2000), appendicitis was second only to meningitis as the diagnosis involved most in pediatric emergency medicine malpractice claims.[9] A thorough evaluation, adequate communication, and diagnostic testing, coupled with appropriate follow-up can enhance parental confidence in treating physicians and potentially diminish physician vulnerability.

Attention to pediatric pain may enhance the clinician's assessment of the child and has not been reported to diminish diagnostic accuracy. Treatment of pediatric pain may allow physicians an opportunity to reduce a child's pain by pharmacologic adjuncts, improve diagnostic accuracy, and address a family's angst and concern.

The most obvious measurable effect of perforation of the appendix in young children is length of hospital stay.[6,7,10] Hospital stays may be favorably affected by the selection of antibiotic therapy. Researchers reported on 150 patients treated with a single antibiotic in the management of perforated appendicitis.[11] In comparison with a previous antibiotic regimen of ampicillin, gentamicin, and clindamycin the use of piperacillin-tazobactam for 10 days allowed for shorter hospital stays with less expense. Of the 52 patients discharged home to receive the single antibiotic therapy, their length of stay was only 5.7 days compared with 11.2 days for patients who remained in the hospital for triple antibiotic therapy. Hospital charges for those patients who remained hospitalized for the triple antibiotic regimen averaged $21,533 compared with hospital charges of $13,188 for those discharged on single antibiotic therapy.

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A reduced number of hospital days and charges were documented for children with acute appendicitis who were treated by pediatric surgeons compared with those treated by general surgeons.[12] Independent of diagnosis (simple or perforated appendicitis), younger children (0-4 years, 5-8 years, and 9-12 years) who were treated by pediatric surgeons had a significantly shorter hospital stay and/or decreased hospital charges when compared with those who were treated by general surgeons. Older children (13-15 years) seemed to have comparable outcomes.

Complications of perforated appendicitis also may result in prolonged hospitalizations. In a review of children younger than 3 years with appendicitis, one study found numerous complications including wound infection, abscess formation, wound dehiscence, pneumonia, small bowel obstruction, and enterofistula formation.[4] Another study found that 47% of patients with perforation developed abscess formation.[6] Other researchers also reported a higher number of postoperative complications in those patients with perforation: 6 of 51 patients without perforation showed complications, and 20 of 78 patients with perforation had complications.[10] A similarly higher postoperative complication rate was found in the review by Huang: 41.7% of those patients younger than age 3 years with perforation experienced complications compared with 11.5% of patients younger than 3 years who presented without perforation.[11]

Long-term complications of appendiceal perforation are less clearly defined, but are becoming more evident in the literature. Reynolds and colleagues reported the case of a 17-year-old girl who presented to her pediatrician with symptoms of diarrhea and fever and was sent home with a diagnosis of gastroenteritis.[14] She subsequently was diagnosed with a perforated appendix and underwent an operation. The pediatrician was sued on the basis of expert witness testimony pointing to an increased infertility rate in women with a history of perforated appendicitis. One study reported that a ruptured appendix increases the relative risk of tubal infertility between 3.2 and 4.8 times for women.[15]

Presentation and Differential Diagnosis

The diagnosis of appendicitis in the young child is challenging because of the nonspecific signs and symptoms involved in this age group; the most common misdiagnosis is gastroenteritis.[17] The age-based differences in the presentation of pediatric appendicitis may be related to anatomic and developmental differences. As inflammation spreads to the parietal peritoneum, abdominal pain due to appendicitis in adults typically localizes to the right lower quadrant. Younger children, however, have an underdeveloped omentum and often cannot contain the purulent material that occurs with appendicitis.[20] Therefore, diffuse peritonitis is found more frequently in children younger than 5 years compared with older children.[21]

Among neonates with appendicitis, obstruction of the appendix typically follows colonic obstruction with conditions such as Hirschsprung's disease, cystic fibrosis, or meconium plug syndrome. In the first 9-12 months of life, a tapered cecum and a funnel-shaped appendix make obstruction less likely.[22] The differences in anatomy, a relatively soft-food diet, and less prominent lymphoid tissue are believed to account for the lower incidence of appendicitis in infants.[23-25]

Rothrock reported that localized right lower quadrant tenderness is noted in less than 50% of patients with appendicitis and that nonspecific signs such as lethargy, abdominal distention, and abdominal rigidity also are found in children with appendicitis.[17] The nonspecific nature of presenting symptoms in this age group clearly makes the diagnosis of appendicitis difficult.

The most common presenting symptoms for young children with appendicitis are vomiting, fever, and abdominal pain.[4] Only 56% of the patients in one study presented with anorexia, and 41% had diarrhea. Although all the patients had abdominal tenderness, only 52% had localized right lower quadrant tenderness; 37% presented with diffuse peritonitis. Another study found that a significantly greater percentage of patients with perforation had fever and vomiting as the initial presenting symptoms.[7]

Patients with perforated or nonperforated appendicitis may have similar symptoms at the time of presentation.[6] In one study, the percentage of patients with diarrhea, fever, vomiting, anorexia, and abdominal pain was not significantly different between those with and without perforation. Guarding, rebound tenderness, diffuse tenderness, focal tenderness, and rectal tenderness also were not significantly different between the two groups. In another study, children with a missed diagnosis more frequently complained of vomiting prior to pain, dysuria, constipation, diarrhea, and respiratory signs and symptoms compared with children with a correct diagnosis.[20]

In the newborn baby presenting with appendicitis, continuous vomiting, refusal to feed, signs of irritability, restlessness, sleep disturbance, or abdominal distension should lead to strong suspicion for appendicitis. In a case series of seven infants with acute appendicitis, fever, abdominal tenderness and distension were reported as the most frequent findings on physical examination, and vomiting was the most common presenting symptom.[2] A bulging umbilicus with surrounding erythema and abdominal wall redness also have been reported in newborns with appendicitis.[18] A review by Karaman highlighted the need for a thorough genitalia examination as well.[5] The authors' found that in three-fourths of the cases of neonatal appendicitis, the problem was due to an intraabdominal process; however, in one-fourth of the patients, the acutely inflamed appendix was found to be present within an inguinal hernia. Without a genitalia examination, the diagnosis may have been missed. Abdominal distention and bilious vomiting were the most common symptoms.[5]

Laboratory Testing

Unfortunately, the decision to obtain laboratory tests in the young child with suspected appendicitis may add little information for the clinician. A white blood cell (WBC) count often is ordered but is relatively nonspecific and insensitive. Rothrock reported that a WBC count of more than 12,000 is 51-91% sensitive for appendicitis and that the use of a higher threshold of 15,000 reduces the sensitivity to 41-68%.[16] Alloo and colleagues found that 18 of 27 patients had a WBC count of more than 12,000. Of the eight children with documented leukocyte differential counts, seven (87.5%) showed a definite left shift defined as an absolute neutrophil and band cell percentage greater than 50%.[4] The mean WBC count, in several series, did not differ significantly between perforated and nonperforated patients.[6,7,11] Nelson and colleagues reported a mean WBC count of 16.0 in the nonperforated group vs 16.8 in the perforated group.[7]

C-reactive protein (CRP) testing has been reported to be 43-92% sensitive and 33-95% specific for appendicitis in children with acute abdominal pain.[16] Some studies suggested that CRP level measurement may be more sensitive than the WBC count in detecting appendiceal perforation and abscess formation, which as noted above, are more common in younger children.[26]

Gronross undertook a study to determine the role of WBC and CRP measurements in the diagnosis of acute appendicitis in children.[27] Children with acute appendicitis had a WBC count of 15.0 +/- 0.4 x 10^9/L that was statistically different from the group with a normal appendix at the time of surgery (WBC count of 10.2 +/- 0.4 x 10^9/L). The two groups had no statistical difference in CRP levels (30 +/- 4 mg/L vs 31 +/- 4 mg/L). Although there was a statistically significant difference in WBC counts between the groups, 7 of 100 patients had normal laboratory values; the age range of these patients was 7-14 years. The overall sensitivity of the WBC in the diagnosis of acute appendicitis was 88%, and the specificity was 53%. The sensitivity of CRP measurement in the diagnosis of acute appendicitis was 48%, and the specificity was 57%. These study results are certainly not applicable to the very young child who presents with appendicitis; none of the patients in their study was younger than 2 years. The authors concluded that normal WBC and CRP values did not effectively exclude acute appendicitis for the pediatric population in their study.

Imaging Modalities

Conventional Radiographs. A variety of imaging studies are available for pediatric patients who present with abdominal pain. One review concluded that plain radiographic findings are nonspecific and seldom affect decisions regarding patient management, except the presense of an appendicolith.[28] The radiographs of children with perforated appendicitis are more likely to show abnormality, and in some cases, the findings could be highly suggestive of the diagnosis. A radiographic review highlighted the following findings, which are highly suggestive of perforated appendicitis:

- small bowel obstruction pattern
- localized paucity of gas or soft tissue mass in the right lower quadrant
- soft tissue opacity displaced in the ascending colon medially ("flank stripe sign")
- distention of the transverse colon with abrupt cutoff at the hepatic flexure ("colon cut-off sign").

Free intraperitoneal air is uncommon in children with perforated appendicitis. The findings on plain radiograph findings may help guide the subsequent imaging workup for suspected appendicitis; a child with a relatively gasless abdomen is approached more easily with ultrasonography than is one with a large amount of intestinal gas present. Radiographs that suggest perforated appendicitis should be followed by a computerized tomography (CT) examination, especially if percutaneous abscess drainage is being considered.

A critical component of the acute abdomen series is inclusion of a view of the chest. Pneumonia may be present in children with abdominal pain and little or no clinical evidence of respiratory abnormality.

Although plain radiographs are beneficial if associated with significant findings, their subjective nature makes their use in diagnosing appendicitis questionable.

In a retrospective chart review of 821 consecutive patients hospitalized for suspected appendicitis, 78% of the patients had plain abdominal radiography performed.[29] Radiographic findings were noted in 51% of patients with appendicitis, and in 47% of patients without appendicitis. The study found that no individual radiographic finding was sensitive or specific. Specific conditions were suggested in only 10% of impressions, and these conditions failed to correlate with the final clinical diagnosis 57% of the time. The authors concluded that these radiographic findings frequently are misleading and are costly per specific and correct diagnosis and suggested that radiographs should not be obtained routinely on patients with suspected appendicitis. The presence of a calcified appendicolith may lead to the diagnosis of appendicitis in a young child, however, this was present in only 10% of patients undergoing plain radiographs.[30]

Ultrasonography. The advantages of the use of ultrasonography in the evaluation of the child with suspected appendicitis include the lack of ionizing radiation, low cost, lack of exposure to contrast material, lack of need for sedation, and improved ability to assess ovarian pathology. In a previous study, researchers emphasized that an ultrasound diagnosis is most effective when the radiologist plays an active role in the performance of the examination.[28] This fact certainly highlights the variability that can be found among institutions that may or may not have a radiologist available to perform the study. Ultrasound is certainly less likely to be the procedure of choice when those performing the examination have limited experience or when the interpreter must view the images from a remote location. Higher frequency transducers, which allow for more detailed visualization of the bowel wall, are needed to penetrate well into the abdomen. If the appendix lies in a retrocecal position or deep within the pelvis, the technique is less acceptable. The findings on ultrasound that indicate the presence of appendicitis include:

- diameter of the appendix greater than 6 mm (*Figure 1*)
- lack of a decrease in the diameter of the abnormal appendix by more than 1 mm with compression (*Figure 2*)

Figure 1. Ultrasound Image of a Thickened Appendix

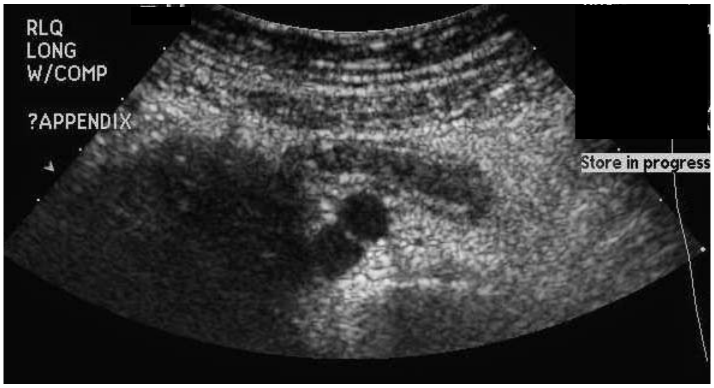

Figure 1. Ultrasound showing thickened appendix in an 18-month-old child with vomiting.

Figure 2. Ultrasound Compression of Appendix

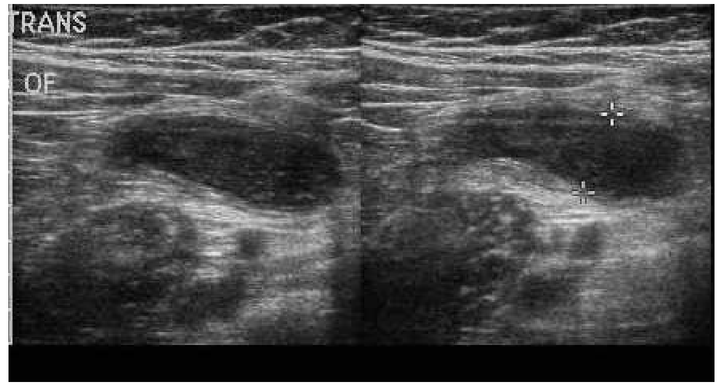

Figure 2. Ultrasound of a 2-year-old child showing a dilated tubular structure without change with compression.

- greater pain with compression over the appendix
- the presence of free fluid on ultrasound
- noncalcified appendicolith as echogenic shadowing foci within the lumen of the appendix
- inflammation evident in the cecum or adjacent small bowel.

The value of ultrasonography in diagnosing appendicitis also depends upon the stage of the infection. Early in the course of appendicitis, there actually may be very little change in the thickness and definition of the appendiceal wall. As inflammation progresses, the normally echogenic mucosa of the appendix becomes altered and visibly disrupted. The peristalsis of surrounding bowel loops and lack of fixation by local inflammation result in fleeting opportunities for visualizing a normal appendix. The accuracy in identifying the normal appendix varies from 30% to 56%.[28]

In one study, compression sonography was prospectively performed in 120 consecutive children with suspected appendicitis.[31] In 27 cases, the appendix was not identified; 12 of these patients had their appendix identified with the use of a saline enema. A normal appendix was found in 11 of these 12 children, and acute appendicitis confined to the appendiceal tip was found in one patient. The difficulty in visualizing the normal appendix was due to its location in these patients; it was located in the pelvis posterior to the cecum, posterior to the ileum, or anterior to the ileum making visualization difficult.

One review reported the sensitivity of sonography in children with appendicitis ranging from 44% to 94% and the specificity ranging from 47% to 95%.[32] Reasons for nonvisualization included the inability to compress the right lower quadrant adequately, aberrant location of the appendix (e.g., in the retrocecal position), and appendiceal perforation. The authors pointed out several causes of false-positive diagnosis (e.g., the normal appendix may be visible with graded compression sonography and mistaken for appendicitis). Periappendiceal inflammation due to the Crohn's disease or pelvic inflammatory disease also may be a cause of a false-positive examination. Another study found that only 22% of children referred for sonography for suspected acute appendicitis actually were found to have appendicitis; 29% of children had other specific diagnoses found with ultrasonography.[33] Sivit and researchers found alternative diagnoses at sonography in 25% of patients who did not have appendicitis; 29% of children referred for ultrasonography were found to have appendicitis.[34] Researchers here emphasized that a survey of the pelvis and upper abdomen should be performed in patients who have a normal sonographic examination of the right lower quadrant to identify alternative diagnoses.

In a retrospective review of children who underwent appendectomy and all children who underwent ultrasound during a three-year period, 84% had acute appendicitis; 26% of these showed perforations.[35] Ultrasonography in this setting had a sensitivity of 89%, specificity of 95%, a positive predictive value (PPV) of 86%, and a negative predictive value (NPV) of 96%. The authors concluded that ultrasound improved the diagnostic accuracy in children with suspected appendicitis. The study is somewhat limited by its retrospective nature but more importantly, because the ultrasound examinations were performed by staff radiologists who were available 24 hours a day.

In a prospective study designed to evaluate the clinical utility of ultrasonography in appendicitis, researchers analyzed a group of patients during a one-year period.[36] Children with a high clinical suspicion of appendicitis were referred directly for surgery; those children with equivocal findings of appendicitis were referred for early ultrasonography. Clinical judgment by the pediatric surgical fellows showed a sensitivity of 38% and a specificity of 95%. Using early ultrasound alone, the sensitivity was 87%, and specificity was 88%. The management of 30 of 103 patients (30%) was changed after early ultrasonography was completed: a decision to operate in 28 patients and a decision not to operate in two patients. The authors concluded that the use of early ultrasonography appears to have substantial clinical utility in children with equivocal findings of appendicitis and that this imaging modality should be used as a compliment to the initial clinical management of patients with suspected appendicitis.

Finally, researchers analyzed data of 736 pediatric patients who had undergone appendectomy between 1995 and 2000.[37] A total of 643 (87.4%) of the 736 pediatric patients had preoperative ultrasound. Ninety-seven (13.2%) of the 736 patients underwent a negative appendectomy. Thirty-four (36.6%) of the 92 patients who had appendectomy with no preoperative ultrasound, and 63 (9.8%) of the 643 patients who underwent preoperative ultrasound had a negative appendectomy. The authors found a significant association between ultrasound and positive appendectomy. They concluded that ultrasound in pediatric patients suspected of having appendicitis can significantly lower the negative appendectomy rate.

Therefore, ultrasound may be used as an adjunct to the clinical examination to confirm the diagnosis of appendicitis, but a negative ultrasound should not be used as confirmation that the child does not have appendicitis.

Computed Tomography Scanning. The use of helical CT has gained popularity as an adjunct for the diagnosis of appendicitis. Many institutions now consider CT imaging to be the procedure of choice in adult patients with suspected appendicitis. The advantage of CT imaging is the ease of performing the examination according to a standardized protocol without direct involvement of a radiologist, thereby eliminating interoperator variability and allowing for remote image interpretation. Therefore, this technology is more likely to yield consistent results across various institutions. Institutional protocols vary with combinations of oral, rectal, and IV contrast implemented as well as noncontrast CT protocols. In addition, the extent of CT imaging has been varied; some institutions restrict images to the pelvis while others have advocated for the use of scanning the entire abdomen to identify nonappendiceal pathology.

The CT diagnosis of acute nonperforated appendicitis relies upon the following criteria:[28]

- identification of a dilated and thickened appendix with 6 mm considered to be the upper limit for the normal appendiceal diameter (*Figure 3*)
- edema or stranding of the surrounding mesenteric fat usually is present
- calcified appendicolith (*Figure 4*)
- focal thickening of the apex of the cecum
- a triangular collection of contrast in the upper portion of the cecum ("the arrowhead sign").

Regarding the value of contrast material with CT imaging (*See Table 1.*), Peck and colleagues reported on their retrospective review of consecutive community hospital patients evaluated for acute appendicitis. During an 18-month period in which 1513 patients were evaluated for abdominal pain in the ED of a 129-bed community hospital, 443 had a presumptive diagnosis of appendicitis after the completion of a history, physical examination, and laboratory tests.[38] A helical CT scan was performed in 401 patients without oral, rectal, or IV contrast; images were obtained from the top of the kidney to the pubic tubercle.A negative appendectomy rate of 5.4% was reported. This study reported 93.8% sensitivity, 91.9% specificity, a PPV of 84.4%, a NPV of 97%, and an accuracy of 92.4%. The authors stated that the liberal use of CT was due to the availability of a rapid definitive test in an institution that did not have an observation unit or surgical residents to perform serial examinations. The number of patients admitted for observation was decreased, and the negative appendectomy rate was improved from 19% to 5.4%. The authors concluded that a focused, unenhanced helical CT scan was helpful for imaging the appendix in patients with equivocal clinical findings of acute appendicitis.

Figure 3. CT Image of a Thickened Appendix

Figure 3. CT scan showing thickened appendix of an 18-month-old child with vomiting.

In a study of unenhanced limited CT of the abdomen in the diagnosis of appendicitis in children conducted by Lowe and researchers,76 children underwent unenhanced limited CT during an 11-month period for evaluation of suspected appendicitis.[39] The patient age ranged from 11 months to 19 years 8 months with a mean age of 11.5 years. Imaging was obtained only in children with atypical or equivocal findings. CT scans were performed without administration of IV, oral, or rectal contrast. Among the 72 patients who underwent unenhanced limited CT examination, 35 patients had true-positive findings, 36 had true-negative findings, none had false-positive findings, and one had a false-negative finding. The sensitivity of this imaging modality was 97%, specificity 100%, and accuracy was 99%. Alternative diagnoses were suggested in 35% of patients. The unenhanced limited CT required 5 minutes and charges at the institution were $408.

The authors compared their results with a historical cohort of 78 consecutive children identified from computerized hospital records who had undergone graded compression sonography: 20 patients had true-positive findings, 51 had true-negative findings, seven had false-positive findings, and none had false-negative findings. The sonography results showed a sensitivity of 100%, specificity of 88%, and accuracy of 91% respectively. The difference between the sensitivity, specificity, and accuracy of unen-

Figure 4. A CT Image of a Calcified Appendicolith

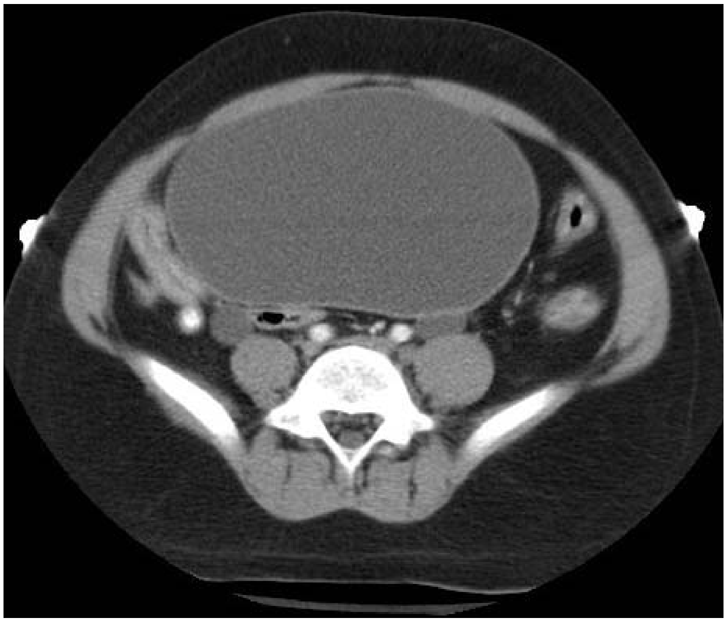

Figure 4. CT scan of a 2-year-old child with right lower quadrant tenderness. Note appendicolith in dilated appendix with little periappendiceal fat stranding.

hanced limited CT and sonography was not significant. An alternative diagnosis was suggested in 16 of 58 patients who underwent sonography, compared with 13 of 37 patients who had undergone unenhanced limited CT. The authors concluded that both unenhanced limited CT and sonography are accurate imaging modalities in children with suspected appendicitis. They stressed that these imaging modalities were applied to patients with an equivocal diagnosis and do advocate that sonography is the preferred imaging modality secondary to the lack of radiation exposure, but must be performed by a radiologist with the appropriate experience and expertise. The use of sonography or CT imaging for the diagnosis of appendicitis will depend upon the available resources and personnel at the institution, clinical history of the patient, physical examination and findings, laboratory data, and differential diagnostic possibilities. They did state that unenhanced limited CT was a valuable tool in the evaluation of children with a clinically equivocal diagnosis of appendicitis.

Sivit and researchers reviewed the medical records of 154 children with suspected appendicitis who underwent CT.[40] The age range for these patients was 1 to 20 years with a median age of 12 years. All of the CT scans were done with a helical scanner from the diaphragm to the pubic synthesis. Sixty-one (40%) of 154 patients were proven 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. 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 patients; in the remaining 29 patients a complex mass or fluid collection was noted in the lower part of the abdomen or in the pelvis. Six patients were found to have a false-positive diagnosis for appendicitis at CT. One of these patients underwent laparotomy, and two patients had resolution of their symptoms and were discharged without undergoing laparotomy. One patient had a complex mass in the right side of the pelvis believed to be a periappendiceal abscess; the patient had surgery and was found to have a tubo-ovarian abscess. There were 87 patients with a true negative diagnosis at CT. An alternative diagnosis was established on the basis of CT findings in 32 (37%); the most common was mesenteric adenopathy in 12 patients. There were three false-negative diagnoses in CT in patients with surgically proven appendicitis. The appendix was not visualized at CT in the other two patients, but appendicitis was established at the time of surgery. This study 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 PPV of CT for the diagnosis of appendicitis was 91% (58 of 64 patients), and the NPV was 97% (87 of 90 patients). The authors concluded that the selective use of CT might be more helpful than ultrasound in assisting medical decision-making because the diagnostic accuracy of CT is higher than that of ultrasound. The authors also concluded that CT of the entire abdomen and pelvis was necessary due to the discovery of alternative diagnoses; the location of abnormalities found other than appendicitis was in the upper part of the abdomen in nine of their 32 patients. The approach of imaging the entire abdomen was useful because normal CT findings may prevent unnecessary hospital admission or surgical exploration. Helical CT was useful for the diagnosis of appendicitis in children.

In a study by Fefferman, 93 abdominal CT scans were obtained during a six-year period for patients with right lower quadrant pain.[41] The CT scans were reviewed only for those patients with an equivocal clinical presentation after examination by a pediatric ED attending physician and, either a senior surgical resident or attending surgical physician. Eleven (12%) of these patients were 4 years or younger. All patients received both oral contrast material and nonionic IV contrast material. CT had an accuracy of 95%, sensitivity of 97%, specificity of 93%, a PPV of 90% and a NPV of 98%. Specifically, the helical CT scans had a sensitivity of 100%, and a specificity of 96%. There was a statistically significant difference in the sensitivity and specificity of the scan acquired with nonhelical CT as compared with that of the larger group of scans acquired with helical CT. On 20 of the CT scans performed, oral contrast material did not opacify the cecum. The single false-negative CT scan and the four false-positive CT scans showed no oral contrast material in the ileocecal region. The authors pointed out that there was a relatively small number of patients younger than 4 years. Because young children with appendicitis may have difficulty describing

Table 1. Use of CT Imaging in the Diagnosis of Children with Appendicitis: Study Summary

PECK ET AL (38)
- Helical CT without contrast
- Consecutive community hospital patients with appendicitis
- 94% sensitivity, 92% specificity, PPV 84%, NPV 97%
- Reduced negative appendectomy rate from 19% to 5.4%
- Majority of patients underwent CT scanning

LOWE ET AL (39)
- Limited CT without contrast
- Consecutive patients with equivocal findings in children's hospital setting
- 97% sensitivity, 100% specificity, accuracy 99%
- Found no difference with historical cohort who had undergone graded compression sonography

SIVIT ET AL (40)
- Helical CT with oral and/or rectal contrast
- Retrospective review of patients who underwent imaging for suspicion of appendicitis at a children's hospital
- 95% sensitivity, 94% specificity, PPV 91%, NPV 97%, accuracy 94%
- Highlighted the need to scan the entire abdomen and pelvis to find alternative diagnoses

FEFFERMAN ET AL (41)
- Helical and nonhelical CT with both oral and IV contrast
- Retrospective review of patients with equivocal presentation to a pediatric emergency service
- 97% sensitivity, 93% specificity, PPV 90%, NPV 98%, accuracy 95%
- Encouraged limiting imaging below the lower pole of the right kidney

MULLINS ET AL (42)
- Limited helical CT with colonic contrast
- Retrospective review of patients with CT scans done for suspected appendicitis
- 97% sensitivity, 99% specificity, PPV 98%, NPV 98%, Accuracy 96%
- Focused CT provided alternative diagnoses in 48% of patients with suspected appendicitis, reduced radiation exposure, and reduced the negative appendectomy rate from 13% to 9%.

STEPHEN ET AL (43)
- Focused helical and nonhelical CT with rectal contrast
- Retrospective review of patients who underwent appendectomy by a pediatric surgeon
- 95% Sensitivity, PPV 96%
- No differences found in perforation rate between those patients who underwent imaging and those who did not.

DEARMOND ET AL (44)
- Helical CT with oral, IV, and rectal contrast
- Retrospective review of patients who underwent appendectomy in 1995 and in 1998
- Increased use of CT scanning in 1998
- Negative appendectomy rate decreased in both patients who did and did not undergo CT imaging.

PARTRICK ET AL (45)
- CT scan, ultrasound, or no radiographic study
- Retrospective review of children who underwent appendectomy at a children's hospital
- Increased frequency of CT scanning and decreased utilization of ultrasound found over time
- Overall negative appendectomy rate did not change.
- Recommended limiting the use of radiographic studies to children who have an equivocal diagnosis after an evaluation by a pediatric surgeon

Key: PPV = positive predictive value. NPV = negative predictive value.

their symptoms or vocalizing their pain, it could be difficult to apply the careful clinical screening that they believed was imperative to the success of a focused CT technique in this population. Although the authors pointed out the value of a focused CT scan in minimizing the radiation dose of CT imaging, this technique may not be applicable to the younger child with abdominal pain because other diagnoses may indeed be missed.

In a study by Mullins, 199 pediatric patients were examined with focused CT for suspected appendicitis.[42] The patients received colonic contrast material, and the imaging studies were performed from the level of L_3 on the scout image to the top of the acetabulum. CT was interpreted prospectively by the attending radiologist as positive for appendicitis in 65 children (33%), negative in 130 children (65%), and equivocal in four children (2%). On the basis of comparison with surgical findings and follow-up, there were 64 true-positive CT scans, two false-negative, 128 true-negative, one false-positive, and four equivocal. Of the four equivocal cases, one patient had acute appendicitis at surgery, one did not have acute appendicitis at surgery, and the remaining two did not undergo surgery. During the time period of the study, 74 children underwent appendectomy with a negative appendicitis rate of 9%; 125 patients without appendicitis were treated nonoperatively with 123 true-negative results and two equivocal results. The overall CT true-positive rate was 32%, true-negative rate was 64%, sensitivity was 97%, specificity was 99%, the PPV was 98%, the NPV was 98%, and overall accuracy was 96%. Additionally the authors found that in 62 patients, focused helical CT provided alternative diagnoses. The authors also reviewed the use of abdominal radiography and sonography for their patient population during this time. Abdominal radiographs were performed in 98 children and were considered helpful in six of the patients with signs suggestive of appendicitis, including a calcified stone in the right pelvis or a right lower quadrant focal ileus. None of the abdominal radiography results were considered diagnostic by radiologists or surgeons. The abdominal radiograph was considered "not helpful" in 92 patients. Ultrasonography was performed in 32 children who also underwent focused helical CT. Three of the sonographic examinations were true-negative, two were false-positive, one was false-negative, none was true-positive, and 26 were indeterminate. The authors concluded that their focused approach yielded accurate results and reduced radiation exposure and that the use of CT did not add to hospital cost. Before the use of CT, 208 pediatric patients were admitted with a diagnosis of suspected appendicitis; 70% of these patients had an appendectomy. Of those with an appendectomy, 13% did not have acute appendicitis. The authors concluded that 9% of patients taken to surgery in the study did not have acute appendicitis and that the reduction in negative appendectomy rate reduced the overall cost. They estimated that considering only change in surgical observation and CT costs, almost $3,000 savings in hospital total costs per 100 patients would result from the use of CT.

Addressing the issue of the use of a focused abdominal CT with rectal contrast, Stephens and researchers in their five-year retrospective review studied 283 patients age 0.8 to 19.3 years (mean 11.3 years) who had been treated with appendectomy for presumed acute appendicitis.[43] Of 283 patients, 268 were confirmed by pathologic analysis of the specimen to have acute appendicitis, for a diagnostic accuracy at their institution of 94.7%. Ninety-six patients (34%) underwent a focused CT scan of the lower abdomen following administration of rectal contrast. The sensitivity of the CT scan was 94.6%, and the PPV was 95.6%. Comparing the difference in PPVs of the two groups was not significantly different. A clinical PPV of 94.1% was found. Five patients had CT scans that were interpreted as negative for appendicitis but were found to have acute appendicitis at operation and subsequent pathology. There were 39 cases of perforated appendicitis for a perforation rate of 14% with a rate of 14.5% among patients who had CT imaging and 13.3% in those who did not have imaging. The authors concluded that although a focused appendiceal CT with colon contrast is a reliable test for the diagnosis of appendicitis, they were skeptical whether the widespread use of the test will result in improvement in the accurate diagnosis of appendicitis in the pediatric population. However, their study did not specifically address the younger patient.

Studies also have been done to evaluate the effect of increased use of abdominal CT imaging. Dearmond and colleagues compared patients demographics, use of CT imaging, perforation rate, and incidence of negative appendectomy in patients who underwent appendectomy in 1995 with those who underwent the procedure in 1998.[44] The mean age was comparable in the two patient populations and included children as young as 1 year. In 1995, 394 patients underwent appendectomy vs 372 patients in 1998. Gender, age, and perforation rates did not change over time, despite an increased use of CT scanning. In 1995, 12% of patients underwent CT imaging vs 34% in 1998. The overall nontherapeutic appendectomy rate decreased significantly from 14% to 7% ($P < 0.005$). The decrease in nontherapeutic appendectomy was seen in patients who underwent surgery without CT and with CT; the perforation rate was not significantly different between the two patient populations. However, when the pediatric patient population was evaluated, no change in negative laparotomy rate was found. For patients 0-12 years of age, the negative laparotomy rate in 1995 was 9% compared with 4% of patients in 1998.

The issue of negative appendectomy rate with the increased utilization of focused CT scanning was addressed in a study of a retrospective review of 616 children who underwent appendectomy during 1997-2001 at a children's hospital.[45] Overall 184 children underwent CT scanning, 104 (17%) had ultrasound performed, and 310 (50%) had no radiographic study performed. The frequency of the CT scanning increased from 1.3% of all children in 1997 to 58% in 2001; utilization of ultrasound decreased from 40% to 7%. The overall negative appendectomy rate did not change significantly(8% to 7%). The authors concluded that it would be prudent to limit the use of radiographic studies to children who have been examined and in whom a surgeon remains uncomfortable with the diagnosis of appendicitis.

Overall, this review of imaging modalities does not appear to show a decrease in the perforation rate in the young child who presents with suspected appendicitis. Although these imaging studies appear to have increased the accuracy of making the diagnosis of appendicitis and, in some cases, have shown a decrease in the negative appendectomy rate, their application to the very young child with appendicitis does not appear to have been fully evaluated. Sonography and CT imaging do appear to have some benefit in the child with an equivocal diagnosis for appendicitis and also appear to identify alternative diagnosis. The goal of discovering the young child who has appendicitis earlier in their presentation through the application of various imaging modalities has not been achieved.

Imaging Protocol

A study by Garcia Pena addressed the overall approach to the child with suspected appendicitis in relation to imaging studies.[46] In 1998, the authors implemented a clinical imaging protocol in which children with suspected appendicitis underwent ultrasonography followed by CT imaging. Children with unequivocal presentations for appendicitis went to the operating room without entering the imaging protocol. The authors identified 1338 children in their modified time series study involving a prospective and retrospective cohort; 810 (60.5%) children had equivocal clinical findings. A total of 920 patients were admitted for suspected appendicitis before the protocol was implemented. Of the 920 children, 526 (57.2%) had appendicitis, and 186 (35.4%) of them had perforation. A total of 91 of 617 (14.7%) had negative appendectomies before the protocol was implemented. After the protocol was initiated, 418 patients were admitted for suspected appendicitis; 328 (78.5%) had appendicitis with 51 (15.5%) having perforation. Fourteen (4.1%) of 342 cases had negative appendectomies. The perforation rate decreased from 35.4% to 15.5%, and the negative appendectomy rate decreased from 14.7% to 4.1% after initiation of the imaging protocol. Based upon the results of this study, it appears that a well-planned, focused protocol may assist with the earlier identification of the young patient with appendicitis. This study also reported on the perforation and negative appendectomy rate by various age groups before and after implementation of their imaging protocol.[46] Before the protocol was initiated, the perforation rate in children 5 years or younger was 55.8%. Although not a statistically significant decrease, the perforation rate after the initiation of the protocol for this age group of patients did decrease to 36%. The negative appendectomy rate went from 10.3% in this age group before the protocol was initiated to 7.4% after the protocol was initiated without statistical significance.

The need for implementation of a focused protocol for young children with abdominal pain also is emphasized in the article by Newman and colleagues.[8] The wide variability (0-17%) in the negative appendectomy rate, as well as the incidence of ruptured appendicitis among 30 children's hospitals was highlighted in the study. Among these institutions, the ruptured appendicitis rate varied from 20% to 76% with a median of 36.5%. Children receiving any study varied from 18% to 89% with a median of 69%. Ultrasound and CT were comparable in both nonruptured (13% ultrasound vs 14% CT) and ruptured appendicitis (14% ultrasound vs 21% CT). The authors concluded that significant variability in practice patterns and resource utilization exists in the management of acute appendicitis in pediatric hospitals. Clinical outcomes can be improved by collaborative initiatives to adopt evidenced-based best practices. The authors also emphasized a need to extend public and provider education in a public health context to reduce delays in the diagnosis of appendicitis and, therefore, perforation. Also, the majority of patients with perforation had undergone surgery within 24 hours of admission suggesting that most patients already had perforation on presentation to the hospital. They proposed that the model of pediatric trauma care with prevention as a core value might be worth applying to pediatric abdominal pain as well. The authors did not identify a correlation between the appendiceal perforation rate and the pattern of diagnostic testing.

Summary

The young child with appendicitis is often a challenge. Determining the type, location, and migration of pain in this patient population may be difficult for the clinician. Delays in diagnosis certainly can lead to significant morbidity and mortality. Many patients with appendicitis in this age group have perforated at the time of their presentation because of these diagnostic difficulties.

The diagnosis of appendicitis should be considered in a young child with symptoms of vomiting or diffuse abdominal pain. A high index of suspicion along with special attention to each patient's history and physical examination most likely will lead to a more prompt diagnosis. When the diagnosis is clear, surgical intervention by practitioners experienced in caring for children should be prompt. Serial examinations with a period of observation along with the judicious use of ultrasonography and CT imaging can aid in improving the diagnostic accuracy. No definitive laboratory test currently exists to make the diagnosis. Whenever the diagnosis of appendicitis cannot be ruled out with confidence based on history and physical examination, further evaluation utilizing the expertise of experienced colleagues in radiology and surgery is indicated. The development of an organized and systematic approach to the young child with suspected appendicitis should be made at each institution where this patient population presents for evaluation and care (*Figure 5*).

Acknowledgements

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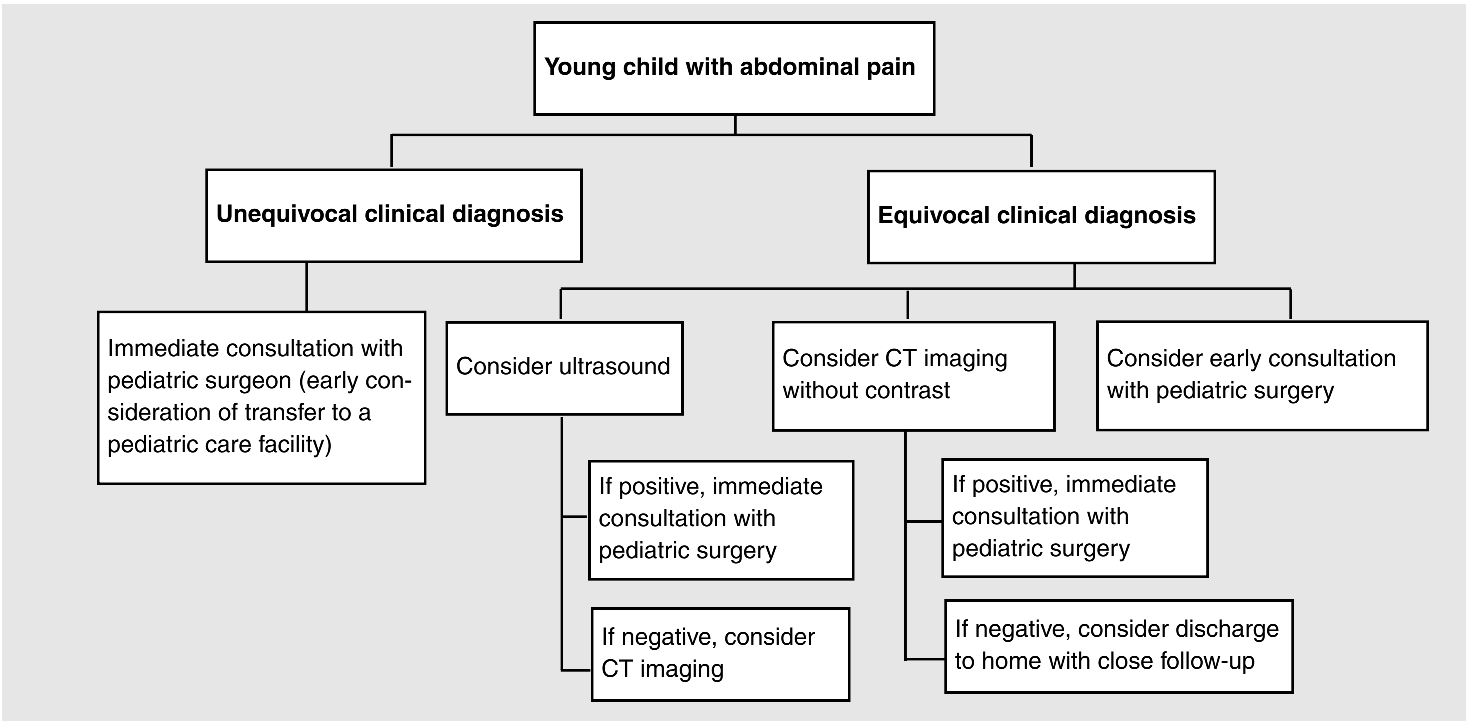
Figure 5. Suggested Approach to the Young Child with Suspected Appendicitis



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CME Instructions

Physicians participate in this continuing medical education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge.

To clarify confusion surrounding any questions answered incorrectly, please consult the source material. After completing this activity, you must complete the evaluation form that will be provided at the end of the semester and return it in the reply envelope provided to receive a certificate of completion. When your evaluation is received, a certificate will be mailed to you.

CME Objectives

The CME objectives for *Pediatric Emergency Medicine Reports* are to help physicians:

a.) Quickly recognize or increase index of suspicion for specific conditions;

b.) Understand the epidemiology, etiology, pathophysiology, historical and physical examination findings associated with the entity discussed;

c.) Be educated about how to correctly formulate a differential diagnosis and perform necessary diagnostic tests;

d.) Apply state-of-the-art therapeutic techniques (including the implications of pharmacologic therapy discussed) to patients with the particular medical problems discussed;

e.) Provide patients with any necessary discharge instructions.

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CME Questions

91. Which one of the following statements regarding appendicitis is true?
    A. The peak incidence for appendicitis in children is 5 to 7 years.
    B. Less than 2% of children treated for appendicitis are younger than 2 years.
    C. The perforation rate for appendicitis in children younger than 2 years is 40%.
    D. All of the above

92. Which of the following conditions is suggestive on plain radiographs of a perforated appendix?
    A. Small bowel obstruction
    B. Localized paucity of gas in the left upper quadrant
    C. Nonspecific bowel gas pattern
    D. None of the above

93. Which one of the following are potential short- and long-term complications for patients with appendiceal perforation?
    A. Longer duration of hospital stay
    B. Higher rate of complications
    C. Increased rate of infertility among women
    D. All of the above

94. Appendicitis is less common among infants because children have:
    A. a tapered cecum and funnel-shaped appendix making obstruction less likely.
    B. a relatively soft-food diet.
    C. less prominent lymphoid tissue.
    D. All of the above

95. Which of the following statements regarding imaging studies for children with suspected appendicitis is true?
    A. Plain radiographs are diagnostic in 100% of patients.
    B. The usefulness of ultrasonography is dependent upon the stage of the inflammatory process.
    C. Imaging capabilities are uniform across institutions.

96. The incidence of appendiceal perforation is higher in children younger than 2 years than in older children.
    A. True
    B. False

97. The second most comon diagnosis involved in pediatric emegency malpractice claims during the time period 1985-2000, according to the Physician Insurers Association of America database, was appendicitis.
    A. True
    B. False

98. Which one of the following symptoms distinguishes a child with a perforated appendix from a child with a nonperforated appendix?
    A. Diarrhea
    B. Vomiting
    C. Anorexia
    D. None of the above

99. A 3-year-old child presents with abdominal pain and vomiting. The presence of diarrhea excludes the diagnosis of appendicitis.
    A. True
    B. False

100. A 2-year-old child presents with abdominal pain and vomiting. An ultrasound is performed, and the child's appendix cannot be visualized. The child's abdomen is very tender. What should be done?
    A. Discharge the patient to follow-up in three days.
    B. Discharge the patient to follow-up in 48 hours.
    C. Perform an UGI.
    D. Perform a CT scan of the abdomen.

ANSWERS:
91. B; 92. A; 93. D; 94. D; 95. B; 96. A; 97. A; 98. D; 99. B; 100. D

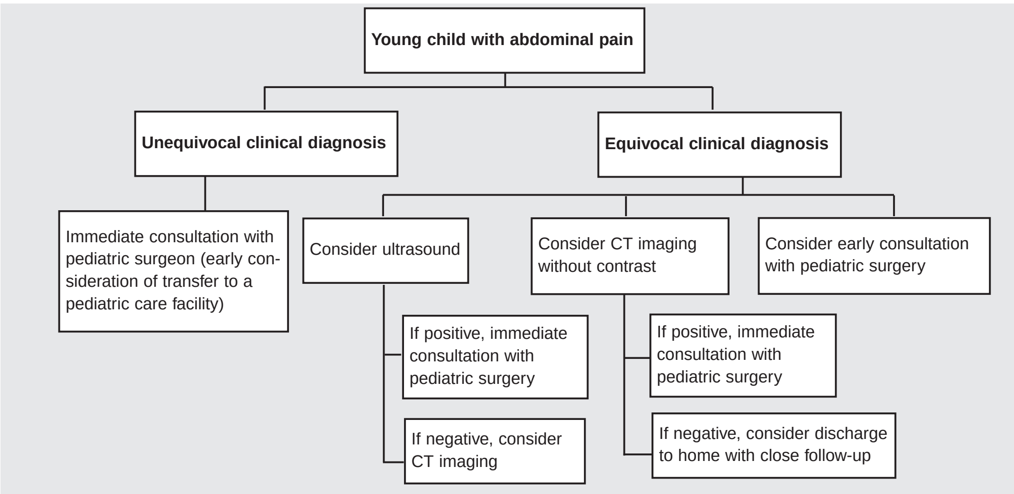
In Future Issues:

Sickle cell disease

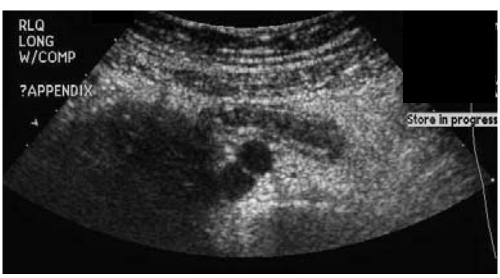
PEDIATRIC Emergency Medicine Reports
The Practical Journal of Pediatric Emergency Medicine

Appendicitis in the young child

Suggested Approach to the Young Child with Suspected Appendicitis

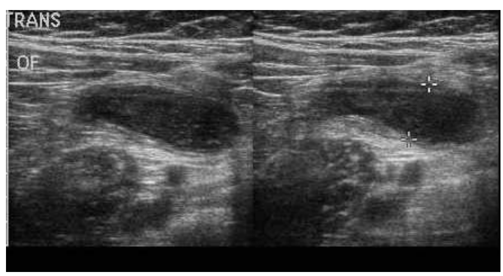


Ultrasound Image of a Thickened Appendix



Ultrasound showing thickened appendix in an 18-month-old child with vomiting.

Ultrasound Compression of Appendix

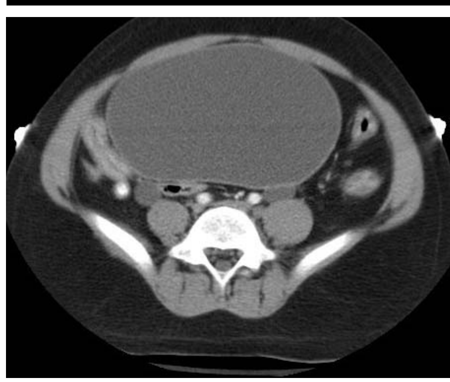


Ultrasound of a 2-year-old child showing a dilated tubular structure without change with compression.

CT Image of a Thickened Appendix

CT scan showing thickened appendix of an 18-month-old child with vomiting.

A CT Image of a Calcified Appendicolith



CT scan of a 2-year-old child with right lower quadrant tenderness. Note appendicolith in dilated appendix with little periappendiceal fat stranding.

Use of CT Imaging in the Diagnosis of Children with Appendicitis: Study Summary

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- Helical CT without contrast
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- 94% sensitivity, 92% specificity, PPV 84%, NPV 97%
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- Limited CT without contrast
- Consecutive patients with equivocal findings in children's hospital setting
- 97% sensitivity, 100% specificity, accuracy 99%
- Found no difference with historical cohort who had undergone graded compression sonography

SIVIT ET AL (40)
- Helical CT with oral and/or rectal contrast
- Retrospective review of patients who underwent imaging for suspicion of appendicitis at a children's hospital
- 95% sensitivity, 94% specificity, PPV 91%, NPV 97%, accuracy 94%
- Highlighted the need to scan the entire abdomen and pelvis to find alternative diagnoses

FEFFERMAN ET AL (41)
- Helical and nonhelical CT with both oral and IV contrast
- Retrospective review of patients with equivocal presentation to a pediatric emergency service
- 97% sensitivity, 93% specificity, PPV 90%, NPV 98%, accuracy 95%
- Encouraged limiting imaging below the lower pole of the right kidney

MULLINS ET AL (42)
- Limited helical CT with colonic contrast
- Retrospective review of patients with CT scans done for suspected appendicitis
- 97% sensitivity, 99% specificity, PPV 98%, NPV 98%, Accuracy 96%
- Focused CT provided alternative diagnoses in 48% of patients with suspected appendicitis, reduced radiation exposure, and reduced the negative appendectomy rate from 13% to 9%.

STEPHEN ET AL (43)
- Focused helical and nonhelical CT with rectal contrast
- Retrospective review of patients who underwent appendectomy by a pediatric surgeon
- 95% Sensitivity, PPV 96%
- No differences found in perforation rate between those patients who underwent imaging and those who did not.

DEARMOND ET AL (44)
- Helical CT with oral, IV, and rectal contrast
- Retrospective review of patients who underwent appendectomy in 1995 and in 1998
- Increased use of CT scanning in 1998
- Negative appendectomy rate decreased in both patients who did and did not undergo CT imaging.

PARTRICK ET AL (45)
- CT scan, ultrasound, or no radiographic study
- Retrospective review of children who underwent appendectomy at a children's hospital
- Increased frequency of CT scanning and decreased utilization of ultrasound found over time
- Overall negative appendectomy rate did not change.
- Recommended limiting the use of radiographic studies to children who have an equivocal diagnosis after an evaluation by a pediatric surgeon

Key: PPV = positive predictive value. NPV = negative predictive value.

Supplement to *Pediatric Emergency Medicine Reports*, October 2005: "Appendicitis in the Young Child: Making the Right Diagnosis." *Author:* **Mark S. Mannenbach, MD**, Division Head, Pediatric Emergency Medicine; Assistant Professor; Department of Pediatric and Adolescent Medicine, Mayo Medical Center, Rochester, MN. *Peer reviewer:* **Ronald M. Perkin, MD, MA,** Professor and Chairman, Department of Pediatrics, The Brody School of Medicine, East Carolina University, Greenville, NC.